



Jo Mackiewicz

Learning Skilled Trades in the Workplace

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Dedicated to Jim Howe

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Contents

1	Describing Expertise(s)	1
	The Road to Howe's	2
	Research on Trades Learning	7
	Other Books About Skilled-Trades Work	8
	Describing Experts and Expertise	10
	The Steps from Novice-Level to Expert-Level Knowledge	11
	Conclusion	14
	References	17
2	The Learning Context	21
	Jim Howe, My Boss	22
	Howe's: An Overview	26
	Howe's Projects and the Pile	34
	A Spectrum of Production Work	38
	Conclusion	40
	References	40
3	Learning and Practicing	43
	Six Characteristics of a Scaffolded Interaction	45
	Contingency and the Zone of Proximal Development	50
	The Complexities of Practice	52
	Conclusion	59
	References	60
4	Challenges in Shop Learning	63
	Perfect and Imperfect Projects for Learning	64
	Impromptu Instruction	68

	Planning a Project's Steps	71
	The Nonlinear Path Toward Competence	74
	Conclusion	76
	References	77
5	Learning Arcanities	79
	Drill-Bit Sizes and Thread Counts	81
	Pipe Sizes and Schedules	82
	Metal Gauges	84
	Converting Between US Customary and Metric	84
	Conclusion	86
	References	87
6	Learning from Mistakes	89
	Dope-Slap Mistakes	90
	Communication Mistakes	95
	Perception Mistakes	97
	Knowledge-of-What Mistakes	99
	Knowledge-of-How Mistakes	101
	Conclusion	102
	References	104
7	Learning Health and Safety (and Danger)	107
	Promoting (and Ignoring) Safe Practices	108
	Mitigating UV Radiation	112
	Mitigating Fumes	114
	Connecting with Scar Stories	116
	Conclusion	118
	References	119
8	Learning Technical Drawings	123
	Representing 3D in 2D	124
	Learning to Interpret Technical Drawings	129
	Developing Spatial Ability	129
	Learning the Syntax of Welding Symbols	131
	Using Technical Drawings on the Job	134
	Conclusion	140
	References	142

9	Learning Shop Genres	145
	Introduction	145
	Invoices	146
	Near-Miss Reports	149
	Nonconforming-Part Tags	151
	Skilled-Trade Knowledge in the Writing Classroom	153
	Writing in Skilled-Trade Classes	156
	Challenges to Contextualized Writing Courses and WAC Programs	159
	Conclusion	160
	References	161
10	Women Learning	165
	Introduction	165
	Outsider Status	167
	Scrutiny	169
	Stereotypes	170
	Sexual and Gender Harassment	174
	Condescension	177
	Conclusion	178
	References	180
11	Developing Competences	183
	Consciously Deliberating	184
	Being Right	187
	Achieving Independence (Mostly)	189
	Learning Outside the Box (of the Shop)	194
	Conclusion	200
	References	200
12	Learning Community	203
	A Learning-Conducive Context	204
	Enculturation into a Community	206
	Toward a Vocational Identity	208
	A Final Note	209
	References	211
	Glossary	213
	Index	217

Chapter 1

Describing Expertise(s)



Abstract How do people develop competence and even expertise across knowledge domains? This chapter introduces the goal of the book: to relate my journey toward the breadth as well as depth of competences required by work in a repair and metal fabrication shop. After relaying my road to Howe's Welding and Metal Fabrication, the context of this autoethnography, I discuss related research on career and technical education (i.e., vocational education and training), and I explain how *Learning Skilled Trades in the Workplace* adds to those contributions. I relate the book's data: my daily notes and photographs from the shop; my conversations with welders and other employees at the 10 shops that I visited from January to December 2022; conversations among members of online communities focused on welding and machining; and secondary research from experts in education, sociology, and other fields. Then, I describe the path from novice-level to expert-level knowledge and delineate the characteristics of expert-level knowledge. In relating the ways my learning experiences support and sometimes contradict research on workplace learning and how my burgeoning competences compare to the myriad expertises of my boss, I hope to further research on workplace learning and to make the way easier for others who are learning a trade.

Back in 2016, when you wanted to go up for promotion to full professor at a university, you had to print out hard copies of all the articles you've written since your last promotion. This pile of stapled papers would get stacked with any books you've written. And there you would see, in that stack of however-many inches of paper, the totality of your contribution. To your professional world I mean. Twelve or so inches of paper stacked. It can really make you think about what you've done with your life.

That stack of paper was one reason that I found myself in a welding classroom in early 2018.

Back then, I had no sense of the scope of the trade I aimed to pursue. I only knew that I wanted a change from—or rather an addition to—my behind-the-screen life of research and writing. I wanted to make something tangible. Real. And as I progressed through my night courses and through my days at my part-time welding

job, I learned that I wanted, more specifically, to become truly competent in repair and fabrication. And I learned that becoming competent meant developing a broad swath of knowledge—something only hinted at in the welding classes I took for three years (with a year off in the middle for a pandemic). In school, I progressed through the curriculum of different welding processes and different levels of difficulty. I learned, for example, how to stick weld in flat and horizontal positions before moving on to vertical and overhead. But not until I started learning on-the-job, at Howe's Welding and Metal Fabrication, did I begin to recognize, if not understand, whether and how to preheat metal before welding. How to bend and punch metal. How to find *x* and *y* coordinates on a mill. How to drill and tap for threaded holes. How to thread a pipe. How and when to use a reamer. And so on. My job at Howe's has shown me much of what's possible in metal fabrication. And my job made me think about what it means to attain competence in these different knowledge domains because there I had access to true expertise in my boss, Jim Howe. In this book, I draw from my experiences at Howe's to illustrate the bumpy path of learning on the way to skilled-trade competences and, in doing so, to help and encourage others along a similar path.

The Road to Howe's

I lived a pre-Howe's life largely void of trades learning. Jim Howe, on the other hand, was the mechanical equivalent of a hockey kid.¹ In my region of the northern Midwest of the United States, hockey kids have parents who expose them to the sport and give them the resources to continue in it. Hockey parents spend a ton of money on all the equipment their kids need, on hotels for weekend tournaments, and on fuel to cart their kids around. Jim's parents, because they owned an appliance-repair business, gave him sustained access to tools, broken machines ready for tinkering, and opportunities for developing both conceptual and procedural knowledge or, in other words, knowledge of what and knowledge of how. Jim told me too that his folks sent him—when he was twelve—to Maytag repair school in Illinois, with an eye toward giving him something productive to do over the summer. In contrast, when I was twelve, I spent the summer hanging out with my friends and reading books. I wasn't repairing washing machines. And while recent research on expertise has shown that elite athletes are no more likely to start their sports at a lower age than lower-proficiency athletes,² I contend a childhood and adolescence surrounded by all things mechanical will do you more good in a metal shop³ than years spent loitering with your pals and daydreaming of Mr. Darcy.

I took my first steps into Jim's world when I attended my first class in welding school. At 45, I was the oldest person in the class besides the instructor. I was also the only woman. In this first class, we were supposed to learn about shop safety, such as handling gas cylinders and regulators, and technical drawings, including welding symbols and specifications. If I'd not met a supportive friend at that point, I might have quit. The instructor never prepared exercises that would develop our learning of

the subject matter and often made us feel as though we should already know what we were there to learn. His coverage of technical drawings involved pointing at elements in a complicated drawing and saying something like, "This says fillet weld both sides of the joint," rather than starting us on interpreting simple drawings before moving on to more complicated ones. You may think here, perhaps, that I'm a bit fussy about teaching. Maybe I am. I came to this class after twenty or so years in higher ed, teaching first as a graduate student at the University of Minnesota-Duluth and then as a graduate student at Georgetown University. Part of my job as an assistant professor, then as an associate professor, and finally as a full professor, has been teaching. And even though I knew nothing about how to read a gas regulator or a technical drawing, I knew that this guy wasn't teaching. But that terrible class sparked an interest. How do people learn embodied knowledge—knowledge that resides in the body as well as the mind? And how do people develop competence and even expertise in a knowledge domain? These questions would stay with me through the years that followed, as I knocked off one subject per semester by attending welding school from 6:00 p.m. to 10:00 p.m. two days a week—apart from one year off from fall 2020 through spring 2021 during the worst of the pandemic.

Thankfully, the semesters that followed improved upon that inauspicious start. For one thing, the teachers that I encountered next, while not necessarily experts in pedagogy, were nevertheless armed with a curriculum that scaffolded one task progressively on another to move us forward in procedural and, at times, conceptual knowledge. I mean that, for example, we practiced mig welding in flat and horizontal positions before we tackled vertical and overhead and that we welded thick coupons of steel before we attempted thinner ones. But we didn't spend any time in the classroom, as opposed to the welding lab that housed our booths, learning about the concepts behind the procedures. Here's an example. If you've ever used a welding machine, you know it has a positive and a negative terminal. You attach the ground to one of these and the electrode to the other. But which one you attach to each differs for the type of welding you're doing, whether mig (wire from a gun and gas), fluxcore mig (wire from a gun with no gas), stick (an electrode clasped in a holder called a stinger), or tig (a tungsten electrode and filler metal). As a welding student, I memorized the configuration, whether electrode positive (reverse polarity) or electrode negative (positive polarity). But if you know something about the direction of travel of electrons through the current, you can better understand why, for example, in stick welding, you attach the electrode to the positive terminal and the ground to the negative terminal. In other words, our developing greater conceptual knowledge would have reinforced our procedural knowledge, helping us not just to recall one configuration or the other but to understand the reasons that we'd use one configuration or the other.

Although they didn't provide much in the way of conceptual knowledge, my teachers in classes covering brazing, mig, fluxcore, stick, and tig had developed proficiency in welding through their years of work in different fabrication shops. They hadn't necessarily studied how people learn, but their workplace experiences had shown them methods that work—at least for some people, some of the time. In my classes, teachers demonstrated while I observed and then tried to imitate

their movements. They observed as I welded, giving me instruction and other verbal feedback as I did. They stopped me to point out what I was doing wrong. They let me continue as I did something wrong to show me the result, a weld with some defect like undercut, the failure to fill in the base metal where the heat has burned it away. They encouraged me to continue, even through successive disappointments, reminding me that the only way to progress toward expertise is to practice. I know now, after studying expertise more fully, that my teachers were talking not about practice as repetition but as deliberative practice, as described by the psychologist K. Anders Ericsson and others.⁴ Although more recent research has complicated our view of practice's contribution to eventual expertise, that it plays a significant role, particularly in the realm of embodied knowledge, remains clear. And that's what we students did in all those night classes at welding school: We practiced. We welded one lap joint and T-joint and butt joint after the other in one position after the other—flat, horizontal, vertical, overhead—in one welding process after another—oxyacetylene, stick, mig, tig—in hope of training our minds and bodies to lay the weld beads competently.

Meanwhile, in my work as a professor in the English department at Iowa State University, I continued to study how writing tutors scaffold the learning of writing students in one-to-one interactions in the university writing center, a place where students can go to receive free help with their papers and other communication projects. I'd cowritten and written three books on the topic, and I was then working on another, when a conversation with my one of my welding teachers made me realize that my welding teachers' strategies for developing my embodied knowledge substantially overlapped with the strategies that writing tutors used in their interactions with student writers. I set out to study the interactions between welding teachers and welding students in much the same way that I had those of writing tutors and students. I videotaped interactions at three welding schools and analyzed the talk. That study became my book *Welding Technical Communication: Teaching and Learning Embodied Knowledge*.⁵

After I finished that big project, I thought about what I might like to do next. Always interested in writing, I wondered whether writing could play a role in how trades students could further develop their conceptual and perhaps their procedural knowledge. I also considered developing a first-year composition course for trades students, one based on the sorts of texts that those students would use and produce in their work. I looked first to determine whether anyone had already implemented this idea, and of course, someone had. I talked to Maria-Lucia Di Placito at Humber College in Toronto about the composition courses she had developed for students in trades like heating, ventilation, and air conditioning, or HVAC for short. To develop these courses, she had talked to practitioners about the kinds of documents that they used every day. I wondered whether I could build on her work by visiting fabrication shops of different sizes in order to determine the types of texts—both verbal like a packing list and visual like a technical drawing—that welders and others in fabrication use. Toward that end, I looked for fabrication shops in Iowa, and the first one that I saw on Google's list—the one nearest to my apartment—was Howe's Welding and Metal Fabrication.

My first visit there, on January 18, 2022, gave me the initial glimpse of how much I didn't know—not only about welding, but metal work more generally. I followed Jim around as he prepared his truck for a portable—a job outside the shop—and moved from one task to another. All the while I tried to take in the layers of machines and tools. The shop seemed maze-like and foreign to me that first day. I had no idea how any of the machines worked, and I didn't even know what most of them were, like the giant Pullmax. Later I learned that Jim had snatched up the cutting and shaping machine at an auction, fearing he'd never again have the chance to get one. It's accurate to say that my feeling that day was a true sense of awe—awe at the immensity of what I didn't know, and awe that I'd found someone who knew it all. I determined then that my study would shift from one focused solely on skilled-trade documents to one focused on learning trades, which includes but in no way solely comprises understanding and creating shop genres. That is, I determined that my study would be what academics call an autoethnography, a study that:

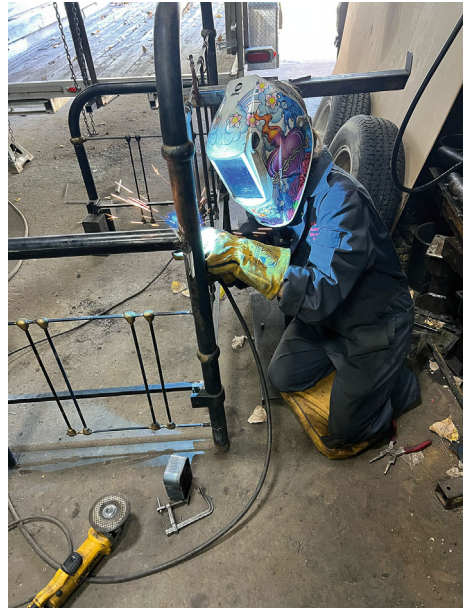
draws on and analyzes or interprets the lived experience of the author and connects research insights to self-identity, cultural rules and resources, communication practices, traditions, premises, symbols, rules, shared meanings, emotions, values, and larger social, cultural, and political issues.⁶

With Jim's approval, I was going to keep showing up at Howe's to learn and to work, and at the same time, I was going to study my path to skilled-trade competences. I was going to keep doing all this until Jim asked me to stop. Luckily, he never did.

In my first months at Howe's, Jim gave me easy jobs to do, such as stick welding reinforcement caps to jersey barricades. Although I knew he wasn't impressed with my knowledge—conceptual or procedural—in even simple welding tasks, I decided to ask him for a part-time job, given that in May I would graduate from my welding program. He said yes, and then my development as not just a welder but also as a fabricator and even as a machinist began. In that time, I've undergone a process of becoming a community member, a change in identity that arises from the development of competences and someday, with any luck, expertises as well (Fig. 1.1).

At the same time, as part of my research, I continued with visits to shops of different sizes.⁷ During these visits, I talked to employees—mostly people on the shop floor but also office employees—about the documents that they use and create. These conversations invariably turned to the topic of learning—how they learned to weld, to read technical drawings, to use safe practices. Because I already had a connection with people at John Deere's Harvester Works in Davenport, Iowa, through my job at the university, I visited that facility twice, each time spending a day observing, taking dozens of pictures, and conversing both with welders on the shop floor and with salaried people who worked as safety experts. I visited another large facility, Vermeer, located in Pella, Iowa. There I spent time with welders and others on the shop floor, once again taking pictures and interviewing people about their work and the types of documents that they use. John Deere and Vermeer are by far the two biggest facilities that I visited. John Deere's Harvester Works employees around 2,000 people, and Vermeer employs 3,500 people. Another large facility, Quality

Fig. 1.1 This is me, mig welding a bed frame near the back bay door at Howe's



Manufacturing in Urbandale, Iowa, manufactures components for John Deere and other brands and employs about 750 people. At Quality, I spoke not only with welders but also to those salaried employees who develop Quality's documentation. Not far from Quality is Power Brace, a company of 80 people that produces foundation-repair components, cell-phone towers, zero-turn mower frames, steel components for solar panels, among other varied products. In my two visits there I witnessed the methodical implementation of an online system for tracking orders. Welders began to use tablets to report their work; this system helps management track jobs, materials, and employee performance.

I visited some smaller fabrication shops as well, mostly in Ames. I visited Custom Steel Service twice. The shop where Jim worked during high school, the company employs three people. Neighbors Heating and Cooling, which has a small fabrication shop for duct work, employs roughly 30 people. Sargent Metal Fabricating employs 21 people. Outside of Ames, I visited Lane Trailers in Boone, Iowa, which employs 30 people, and Sorem Manufacturing in Nevada, Iowa, which employs four people full time and two part-time.

Howe's Welding and Metal Fabrication, the first shop that I visited, is also the smallest shop. I describe the shop more fully later, but to complete this list I'll point out that when I started, Jim employed three full-time employees: David, Jessie, and Adam. When Jim hired me, he also hired Zach as a full-time employee, but he lost Adam. Eventually, missing the variety of projects at Howe's, Adam came back, but then Jessie and later David left. So Howe's currently has two full-timers, Adam and Zach. The shop also sometimes employs part-timers like me. For example, another

woman, Regen, joined us in the shop for several months, as did an undergraduate engineering student.

Eventually, I wrapped up my research at other shops, and I concentrated on my work at Howe's. I began to work at least a few hours each day, including Saturdays and even some Sundays. Some days, I worked five or six hours. Occasionally, I put in a full eight hours. Typically, I worked between 25 and 30 hours per week. No matter what, each day, I took pictures of my projects and wrote a journal entry about what happened in the shop, how I proceeded through my task, what I learned, how I succeeded or failed, and how I felt, whether discouraged or elated. This book draws heavily from my daily notes and photographs, gathered from January 2022 to May 2024. But I also draw from my conversations with welders and other employees at the shops that I visited from January to December 2022, and I illustrate my text with pictures from those visits as well. Also, I draw from conversations among members of online communities focused on welding, machining, and fabrication. Finally, I also look to research on workplace learning, particularly from Selena Chan and Stephen Billett, but also research on expertise, particularly from Hubert L. Dreyfus and Stuart E. Dreyfus and K. Anders Ericsson. All these sources help me to relate my experience on the twisting path toward not just competence in one knowledge domain, but rather competences in the many knowledge domains pertinent to effective and independent work in a job shop like Howe's. In relating my experiences and the ways they support and sometimes contradict research on workplace learning, I hope through this autoethnography to make the way easier for others interested in learning a trade and more broadly for people interested in learning something completely new later in life.

Research on Trades Learning

Learning Skilled Trades in the Workplace builds on earlier research focusing on what's called career and technical education, or CTE, in the United States and what's called vocational education and training, or VET, in most other parts of the world.⁸ Such research has investigated how trade students learn⁹ and has compared the pedagogical practices and student learning outcomes of VET programs in Canada, the United Kingdom, and in European countries, including Germany, the Netherlands, and Finland.¹⁰ It has also examined how trade students learn during workplace apprenticeships.¹¹ Selena Chan, for example, has written extensively on pedagogy in the context of trade apprenticeships.¹² She's investigated the role of observation,¹³ imitation,¹⁴ and feedback¹⁵ in the development of embodied knowledge.

This book, however, mainly builds on research about learning in trades workplaces, exemplifying, adding detail to, and complicating major findings from researchers such as Stephen Billett. Billett has studied workplace learning in depth,¹⁶ trying to determine how trades programs can better create practice sessions that generate the conceptual and procedural knowledges necessary for trades work. This

book builds Billett's and Chan's studies of observation, imitation, feedback, and practice by analyzing examples of learning that illustrate progression toward expert-level knowledge.

The work of Billett and others has also found that tradespeople's learning includes their development of expert perception, with which workers learn to identify, or highlight, phenomena in the environment and then to code, or interpret, their meaning.¹⁷ Phenomena convey meaning multimodally, so workers' perception develops across senses. As Billett and Sarojni Choy pointed out, the multimodal nature of work tasks might explain why people need authentic and contextualized practice activities.¹⁸ In this book, I examine and exemplify the development of expert perception, discussing how through scaffolded-learning interactions with Jim and my coworkers, I have furthered my ability to highlight and code relevant phenomena, like the screech a dull drill bit makes on steel.

In addition, workplace research has shown that people learn not just through learning-focused interactions but more broadly through social activity in general, as when a worker understands through immersion in a shop community how to talk to customers and which worktable to use. Jean Lave and Etienne Wenger studied how newcomers integrate into a community of practice, explaining how they increasingly participate in the community's work, adopt the community's values, and thus gradually become full community members. This book illustrates this movement from community periphery to centrality, describing my progression toward trade competences that allowed me to complete projects independently and to identify as a tradesperson, something Chan discussed in her studies of "learning to become."¹⁹

Researchers have also investigated the role that workers' attitudes play in their learning.²⁰ Billett and Choy noted that a learner's motivation can help "redress the weaknesses in the affordances of workplace settings,"²¹ as when an employee pushes on with a task despite malfunctioning or missing tools. This book examines the role of motivation in learning as well, revealing how it sustains effort during the frustrating and mistake-replete process of deliberative practice and through workplace challenges, such as condescending or sexist comments.

Learning Skilled Trades in the Workplace adds to existing research on these broad themes by detailing one woman's progression toward competences within a complex context of people, machines, tools, materials, and spaces.

Other Books About Skilled-Trades Work

Various other academic types—sociologists mostly—have ventured into the realm of trades or, more generally, blue-collar work. For example, in 1987, sociologist Douglas Harper wrote about his relationship with Willie, a mechanic in northern Maine, describing examples of Willie's expertise and his consequent relationship with and role in the community.²² Reading Harper's *Working Knowledge: Skill and Community in a Small Shop*, you get the sense that he collaborated with Willie, although his anecdotes and photos focus on Willie's work as opposed to collaborative

projects and Harper's own learning. Harper highlighted the value of Willie's expertise to his neighbors and the ways in which that expertise helped the community to function.

Another sociologist, Mike Rose, studied people doing different kinds of blue-collar work, including food service, plumbing, carpentry, and welding, to elucidate the knowledge that people doing "common work" develop and demonstrate every day and to observe cases of that knowledge.²³ Particularly relevant to my project, in the sixth chapter of *The Mind at Work: Valuing the Intelligence of the American Worker*, Rose focused on welding, describing the experience of a welder, a woman, turned welding teacher. Rose highlighted her drive to help her students connect concepts with practice, such as understanding the concept of voltage (an arc's pressure) to understand the relationship between voltage and the practical matter of arc length—the distance from the electrode to the weld surface.²⁴ Throughout his book, Rose argued against a mind-body distinction that splits the work of the hands and the body from cognition. His descriptions of people doing blue-collar work revealed mind-body interconnectedness and the shortsightedness of education that attempts to silo the two.

A few academics have actually *done* the work they examined in book-length projects, as opposed to simply observing it. In *Chaos on the Shop Floor: A Worker's View of Quality, Productivity, and Management*, sociologist Tom Juravich described his experience as a mechanic at the National Wire and Cable Company.²⁵ He argued that management's refusal to incorporate workers' knowledge into the production process led to confusion, characterized by malfunctioning machines and inconsistent quality goals. Integrating the "working knowledge" of shop-floor workers into production, Juravich claimed, would help tame the chaos.

While working as a mason, Jeff Torlina observed and interviewed factory and construction workers throughout the 1990s.²⁶ His masonry work, he wrote, assured his participants that "they were speaking with someone who shared their experience" and who was "committed to [their] trade."²⁷ Like Rose and Juravich, Torlina sought to right some of the misunderstandings about blue-collar labor, particularly misunderstandings in his specific field of study—sociology—but also misunderstandings more broadly in social science. In *Working Class: Challenging Myths about Blue-Collar Labor*, he critiqued the social science research that had helped to promulgate negative views of blue-collar work, views that further expanded into popular media.

Matthew Crawford, in his popular book *Shop Class as Soulcraft: An Inquiry into the Value of Work*, described his experience in motorcycle repair—both as an employee and as a shop owner.²⁸ Crawford argued for the value of blue-collar work, showing in the same vein as Mike Rose the knowledge such work requires and arguing too for a recognition "that productive labor is the foundation of all prosperity."²⁹ A political philosopher by training, Crawford's perspective was certainly more meta-physical than mine, delving for example into the intertwining of intellectual and moral virtue. But his goal—to argue the merit of trades—certainly undergirds the main question of my book. Accepting the argument of Crawford, how does a woman who recognizes the value of a trade develop competences in the knowledge domains that compose it? I came to welding, fabrication, and eventually machining because

I could easily see their value and the value of the people who work in trades, but my progress toward these competences has been a story in which I've oscillated like a sine wave between understanding and confusion, between extreme concentration and daydreaming, between hubris and humiliation, and between failure and success.

Especially in Chapter 10, I contrast my uneven journey against those recorded in *Alone in a Crowd*.³⁰ In this book, Jean Reith Schroedel, a political scientist, recounted the experiences of 25 blue-collar women, including a tugboat mate, a plumber, a truck driver, a painter, a carpenter, a fire fighter, and a pipefitter. Her interest in women in blue-collar jobs grew out of her own experiences as a worker in a garment factory, as a bus driver, and as a machinist. Schroedel helpfully organized the women's accounts into categories—feminism, safety and health, race, unions, and family—while noting that “each of the selections is far too rich in themes to fit neatly within any single category.”³¹ As Schroedel wrote in her preface, “Neither horror stories nor romanticism creates an accurate image of this kind of work.”³² With this idea in mind, I try to walk this line between cynicism and naiveté in recounting how being a woman has shaped my shop experiences and concomitantly my learning.

Unlike the book-length projects before it, *Learning Skilled Trades in the Workplace* focuses on learning, specifically, the development of conceptual and procedural knowledge in a metal-shop environment. Although other studies have examined the value of blue-collar labor and the experiences of blue-collar workers, they have not concentrated on the progression of a tradesperson toward competence across a range of knowledge domains.

Describing Experts and Expertise

Expertise is a concept that's difficult to nail down. Researchers who study how the brain processes new information and connects it with existing knowledge say someone with expertise holds “deeply structured and indexed” knowledge.³³ Deeply structured means the person's knowledge is thoroughly linked together, and indexed means the knowledge is thoroughly associated with circumstances for using it. This description of expertise, while useful, is also quite abstract. I find it more useful to think about what a person with expert-level knowledge can do. Stephen Billett, the prolific researcher noted above, delineated these characteristics of expertise:

1. Experts can diagnose and categorize problems better than novices. They have the knowledge required to analyze problems, and they can determine whether the problems are new or familiar.
2. Experts effectively monitor the progression of the ongoing task.
3. Experts can more efficiently close gaps in the available information to produce a viable answer.
4. Experts complete tasks efficiently. They can do this because they have sufficient conceptual and sufficient procedural knowledge. They perform the routine activities of a task automatically, leaving capacity for unfamiliar activities.³⁴

The first two of these characteristics involve problem and task analysis. Such analysis requires expert perception—the ability to highlight relevant data in the environment, such as black speckles in an aluminum weld, and the ability to code what those data mean, such as contamination in the weld. The ability to highlight and code stems from knowledge of how items in the environment should look, sound, feel, smell, or taste. Developing expertise means learning to perceive relevant cues and to understand what they likely mean.

The third characteristic refers to experts' ability to draw upon experience to hypothesize about missing information so that they can plan the steps for solving the problem. For example, an expert who sees black speckles in an aluminum weld would first think that the welder has not sufficiently cleaned the base metal and the filler metal. The expert would also check to make sure the welder isn't moving the filler metal outside of the gas shield, thus contaminating the weld. In other words, an expert conceives of possible solutions and efficiently tests them.

Finally, and unsurprisingly, experts finish tasks efficiently because more of what they encounter already falls within their "deeply structured and indexed" knowledge and thus leaves capacity for unfamiliar information. Jim's breadth of know-what and know-how means he can more readily process a new task, such as installing a new waterjet machine for cutting metal.

Billett's list of characteristics of a person with expert-level knowledge applies to expert-level knowledge of one domain. It would be possible, for example, to work at a large production facility like Vermeer or John Deere using just pulsed-spray-transfer mig welding in flat and horizontal positions. Expert-level knowledge at John Deere would mean using pulsed-spray transfer to lay long, consistently sized welds and reading complex technical drawings. But Howe's isn't a big production facility; it's a job shop. The projects that come in vary widely and require knowledge across domains. Because the work varies so much and because Jim has, depending on where you start counting, around 50 years of experience, he has developed expert-level knowledge—deeply structured and indexed knowledge—in myriad domains. His knowledge has breadth as well as depth. Thus, I think about Jim as having not expertise, but expertises. And now I'm following along behind him, taking the first steps of my unlikely journey toward expertises—but first competences—as well.

The Steps from Novice-Level to Expert-Level Knowledge

Whether abstract or practical, descriptions of expertise sidestep the question of *how* someone develops expert-level knowledge over time. As education researchers Carl Bereiter and Marlene Scardamalia wrote, "The ten years or so of training and experience that typically go into the making of an expert pose a serious obstacle to research on the acquisition of expertise. The obvious kind of research to do is longitudinal and prospective."³⁵ Especially in Chapters 3, 4, 6, and 11, where I talk about learning via one-to-one interactions with Jim and via deliberative practice, learning from mistakes, and demonstrating competences through independently accomplished

projects, my longitudinal development as a tradesperson comes through. It's helpful, however, to keep in mind markers along the path towards expert-level knowledge in a domain. In a book arguing the for the supremacy of human intuition and expertise in the age of computers, Hubert L. Dreyfus and Stuart E. Dreyfus usefully described five stages from novice to expert.³⁶

A novice learner follows explicit rules and does not analyze a context. Rather than highlighting phenomena in an environment themselves, they adhere to the descriptions given to them and apply the rules they've been told to follow. Dreyfus and Dreyfus called this type of interaction with the learning environment "information processing," likening it to identifying an uppercase E by recognizing its one vertical and three horizontal lines.³⁷ In response to a post on the machinists subreddit asking others for the speed at which they run their edge-finder bit (used on a mill to find x and y), one commenter responded by saying that no one cares how you get a task finished as long as you don't break anything or wear anything out. Responding to this person, yet another machinist pointed out the importance of rules for beginners:

I think this is the problem. If you're just starting out, you'll probably know when it's too late. That's why you take the advice from someone more experienced who now knows that X RPM was too fast because it wore out unreasonably fast. So I think OP's question is valid.³⁸

At the advanced beginner stage, the learner begins to recognize features of context based on their similarity to the rules they learned before. One project in particular clarified this stage for me. A customer had dropped off eight railroad spikes and eight slices of railroad tie. He wanted each spike welded to a slice of tie. He'd sell pairs to railroad aficionados as bookends (Fig. 1.2). Jim gave me the project, telling me that I'd have to preheat the spot where a spike met its slice because the items were forged steel. Forged steel will crack if subjected to dramatic temperature changes (such as from stick welding), so you need to heat it up before you weld it. I'd also have to peen the newly welded bookends, which means striking a weld to release the stress created in the metal by the heat. This too helps prevent cracking. Jim told me that I could use one of our needle guns—a tool we use to quickly remove slag from stick welds—to peen each bookend. I'd already developed competence through deliberative practice in using the oxyacetylene torch for cutting, but this time I'd need to use a rosebud torch tip, which would disperse the flame over a wider area than a cutting tip would.

Jim demonstrated how to position the slice and its spike in the fixture we'd fashioned, clamped both in place, and preheated the slice and the spike where they'd joined. He noted how the heated area changed color and pointed out that he had heated them for just 15 seconds or so. Then, he grabbed a stick electrode, tacked the spike to the slice, and then welded all around the top of the spike, neatly securing it to its counterpart. Although I'd watched Jim and paid attention as he pointed out and explained the color of the metal as it heated, I wanted a definitive rule to associate with the contextual clue. Rather than simply preheating for about 15 seconds, I wanted to know the preheat temperature Jim had achieved when he'd welded the two pieces together so that I'd have a number to associate to the pieces' appearance. I wrote in my journal that day, "Jim says you just need to get them hot, but he knows how hot is hot enough. I have no clue."

Fig. 1.2 Bookends made from railroad spikes and railroad-tie slices



I ran to get the laser thermometer that Jim keeps tucked away and asked him to preheat and weld another set so that I could associate a temperature—a rule—to my perceptions. Then, when it was time for me to carry out the multistep process myself, I tried to use the metal's color to determine when to stop the preheating, but I verified my decision with the thermometer. My perception advanced, but it advanced with the security given by a rule.

With competent-level knowledge, a learner “sees a situation as a set of facts.”³⁹ The learner prioritizes features within a situation and considers prior situations to make decisions. At this stage, the learner remains within “the Hamlet model” of decision-making, “the detached, deliberative, and sometimes agonizing selection among alternatives.”⁴⁰ As someone who has after more than two years at Howe's developed some competences, this description hits me hard; on countless projects I've slowed myself down with hesitations in decision-making, afraid that one error, like the angle of a bend, would cascade and create other problems. Especially in Chapter 11, I describe how I've developed competent-level knowledge in some domains, allowing me to work independently—or nearly independently—on some projects.

Leaving the Hamlet model, at the proficient stage a learner makes decisions based on the holistic context, as opposed to specific situational features. Holistic situations trigger plans.⁴¹ Even with this ability to recognize situations holistically, proficient learners will still analyze the situation for relevant features, but those relevant features combine with their holistic understanding to expediate decision-making. A proficient person, then, more efficiently completes tasks because they have a cadre of routinized knowledge.⁴² My most senior coworker, Adam, exhibited proficient-level knowledge in his approach to new projects. After 10 years in welding and fabrication, he assessed a problem, like a crushed loader bucket, holistically, and thus he worked more efficiently than the rest of us.

“When things are proceeding normally, experts don't solve problems and don't make decisions; they do what normally works,” Dreyfus and Dreyfus wrote.⁴³ Dreyfus and Dreyfus equated the fifth stage, expertise, with a sort of flow state borne from a wealth of analyzed and categorized experiences and of the decisions and actions arising from them. Someone with expertise in a knowledge domain, they

wrote, “seems to group together situations sharing not only the same goal or perspective but also the same decision, action, or tactic. At this point not only is a situation, when seen as similar to a prior one, understood, but the associated decision, action, or tactic simultaneously comes to mind.”⁴⁴ After 50 plus years in repair and fabrication, Jim has experienced countless problems across domains, many often enough that he concurrently equates them with a solution.

As with Billett’s list of an expert’s characteristics, the Dreyfus and Dreyfus path from novice to expert targets only depth of knowledge in one domain. It doesn’t account for scope of expertises or, at least, competences needed to work at a job shop like Howe’s, especially unassisted. Like all my coworkers, I have competency in some domains, like mig, stick, and tig welding, and advanced-beginner-level knowledge of other domains, like bending metal on the press brake. I can complete some steps of a job on my own but need help with other steps. So while the Dreyfus and Dreyfus schema unfortunately lends itself too easily to thinking about people, as opposed to their knowledge, in terms of novice and expert, it’s more useful to think of each person in the shop as a walking, talking network of knowledge levels, with novice-level knowledge of one domain and competent-level knowledge of another. Or, in Jim’s case, with expert-level knowledge in nearly everything related to metal work.

Conclusion

My goal in this book is to describe the intertwining paths of my learning—the hiccups, hesitations, and occasional triumphs—and to explain my learning experiences in relation to relevant but diverse research, including research from sociology, labor studies, gender studies, and linguistics. As I mentioned above, I draw from research on learning, especially research on CTE, VET, and workplace learning. My goal is fairly typical for an autoethnography,⁴⁵ which, according to Carolyn Ellis and her colleagues, “is an approach to research and writing that seeks to describe and systematically analyze (graphy) personal experience (auto) in order to understand cultural experience (ethno).”⁴⁶ Likewise, as both a researcher and a research participant, I here try to relate my story to help others—especially those learning and working in skilled trades—to understand their own journeys toward competences. In this, I attempt to, in the words of Stacy L. Holman Jones and her colleagues, embrace “vulnerability with a purpose.”⁴⁷

Foregrounding subjectivity allows me to analyze my decisions and actions, to explore my experiences within a social context and, at times, to critique the prior research findings in light of my own experience. I try to acknowledge in my account what Judith C. Lapadat pointed out in her discussion of autoethnography ethics. She wrote:

Reflexive researchers acknowledge that their own objectivity is a fiction and embrace the idea that any account they provide is a partial perspective as seen through their own point of view at a particular place and point in time. They say “I” in their research writing, aim for

transparency, attend to voice, present their interpretations as a constructed text, and resist the temptation to produce authoritative accounts or interpretations that generalize.⁴⁸

In this book, I compare my experiences as a skilled-trade learner to Jim's story and occasionally to the experiences of others, as gleaned through interviews and secondary research. But I try to, for the most part, focus on what I know because I've lived it.

In addition, I try to relate my journey toward competences with less jargon than is typical in most academic books. Lapadat continued, "By telling personal narratives situated in the particular, including emotional aspects, and attending to aesthetic qualities of writing and performance, autoethnographers open their research to a wider audience."⁴⁹ In trying to write for a broad audience that includes skilled-trade workers and academic researchers, I strive to explain jargon from research on learning (e.g., "cognitive scaffolding") in the text. I explain shop jargon (e.g., "chamfer") either in the text or in the glossary, depending on how critical the term is to the narrative. I hope in doing so I maintain readability and interest while boosting accessibility.

This autoethnography is, in part, a response to calls for empirical studies of work. For example, organizational studies researchers Stephen R. Barley and Gideon Kunda wrote, "The dearth of data on what people actually do—the skills, knowledge, and practices that comprise their routine work—leaves us with increasingly anachronistic theories and outdated images of work and how it is organized."⁵⁰ Here, connecting prior research to my own experiences as a learner in a small fabrication and repair shop, I try to illustrate the path toward the depth and the breadth of competences required to function in a job shop and the depth and breadth of expertises required to function like my boss, Jim Howe.

Notes

1. My coworkers have given me permission to use their names, as has Maria-Lucia Di Placito at Humber College. I've used pseudonyms for everyone else paraphrased or quoted in this book, namely, the people I interviewed in the fabrication shops besides Howe's.
2. Macnamara, Moreau, and Hambrick, "The Relationship."
3. While the word "shop" can refer to any place that items are sold, such as a record, book, or kitchenware shop, it also, according the *Oxford English Dictionary's* fourth entry for the term, refers to "a building or room equipped and used for a particular craft or manufacturing trade; a workshop (frequently as opposed to an office)." Throughout this book, I use the word to refer to fabrication facilities in general, although in my mind it applies best to small places of skilled-trades work such as Howe's. In this sense, the word appears in other books about skilled trades, such as Douglas Harper's *Working Knowledge: Skill and Community in a Small Shop*. In a related sense, the word appears adjectivally in "shop class," used in the United States to denote a class where students learn about tools and machines (as in the title *Shop Class as Soulcraft: An Inquiry into the Value of Work* by Matthew Crawford).
4. Ericsson, Krampe, and Tesch-Römer, "The Role of Deliberate Practice."
5. Mackiewicz, *Welding Technical Communication*.
6. Poulos, *Essentials of Autoethnography*, 4.

7. Iowa State University study 20-134-00, IRB approved March 24, 2020.
8. The term “technical and vocational education and training,” or TVET, is also used.
9. Asplund, Kilbrink, and Asghari, “Teaching and Learning”; Kilbrink, Asplund, and Asghari, “Introducing the Object”; Asplund and Kilbrink, “Learning How (And How Not) to Weld”; Kilbrink and Asplund, “‘This Angle.’”
10. Avis, “Workplace Learning”; Brockmann, Clarke, and Winch, “Knowledge, Skills, Competence”; Brockmann, Clarke, and Winch, “Competence and Competency”; Clarke, Westerhuis, and Winch, “Comparative VET”; Eichhorst et al. “A Road Map”; Kleinert and Jacob, “Vocational Education and Training”; Stroud and Fairbrother, “Workplace Learning.”
11. Ceelen et al., “Pedagogic Practices”; Fuller and Unwin, “Fostering Workplace Learning”; Jossberger et al., “Learning in Workplace Simulations”; Le Bellu, “Learning the Secrets”; Mikkonen et al., “Guiding Workplace Learning.”
12. Chan, “Belonging to a Workplace”; Chan, “Perspectives of New Trades Tutors.”
13. Chan, “The Contribution of Observation.”
14. Chan, “The Reciprocity of ‘Imitative Learning’ through Apprenticeship.”
15. Chan and Leijten, “Using Feedback Strategies.”
16. Billett, “Learning in the Circumstances of Practice”; Billett, “Learning in the Circumstances of Work”; Billett, *Learning through Practice*; Billett, “Mimesis: Learning through Everyday Activities”; Billett, *Mimetic Learning*.
17. Goodwin, “Professional Vision.”
18. Billett and Choy, “Learning through Work.”
19. Chan, “Learning the Tacit Dimensions”; Chan, *Identity, Pedagogy*; Chan, Baglow, and Lovegrove, “Supporting the Learning.”
20. Billett, “Subjectivity.”
21. Billett and Choy, “Learning through Work,” 268.
22. Harper, *Working Knowledge*.
23. Rose, *The Mind at Work*.
24. Rose, *The Mind at Work*, 124.
25. Juravich, *Chaos on the Shop Floor*.
26. Torlina, *Working Class*.
27. Torlina, *Working Class*, 16.
28. Crawford, *Shop Class as Soulcraft*.
29. Crawford, *Shop Class as Soulcraft*, 9.
30. Schroedel, *Alone in a Crowd*.
31. Schroedel, *Alone in a Crowd*, xiv.
32. Schroedel, *Alone in a Crowd*, xiii.
33. Billett, *Learning in the Workplace*, 435.
34. Billett, *Learning in the Workplace*, 56–59.
35. Bereiter and Scardamalia, *Surpassing Ourselves*, 154.
36. Dreyfus and Dreyfus, *Mind over Machine*.
37. Dreyfus and Dreyfus, *Mind over Machine*, 21.
38. Ozo42, “If you’re just starting out.”
39. Dreyfus and Dreyfus, *Mind over Machine*, 24.
40. Dreyfus and Dreyfus, *Mind over Machine*, 28.
41. Dreyfus and Dreyfus, *Mind over Machine*, 28.
42. Dreyfus and Dreyfus, *Mind over Machine*, 28–29.
43. Dreyfus and Dreyfus, *Mind over Machine*, 30–31.
44. Dreyfus and Dreyfus, *Mind over Machine*, 32.
45. Holt, “Beyond Technical Reflection”; Sparkes, “The Fatal Flaw.”
46. Ellis, Adams, and Bochner, “Autoethnography,” 273.
47. Jones, Adams, and Ellis, “Introduction,” 22.
48. Lapadat, “Ethics in Autoethnography,” 592.
49. Lapadat, “Ethics in Autoethnography,” 593.
50. Barley and Kunda, “Bringing Work Back In,” 90.

References

- Asplund, Stig-Börje, and Nina Kilbrink. "Learning How (And How Not) to Weld: Vocational Learning in Technical Vocational Education." *Scandinavian Journal of Educational Research* 62, no. 1 (2018), 1–16.
- Asplund, Stig-Börje, Nina Kilbrink, and Hamid Asghari, "Teaching and Learning How to Handle Tools and Machines in Vocational Educational Workshop Sessions." *Journal of Curriculum Studies* 54, no. 6 (2022), 809–831.
- Avis, James. "Workplace learning, VET and Vocational Pedagogy: The Transformation of Practice." *Research in Post-Compulsory Education*, 19, no. 1 (2014): 45–53.
- Barley, Stephen R., and Gideon Kunda. "Bringing Work Back In," *Organization Science* 12, no. 1 (2001): 76–95.
- Bereiter, Carl, and Marlene Scardamalia. *Surpassing Ourselves: An Inquiry into the Nature and Implication of Expertise*. Chicago: Open Court, 1993.
- Billett, Stephen. "Learning in the Circumstances of Practice." *International Journal of Lifelong Education* 33, no. 5 (2014): 674–693.
- Billett, Stephen. "Learning in the Circumstances of Work: The Didactics of Practice." *Éducation et Didactique* 5, no. 2 (2011): 125–146.
- Billett, Stephen. *Learning in the Workplace: Strategies for Effective Practice*. New York: Routledge, 2001.
- Billett, Stephen. *Learning through Practice: Models, Traditions, Orientations, and Approaches*. Dordrecht: Springer, 2010.
- Billett, Stephen. "Mimesis: Learning through Everyday Activities and Interactions at Work." *Human Resource Development Review* 13, no. 4 (2014): 462–482.
- Billett, Stephen. *Mimetic Learning in and for Work: Learning in the Circumstances of Practice*. Cham: Springer, 2014.
- Billett, Stephen. "Subjectivity, Self and Personal Agency in Learning through and for Work." In *The Sage Handbook of Workplace Learning*, edited by Margaret Malloch, Len Cairns, Karen Evans, and Bridget N. O'Connor, 60–72. Los Angeles: Sage, 2011.
- Billett, Stephen, and Sarojni Choy. "Learning through Work: Emerging Perspectives and New Challenges." *Journal of Workplace Learning* 25, no. 4 (2013): 264–276.
- Brockmann, Michaela, Linda Clarke, and Christopher Winch. "Competence and Competency in the EQF and in European VET Systems." *Journal of European Industrial Training* 33, no. 8/9 (2009): 787–799.
- Brockmann, Michaela, Linda Clarke, and Christopher Winch. "Knowledge, Skills, Competence: European Divergences in Vocational Education and Training (VET)—the English, German and Dutch Cases." *Oxford Review of Education* 34, no. 5 (2008): 547–567.
- Ceelen, Lieke, Anne Khaled, Loek Nieuwenhuis, and Elly de Bruijn. "Pedagogic Practices in the Context of Students' Workplace Learning: A Literature Review." *Journal of Vocational Education & Training* 75, no. 4 (2023): 810–842.
- Chan, Selena. "Belonging to a Workplace: First-Year Apprentices' Perspectives on Factors Determining Engagement and Continuation through Apprenticeship." *International Journal for Educational and Vocational Guidance* 16 (2016): 9–27.
- Chan, Selena. "Learning the Tacit Dimensions of Craft and Industrial Trades Work through Apprenticeship." In *Implizites Wissen*, edited by Rico Hermkes, Georg Hans Neuweg, and Tim Bonowski, 175–193. Bielefeld: wbv Publikation, 2020.
- Chan, Selena. "Perspectives of New Trades Tutors: Boundary Crossing between Vocational Identities." *Asia-Pacific Journal of Teacher Education* 40, no. 4 (2012): 409–421.
- Chan, Selena. "The Contribution of Observation to Apprentices' Learning." *Journal of Vocational Education & Training* 67, no. 4 (2015): 442–459.
- Chan, Selena. "The Reciprocity of 'Imitative Learning' through Apprenticeship." *Vocations and Learning* 10, no. 3 (2017): 325–342.

- Chan, Selena, Lee Baglow, and Chris Lovegrove. "Supporting the Learning of the Sociomaterial: Novices' Perspectives on Virtual Reality Welding Simulators." In *Contemporary Apprenticeship Reforms and Reconfigurations*, edited by Thomas Deißinger, Ursel Hauschildt, Philipp Gonon, Silke Fischer, 63–66. Zurich: Lit Verlag, 2019.
- Chan, Selena, and Flip Leijten. "Using Feedback Strategies to Improve Peer-Learning in Welding." *International Journal of Training Research* 10, no. 1 (2012): 23–29.
- Clarke, Linda, Anneke Westerhuis, and Christopher Winch. "Comparative VET European Research Since the 1980s: Accommodating Changes in VET Systems and Labour Markets." *Journal of Vocational Education & Training* 73, no. 2 (2021): 295–315.
- Crawford, Matthew. *Shop Class as Soulcraft: An Inquiry into the Value of Work*. New York: Penguin, 2010.
- Dreyfus, Hubert L. and Stuart E. Dreyfus. *Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*. Washington, D. C.: Free Press, 1986.
- Eichhorst, Werner, Núria Rodríguez-Planas, Ricarda Schmidl, and Klaus F. Zimmermann. "A Road Map to Vocational Education and Training in Industrialized Countries." *ILR Review* 68, no. 2 (2015): 314–337.
- Ellis, Carolyn, Tony E. Adams, and Arthur P. Bochner. "Autoethnography: An Overview." *Historical Social Research/Historische Sozialforschung* 36, no. 4 (2011): 273–290. <https://www.qualitative-research.net/index.php/fqs/article/view/1589/3096>.
- Ericsson, K. Anders, Ralf T. Krampe, and Clemens Tesch-Römer. "The Role of Deliberate Practice in the Acquisition of Expert Performance." *Psychological Review* 100, no. 3 (1993): 363–406. <https://doi.org/10.1037/0033-295X.100.3.363>.
- Fuller, Alison, and Lorna Unwin. "Fostering Workplace Learning: Looking through the Lens of Apprenticeship." *European Educational Research Journal* 2, no. 1 (2003): 41–55.
- Goodwin, Charles. "Professional Vision." *American Anthropologist* 96, no. 3, (1994): 606–633.
- Harper, Douglas. *Working Knowledge: Skill and Community in a Small Shop*. University of Chicago Press, 1987.
- Holt, Nicholas L. "Beyond Technical Reflection: Demonstrating the Modification of Teaching Behaviors Using Three Levels of Reflection." *Avante-Ontario* 7, no. 2 (2001): 66–76.
- Jones, Stacy Holman, Tony E. Adams, and Carolyn Ellis. "Introduction: Coming to Know Autoethnography as More Than a Method." In *Handbook of Autoethnography*, edited by Tony E. Adams, Stacy Holman Jones, and Carolyn Ellis, 17–47. Walnut Creek, CA: Left Coast Press, 2013.
- Jossberger, Helen, Saskia Brand-Gruwel, Margje W. J. van de Wiel, and Henny Boshuizen. "Learning in Workplace Simulations in Vocational Education: A Student Perspective." *Vocations and Learning* 11 (2018): 179–204.
- Juravich, Tom. *Chaos on the Shop Floor: A Worker's View of Quality, Productivity, and Management*. Philadelphia: Temple University Press, 1988.
- Kilbrink, Nina, and Stig-Börje Asplund. "'This Angle that We Talked About': Learning to Weld in Interaction." *International Journal of Technology & Design Education* 30 (2018), 83–100.
- Kilbrink, Nina, Stig-Börje Asplund, and Hamid Asghari. "Introducing the Object of Learning in Interaction: Vocational Teaching and Learning in a Plumbing Workshop Session." *Journal of Vocational Education & Training* 75, no. 2 (2023), 323–348.
- Kleinert, Corinna, and Marita Jacob. "Vocational Education and Training in Comparative Perspective." In *Research Handbook on the Sociology of Education*, edited by Rolf Becker, 284–307. Cheltenham: Edward Elgar Publishing, 2019.
- Lapadat, Judith C. "Ethics in Autoethnography and Collaborative Autoethnography." *Qualitative Inquiry* 23, no. 8 (2017): 589–603.
- Le Bellu, Sophie. "Learning the Secrets of the Craft through the Real-time Experience of Experts: Capturing and Transferring Experts' Tacit Knowledge to Novices." *Perspectives Interdisciplinaires sur le Travail et la Santé* 18, no. 1 (2016). <https://doi.org/10.4000/pistes.4685>.

- Mackiewicz, Jo. *Welding Technical Communication: Teaching and Learning Embodied Knowledge*. Albany, NY: State University of New York Press, 2022.
- Macnamara, Brooke N., David Moreau, and David Z. Hambrick. "The Relationship between Deliberate Practice and Performance in Sports: A Meta-Analysis." *Perspectives on Psychological Science* 11, no. 3 (2016): 333–350.
- Mikkonen, Susanna, Laura Pylväs, Heta Rintala, Petri Nokelainen, and Liisa Postareff. "Guiding Workplace Learning in Vocational Education and Training: A Literature Review." *Empirical Research in Vocational Education and Training* 9 (2017): 1–22.
- Ozo42. "If you're just starting out, you'll probably know when it's too late." Reddit, January 21, 2024. <https://www.reddit.com/r/Machinists/comments/19bot7i/comment/kivm5ao/>.
- Poulos, Christopher N. *Essentials of Autoethnography*. Washington, D. C.: APA, 2021.
- Stroud, Dean, and Peter Fairbrother. "Workplace Learning: Dilemmas for the European Steel Industry." *Journal of Education and Work* 19, no. 5 (2006): 455–480.
- Rose, Mike. *The Mind at Work: Valuing the Intelligence of the American Worker*. New York: Penguin, 2004.
- Schroedel, Jean Reith. *Alone in a Crowd: Women in the Trades Tell Their Stories*. Philadelphia: Temple University Press, 1985.
- Sparkes, Andrew C. "The Fatal Flaw: A Narrative of the Fragile Body-Self." *Qualitative Inquiry* 2, no. 4 (1996): 463–494.
- Torlina, Jeff. *Working Class: Challenging Myths about Blue-Collar Labor*. Boulder, CO: Lynne Rienner, 2011.

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Chapter 2

The Learning Context



Abstract I begin this chapter with the story of my boss, Jim Howe, using his own words to relate his path through early work in his parents' appliance-repair shop, through work as a welder in the Navy, and to shop ownership. Then, I describe Jim's shop. At Howe's, we repair and fabricate most anything, such as trailers, tractors, lawn mowers, ladders, dumpsters, and lawn art. Customers include farmers who work the vast fields of corn and soybeans outside Ames, employees from construction and other local businesses, city and county workers, and just regular people who have something that needs fixing. Work at Howe's develops not just depth of knowledge but also breadth because we grapple with a wide range of projects. And in repairing and fabricating, we use a range of welding processes (namely stick, mig, tig, and oxyacetylene) and machining tools (such as lathes, drill presses, mills, press brakes, ironworkers, box-and-pan brakes, and shears) on not just steel but also aluminum and stainless and occasionally other metals. This project variety consistently challenges me, posing unfamiliar problems and necessitating help from someone who has already developed greater expertise in the relevant knowledge domain. That person is often, but not always, Jim.

I mentioned before that Howe's Welding and Metal Fabrication was the first fabrication shop that I visited when I started this project. I still haven't seen another place like it. No other trades workplace I've seen has the same cluttered, analog quirkiness. That oddness arises in part from Jim's focus on repair and one-off fabrication jobs. Unlike many larger shops, we don't do a lot of long production runs. If we make multiples of something, the multiple usually equates to a number like five or ten, not one thousand or even one hundred. That's an important distinction in the world of fabrication. When you're going to make hundreds or thousands of something, you hone your processes to its fabrication. In this chapter, I introduce my boss, Jim Howe, relating his path toward expertises. Then, I describe his metal shop, the site of my own journey toward skilled-trade competences.

Jim Howe, My Boss

Jim's life has revolved around his passion for repair and fabrication. He's pursued opportunities to learn more about metal work and mechanics throughout his life, starting when he was just a kid. His mom and dad opened an appliance repair shop, which started when his dad, discharged honorably from the military, started to repair washers that people had left out as trash. He would rent them out, along with dorm refrigerators. When I asked Jim whether he remembered his dad and mom teaching him about repair, he answered affirmatively:

Jim: Oh, yeah. You better know what a 10–24 screw was. We had to strip appliances. So what we would do is if one didn't work, like if it was scrap, we'd pull every screw, every nut, every bolt. The motor, pump, the transmission, all that, and then scrap the rest of it out. So you got to learn real quick a 5/16ths nut driver is going to fit this, and what a quarter 20 was because you didn't want to sit there and mess around with wrenches all day. Every Sunday we'd go out to the barn which had... hundreds, and hundreds, and hundreds of appliances, and we'd strip them. And that's how we'd spend our Sundays.

Repair filled his life, including repair to keep the family business going:

Jim: I put my first engine in a truck when I was 14. The service truck went down, and so we pulled the engine out, rebuilt it, and put it back in. Used a tree to hold the engine up while we were swapping engines. Yeah, we just looped over and had a chain fall and away we went.

Because the business was a 24–7 operation, Jim and his brother Bob were expected to help:

Jim: We'd have to answer the phone if we were watching TV. So we only got an hour of TV a day, but my dad was out on appliances and mom was on taxes or something, and we had to take turns answering the phone. Well sure as shit, it's your turn, and *Dukes of Hazzard's* in the middle of a chase scene, and you got to talk to somebody about their washer that's down. I got my ass chewed more than once for not having all the information he needed when they got home. What was the model number? I don't know. Daisy Duke was in her shorts, man.

He practiced on leftover appliance parts:

Jim: We had a little Lincoln Tombstone sitting in garage six. A miracle I didn't burn that place down. And I'd take old washer panels and weld on them.

When Jim was old enough, he got a job at Industrial Plating, which became Custom Steel Service. But he moved to Barber's Metal Fabrication to escape the monotony of the job he'd been given at Industrial Plating:

Jim: So they're tubes that are 12 inches in diameter. So they had to chamfer the edges for the pistons to go in and out, and then we chromed them. So I had to chamfer them. But if they screwed up the chrome, we'd have to strip them. So I got scars on my legs yet from—Once in a while, I'd drop one in the acid bath, and then that'd splash onto me, and so then I'd have acid burns.

During this time, he discovered that he had real talent for welding:

Jim: So in high school, I went through VICA [Vocational Industrial Clubs of America]. I entered the VICA contest, and I won the state of Iowa. And then I went to nationals, but I was fifth. So I learned real quick that there was always a faster gun. I mean, there was always someone better than you.

Jim joined the Navy on a bit of a whim, accompanying his friend Dixon on the trip to Des Moines mainly for the free food, but finding that the Navy could offer him the education he wanted:

Jim: Went down to the MEP [Military Entrance Processing] center, spent the day doing tests and all that. And they make sure you're healthy, and then they give you the ASVAB [Armed Services Vocational Aptitude Battery], decide how mechanically inclined you are. And Dixon's eyes wouldn't pass for him to be a machinist. He ended up going home, and I had my right hand in the air. I actually called mom. I says, "Mom, what do you think? I'm thinking about joining." And she's like, "It's up to you." So I wanted to come out with money, knowledge, or equipment when I went in. I mean, I figured, well, I'll go ahead and do my six years with two years reserves. And if I save my money up, then I will have the knowledge. They're going to send me through welding school.

He served as a welder on a nuclear sub tender during his six years in the Navy. To be a certified welder for a nuclear sub, you need to be at the top of your class. Jim had already won a welding contest in Iowa, and had gone to the national welding competition, but he knew he'd have to work hard to get to weld on nuclear submarines:

Jim: I mean, when I got into welding school, I thought I was pretty kick ass because I had won the state of Iowa, baby. There were people in that class that were just smoking. So I had to double my- I didn't take any cigarette breaks. It's amazing how many people that weld to smoke. I mean, it's like smoke break. They'd be out there and I'm burning the rod, baby. They were getting bummed because I'd be, "I need 10 more rods." They'd be out of rods. They said, "Don't you ever take a break?" Well, the problem is, out of 300 and some people that start, six go to nuke. That's a big drop. I mean, as they go in, they drop people.

Jim's reluctance to take breaks then, in my view, presaged his later reluctance to take a day off from the shop. Each year, Jim takes one week off, and he doesn't spend it relaxing; he does RAGBRAI, a week-long bike ride, with his long-time friends. Otherwise, the only time I've witnessed him taking an entire day off was when he caught COVID-19. That laid him up for a day. After that, he still went to work at the shop, but he slipped finished work to customers through a cracked-open garage door.

In those Navy welding classes, Jim had to pass difficult assessments, such as welding with mirrors:

Jim: The final test is a 12-inch by 12-inch by 12-inch-deep box with a 1-inch pipe, six inches off it, doing a fillet weld on a socket. So you had to use mirrors, and you can't see it. It's six inches down underneath. So you put mirrors down there, and you weld that. And then they X-ray it. That's your final in that. Because on the submarines or in the ships, you're going to be in spots worse than that. All the time, you're in worse spots than that.

After Jim had earned his place as a nuke on a sub tender, he could act on his motivation to develop greater breadth of knowledge:

Jim: Everybody else, if they had a house on the bay, on shore and all, they'd scatter like cockroaches. At four o'clock, everybody's gone. So I'd go up to the machine shop, or I'd go to the pattern shop or something.... We had a full pattern shop [i.e., a metal foundry], woodworking shop, sheet metal shop, pipe shop, hydraulic shop, nuclear. We had nuclear repair.

During his supplementary work after hours, Jim would gather commonly used items so that he didn't have to waste time requisitioning them. As he recounted memories of working on the tender, it became clear that his penchant for collecting existed long before he opened his own repair and fabrication shop:

Jim: If I needed a quarter-20 bolt, I'd have to go find one, and then I'd have to submit a chit to get a quarter-20 bolt. It's like, "This is bullshit." It's like, "Man." So I'd collect hardware. Anytime a shop was getting rid of stuff, I was on it because then, I had the ghetto in the shop. Everybody's, "How's ghetto?" I had this locker. It was full, but I always had it.

In addition to the extra time he spent developing new skills on the tender, Jim also worked part-time at A & B Precision Machine, where he further developed his competence in machining with the aid of his employer, Clark Thatcher:

Jim: I was doing most of his welding. But now and then, he'd need something to machine, so he'd say, "Well, here's how we do this." And then he'd set me up on the machine, and then I'd run that.

Jim recounted how his boss there modeled creative problem solving, using machines for tasks they weren't supposed to be able to do:

Jim: The mill, we were making 36-inch circles on his mill that I've got in the shop, the one we use every day. He turned the head, jacked it all the way out, and used a turntable. Sit there and put the bit down, and then run your index head, and we'd make a round circle. It's like, "Dude, I mean, you're not supposed to be able to put a 30-inch circle on a mill that size." Well, he'd do it. We had the same equipment on the ship, but they wouldn't... It's like, "No, we can't do this. It's too big for our machines." [He replied] "We do it at Clark's."

About this attitude toward using the Navy's own machines to do the work that it had farmed out to subcontractors, Jim added, "I don't get it. So I mean, the mind is the only limitation."

Because requisitioning parts annoyed him, Jim eventually took a position that allowed him to work in the tender's machine shop, machining what he needed:

Jim: You had to fill out and jump through fiery hoops and all kinds of crap to get something, even if I wanted a hole drilled, which we could do downstairs. We had a drill for us. But I mean, if I wanted to use a lathe, I couldn't do it. Ten lathes open upstairs, but no, I couldn't do it because I was a hull tech, instead of a machinist.

These frustrations, it seems to me, play a role in Jim's drive to fill his shop with machines and tools that facilitate work and to teach his employees to use them. He remembers the frustration of having to wait for basic parts like bolts and of having to wait for someone else to do something like drill a hole—tasks he could easily have done himself.

While in the Navy, Jim bought machines and tools and semitrailers. He'd haul his equipment back to Ames, waiting for the day when he could put it to work in his

own shop. When Jim left the Navy in 1986, he started Howe's Welding and Metal Fabrication, taking over a part of the building vacated by Ames Concrete Block. Jim's dad bought the building to store appliances, but he gave Jim space to start his shop. But soon Jim needed more space than the building could afford, so he began thinking of expanding the workspace:

Jim: So then in '97, we decided to go ahead and build the [new] building. And we really couldn't afford it, but like Mom said, "If we waited until we could afford it, we'd never have it. You're going to have to just borrow the money and do it."

In deciding to take on debt to pursue his shop, Jim thought about a fellow metal worker he knew from his blacksmith's group:

Jim: We had a guy in the blacksmith's group, that every meeting, he was talking to people about this building he was going to build. It would be a great building. "How big should I make the door?" He'd ask everybody at the meeting, "If you had to change something, so what would you do? Would you put tie-downs in the floor? Would you have a pit? Would you have a hoist? Would you have...." And so he had this great, great idea, and then he died. He was probably in his 70s, but he'd worked on a dirt floor the whole time because he was going to build a building. He was going to wait until he could afford it.

Because the shop rested in the flood plain of the Skunk River, Jim determined to build a structure that could withstand floods—the type of crisis that had driven out Ames Concrete Block:

Jim: It's got concrete walls, with three inches of foam in between, carbon fiber ties. We made it so it's not just some pole barn that you just throw together, and it's going to last 30 years. I mean, it's a 100-year building. In-floor heat.... We could have made a cheaper building, but it wouldn't have lasted as much. So we built it, and we're still paying for it. Still paying. But you couldn't build that building today. It'd be twice as much today.

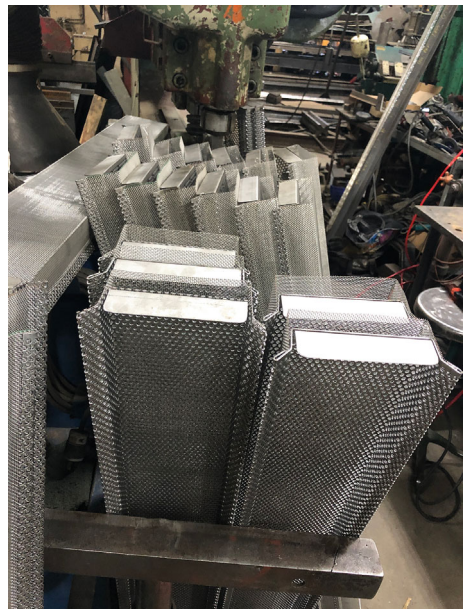
For the first 20 years in business, Jim worked with his Navy friend, Ray Schraeder. The two had roomed together during their time in the Navy because they were the only two in their unit who didn't smoke. Together, Jim and Ray dealt with the floods that eventually came. In 1993, the business flooded three times; after the second flood that year, they hoisted the equipment to the roof and worked from up high. Floods came again in 1996, 1998, and 2000. Each time, Jim and Ray cleaned up the mess. In 2010, after Ray had left, the last flood—and the worst—seeped in. Whereas water had risen to 10 inches in previous floods, this time, over 22 inches of water spread through the shop, wrecking sufficient havoc but making Jim grateful for his preparation: fuse boxes on the second floor, power outlets at 36 inches, and welding machines on wheels and bracketed high on the walls. Still, with each flood Jim had to work even more than he already did, putting in extra hours to clean the machines while maintaining output.

After Ray left, Jim mainly hired undergraduate students who wanted to learn hands-on applications for what they were learning in their engineering classes. Eventually, he hired Adam, Jessie, and David, the three full-time employees who worked for Howe's when I started showing up in early 2022.

Howe's: An Overview

As mentioned above, at Howe's, we fix heavy equipment of all types—trailers, loaders, excavators, and crane buckets, graders, and tractors. Indeed, we repair most anything—lawn mowers, dumpsters, fire doors, elutriators, bike racks, and lawn art. Customers include farmers who work the vast fields of corn and soybeans outside Ames, employees from construction and other local businesses, and city and county workers. They often come in wanting some failed part fixed. Or, sometimes they want something fabricated. Jim, with his expert-level knowledge of machining, creates replacement parts. But all of us at Howe's fabricate a world of items, such as truck and trailer ramps, ladders, and handrails. Sometimes, we make multiples, usually just a few, such as the two skis that sit under the machine that makes rumble strips in the road, but sometimes more, such as the 100 seed bins for agricultural research that Zach and I bent and spot welded (Fig. 2.1). Some clients have ongoing orders, such as the owner of a local frame shop who orders picture hangers from us. We waterjet the spiky oval hole where the nail in the wall goes, round each hanger's corners on an arbor press Jim rigged for the purpose, and bend the hangers on the small mechanical press brake. The client calls every few months to tell Jim how many more she needs of each size—2 ½ inch and 5 inch. Between work on such repair and fabrication projects and throughout the day, we cut tubing, pipe, flat bar, and angle iron and shear sheet and plate for people who call in orders or walk in and wait for us to prepare their metal.

Fig. 2.1 Some of the 100 seed bins that Zach and I made



If a broken part will keep people from working and if the customer's lament of impending doom sounds sufficiently plausible, Jim tries to fix the item that day, immediately if possible. Sometimes those repairs require "portables," those jobs requiring Jim's truck, which contains a welding machine, a generator, and all the tools he needs to make on-location repairs. For example, Jim once took me along when he repaired one of two gates guarding the dumpsters at an apartment complex. The weight of the large gate had twisted and broken the metal at the hinge. Mainly though, customers come to the shop to talk about what they need. And after 37 years in business, Jim has many repeat customers. City employees, for example, come in often for equipment repairs or for steel. Local farmers stop in with broken combine or tractor components. Employees of local construction companies stop in for supplies. In other words, unlike in a big production shop, project management at Howe's arises through one-to-one interactions and sustained personal relationships and through Jim's ongoing assessment of the jobs that need his or our immediate attention.

We log all jobs, emergency or not, in the black binder that sits on the counter at the front of the shop (Fig. 2.2). This pen-and-paper system differs substantially from the project management systems I saw on visits to larger fabrication facilities. With this binder-note method, each time we need to find a customer's phone number, we must sift through the binder's pages, looking for the entry, which can take 10 or so minutes if it's been a few weeks since the client brought in the project. I learned a strategy from Zach that helps us find entries later on; we draw a picture of the part to be fixed or made on the entry's line on the page. That way, we at least have a visual to tip us off as we leaf through the pages.

Fig. 2.2 A page from the job book kept on the front desk. (Note the pictures to convey the idea better and to promote recall.)

NAME AND PHONE	JOB DESCRIPTION	DONE
John [unclear]	8' x 6' x 1/4" [unclear]	Done
John [unclear]	Wants to talk to Jim	Done
John [unclear]	Handle	Done
Mike Moreno	dolly add 5/8 under lines for supports	Done
Clint Kelson	2 1/2" x 5 1/2" x 3/16" rebar X72"	Done
3/8 plate 2x 4 1/2" with holes to match	Don't plate	Done
Ballard & sons	Cady Franklin	Done
Art's Stockade	Oak Drive Ames, IA 50010	Done
Ames Land	10a. #4 Bredal green Horse	Done
68" Lam.	40 1 1/2" x 3/4"	Done
Rick Hammer	1 x 1/2" x 3/4" Hatched Banded	Done
Malen Eck	cut cut 1001 1/2" x 1/2" 1 5' x 3'	Done
Redling	Knicker	Done

Describing Howe's physical space poses a challenge. It's a little like Paris: You could visit a thousand times and still find something new. To inventory Howe's would take years and dozens of spreadsheet pages. Jim built his shop one tool and machine at a time, amassing more by buying used from auctions and from other shop owners. In trying to convince me to buy an old shear he's got sitting outside the shop under a tarp, he tells me of his early shop days when he didn't have his own shear. Then, he had to cut sheets the hard way—with a cutting disc. This early scarcity plays a role, I think, in Jim's ongoing accumulation. Numerous mornings I've come into the shop to find Jim at the front-desk computer, clicking on auction-item pictures and placing bids on bins of hand tools, a spool gun for aluminum mig welding, or what have you.

Jim has collected machines and tools since even before he received an honorable discharge from the Navy over 37 years ago. The shop holds four press brakes of different sizes, both hydraulic and mechanical. It's got three ironworkers (machines for cutting flat bar and angle iron and for punching metal), two vertical band saws, two horizontal band saws, two drill presses, two box-and-pan brakes (machines for bending metal sheets), five lathes, two mills, and a gigantic boring machine in the back. It's got a sandblasting cabinet and two waterjet machines. And this list comprises just the big equipment downstairs. In the loft upstairs, where the office and small kitchen rest, sit row upon row of supply shelves. One shelving bookcase contains only springs. Jim loves springs—collecting them and making them. Behind the library-esque rows of bookcases rests a line-up of stored machines—yet another lathe and more welding machines—and less-commonly used machines, such as the arbor press that we use only for clipping the corners of the framing shop's hangers, a small table saw that I used to cut extruded tubing for an artist's project, and a sand-blasting cabinet that we use for aluminum and stainless steel. I've had to go upstairs a few times to use a machine that hasn't found a place downstairs.

Downstairs, one wall holds racks of metal: sticks of angle iron, tubing, pipe, threaded bar, solid stock and flat bar, mainly steel but also stainless and aluminum (Fig. 2.3). Further back sit bins and racks of stainless and aluminum "drops," the pieces that drop from the shears when we cut metal sheets and plate. Against the other wall rest tall shelving units, stacked high with tools, such as about a dozen hand drills, and small machines, such as pipe threaders of different sizes. Against that wall too sit cabinets and lockers, some with small drawers holding nuts, bolts, screws, and washers of all types and sizes, some holding spray cans and paint supplies, some holding welding blankets and other items of mysterious-to-me purpose (Fig. 2.4). Near the shelves rest a rack of chains and straps and a deburring machine that tumbles metal pieces to smooth their edges. Sitting between the rollers leading to the most-used band saw and the rollers leading to the most-used (hydraulic) ironworker sits a stack of metal—flat bar too wide and thick and tubing too big and heavy to be filed in the wall rack. Using the hoist to pull a stick of metal out of the wall rack often means climbing this long metal mountain and trying not to break your ankle in the process. On the other side of the ironworker are two shears, a gigantic one and a smaller one for cutting 1/4-inch steel and thinner. Behind those shears are our worktables—my little one, a shared one where projects pile up, Zach's long table that sits alongside

the wall shelving, and further back what used to be Adam's table and workspace near the bay door (Fig. 2.5).

Fig. 2.3 Racks and stacks of flat bar, tubing, and angle iron sit between the band saw and the ironworker



Fig. 2.4 The shop's main bay



Fig. 2.5 My little table with a fence project on top of it, the shared table with projects piled up on it, and Zach's long table in the back by the shelves



On the other side of the big shear sits the machine shop, with its five lathes of different sizes, two drill presses, and two mills (Fig. 2.6). Toward the back rests the older waterjet machine, which uses a hardworking computer running Windows XP, an operating system older than my coworker Zach. In the machine shop, Jim keeps drawers and shelves of tapers, collets, dies, drill bits, taps, chucks, and all else machining related—years of tooling accumulated to tackle diverse projects.



Fig. 2.6 The machine shop seen from the back of the big shear



Fig. 2.7 Stuff behind Howe's

In addition to all that's jammed into the shop, Jim's got extra welding machines and stacks of replacement parts that he keeps in five Conex boxes that sit outside, surrounded by a small junk yard of metal augers and aluminum lawn chairs and old shelving and acorn tables along with steel plates and sections of tubing and pipe too big to sit inside and the recycling bins for steel and aluminum (Fig. 2.7). Jim used to have more land—five acres' worth—around the shop to keep all his infrequently used items and back-up equipment. But because Jim's land sits on the flood plain of the Skunk River, the city of Ames used eminent domain in 2021 to acquire half of his acreage for a FEMA-funded flood-mitigation project.¹

The clutter of the shop and the space surrounding it speaks to who Jim is. Jim loves having the exactly right tool for a job, even if that means keeping tools piled up on the shelves that nearly reach the ceiling or outside in a Conex box. Also, he recognizes the value of buying something—and its back-up—before he needs it, even if he might need it only once a year, or decade. And more than that, the crammed-in-ness of the shop indicates Jim's capacity to perceive the potential of an item, be it a tool or a dropped piece of metal or a block of wood. Because Jim sees potential, he collects. One time when we were together at the lathe, he showed me a drawer filled with used carbide bits that he keeps for when he wants to gouge out 1/4-inch or more at a time. Using an old bit, he doesn't care about breaking because he's previously used it and had to sharpen it again, which makes it a less precise instrument. After he's completed a rough gouging with an old bit, he goes back with a newer, precise bit.

Navigating the shop thus means navigating all the items in it, the piles, bins, stacks, and lone items tucked into crevasses between machines or under tables. So we edge ourselves between the two shears, careful to avoid knocking our shoulders against the crank handle that jets out of the big shear's side or around the back of the shop's longest work table, or past the disassembled Land Cruiser, or behind the waterjet and the racks and piles of steel, aluminum, and stainless skeletons (Fig. 2.8), sheets that

Fig. 2.8 Some of the metal skeletons left over once shapes have been cut out of them on the waterjet



have had circles and other shapes cut out of them, and we stretch and climb to reach items on shelves. And we attend to potential trip hazards as if inspired by Simone Biles. The shop contains most anything you'd need to complete a project—to cut, bend, press, roll, punch, shear, drill, ream, whatever—but you better watch where you're walking. One Saturday morning, walking down the main bay past the Land Cruiser carcass, I caught my boot on the corner of a perforated-steel sheet that leaned against a rack of drops from the shears. I fell smack-dab onto my right kneecap, the pain convincing me that I'd fractured it. I escaped with nothing but an ugly bruise, but that nasty spill reinforced my vigilance.

Working in the cramped spaces that the clutter of the machines and the in-progress projects create means that we all, including Jim, end up on semiregular searches for items we've thoughtlessly set down somewhere. I regularly search for my tape measure, set down perhaps on the ironworker or left on the front counter. When you set something down without noting its location, it can be difficult to find it again because it's difficult to fix on something in the environment's visual din. Likewise, calipers—the ones that work well—regularly go missing, even though we try to keep them in a drawer by the mill. We also try to keep the Allen wrenches and open-end wrenches that each machine requires near to it, like the $\frac{3}{4}$ -inch wrench that stays on the ironworker, but that system doesn't always work. Tools walk off. Dies and punches also seem to disappear. Adam and Zach organized them by size once, but the system didn't take. So once again we look through a dozen dies and punches to find the size we need. Jim has lined up US customary wrenches by size, and they hang along the side of a toolbox, but the metric ones and extra US customary ones are mixed up in a drawer. Used grinding wheels and flapper discs lie piled up where

we keep the stack of angle grinders. Discs for stainless and aluminum mix with those for steel. Even more frustrating are searches through the pile and around the shop for missing projects. I've spent hours looking for lost items: a ring for my lampshade project, a bracket off a tractor, the broken base for a vise that needed to be brazed back together.

In his study of a Philadelphia repair shop, historian and sociologist Justin Carone closely examined the work of Vern, an appliance repair worker. Carone discussed how Vern's "mental inventory of the other parts scattered around" allowed him to home in on the exact item he needed when he needed it.² He hypothesized that Vern's system of piles worked, whereas "a strict method of organization" would lose "meaning and utility" when confronted with items that have multiple potential purposes. It seems to me that Carone might have somewhat romanticized this supposed ability of the expert tradesperson to locate what they need in what to the uninitiated seems like chaos. He in part wanted to examine the concept of "deservingness"—how societies determine who deserves which resources and how academia decides who deserves study. Toward this end, he wanted to argue the value of analyzing "the reasons, beliefs, and practical life activities" of tradespeople like Vern who have been "marginalized by the institutions of disciplinary power."³

I obviously can't speak to whether Vern always knew the location of what he needed at a given moment. But I know that Jim, operating within a shop manifesting mainly "loose organization" of tools like hand drills, and components like collets and tooling, and materials like dropped pieces of aluminum and stainless, spends time searching for items every day. Like the rest of us, Jim sometimes looks for a known item—the slug for the ironworker that's supposed to sit on the top shelf of the punches and dies cabinet—and sometimes he searches through drops for an item he's not sure exists, like a piece that will fit the bill for a customer who requests, for example, a 1/8-inch, 12 × 12-inch piece of aluminum. I wonder if there isn't sometimes, in some of these arguments for the value of trades work and the value of studying trades work, an idealization—a sort of Jedification if you will—of the tradesperson, including an ability to immediately locate anything in their workspace.

In addition, every shop—even Howe's and I suspect Vern's as well—displays some strict methods of organization. Without them, work would be untenable. Try to drill a 9/16-inch hole if you have to test the size of each drill bit you pull out of a pile. At Howe's, each size rests in its own drawer. Try to tighten a bolt if you've got to read the sides of two or three wrenches to find the size you want. The wrenches hang from smallest to largest on the side of our most-used toolbox. Try to find a bolt if they're not organized by diameter, thread count, and length. We've got cabinets of bolts and nuts and other fasteners, mainly if not perfectly organized by their types and dimensions. Try to pull a stick of flat bar if you've got to measure the width and thickness of each before finding the one you need. We've got rows containing 1/8-, 3/16-, 1/4-, and 3/8-thick flat bar, organized horizontally from 1/2-inch to 3-inch widths. At Howe's, we maintain strict categorization where loose organization would mean a substantial loss in productivity. I suspect that Vern and others who appear to magically perceive order in the din maintain some strict categorization too.

Howe's Projects and the Pile

Those projects that customers can carry in the shop—as opposed to pulling or driving them in—usually stop at what I think of as “the pile” (Fig. 2.9). It sits just past the front entry and the counter: the spot in the shop where items for repair end up until Jim assigns them to someone. The items can sit there for days, weeks, months, even years, depending on how quickly the customer needs the work done. That prioritization means that hobby stuff, like lawn art, can sit in the pile for a long time. Once, I found a lawn-art windmill with a few blades that needed to be reattached. Someone had taken the time to write on a piece of blue painting tape not only the customer’s name and phone number, but also the date it had been brought in: August 11, 2014. I picked this thing out of the pile on February 22, 2023. After I’d used the small mig welder, the Lincoln 100, to tack the windmill blades back to the rings that held them, I called the customer to tell her that her windmill was finally fixed. She laughed and told me that she’d given away the windmill’s base years ago and that we should just keep it. I ended up giving it to another client who had brought in the same, though much more damaged, windmill. So in that case, everything worked out fine, but more often customers with small projects call to see whether we’ve started working on their windmill or weathervane or pan with a detached handle, and then we’ve got to dig through the pile to find it.

Jim takes on the small-but-time-sucking projects that sit in the pile because he detests waste—the act of throwing away an item that would function once again if it were repaired. Waste offends Jim. Take, for example, the bins full of plastic circles

Fig. 2.9 The pile of projects



that arise from a recurring waterjet project: Harley Davidson speaker mounts. Every few months, this client brings ten or so sheets of hard plastic to the shop, and we waterjet five speaker mounts per sheet. Then we mill three depressions where the mounts attach to the motorbike. We also deburr each mount, making sure no plastic clogs the small waterjetted holes. What remains after the process? Hundreds of five-inch plastic circles. Jim has asked his university professor friends—particularly the ones in engineering—whether their students could invent some way to use all the leftover pieces. So far, no one has brainstormed a way to employ them, so they gather in bins. Jim's distain for waste means that when people bring in their cheaply made shepherd's hooks, trellises, chairs, tables, windmills, watering cans, weathervanes, and so on, he wants to fix them rather than letting them end up in the landfill. In his impulse to reuse and conserve, Jim manifests what psychologist Robert Sternberg, in his description of a consummate expert, called wisdom-based expertise. The wise expert acts ethically, balancing concern for self with concern for others. Such wisdom, said Sternberg "looks at the long term as well as the short term."⁴ Jim's wisdom looks for durable solutions and rejects a throw-away mindset.

That wisdom also manifests in Jim's sense of doing right by the customer. When I first started working at Howe's, Jim gave me what should have been a quick tig project. I was to tig weld a bracket back on to a scroll saw. The bracket held in place an arm that guarded the thin saw blade. Knowing nothing at all about scroll saws, I had no idea that inside the steel casing rested a rubber bellows, a small hollow piece that blows air through a rubber tube to clear wood chips out of the way. Of course, even allowing that I couldn't have known a rubber part lay inside, I can be held accountable for not realizing that the rubber tube, which lay outside the steel casing, would burn up were I to leave it attached as I tig welded the bracket back on.

A moment after I started welding the bracket back on, as you might expect, black smoke rose from inside the casing. In addition, I found that I'd burnt up a few inches of the rubber tube. I told Jim what I'd done, and while he admitted that I should have recognized the problem of welding so close to the rubber tube, he said that he—not I—should have realized that the saw would have a bellows inside. He turned his attention right away to what we could do to fix the main problem—the lack of a bellows that fit. To rectify the problem, I started an online search for the Craftsman component, but I soon found that this model of scroll saw had been discontinued, and the bellows that fit was no longer available, not even from sites specializing in discontinued parts. I ordered one that I thought would at least fit inside the casing, and I waited for Jim to figure out a way to fix what I'd done.

Like other small projects that lack urgency, the scroll saw sat for months on the pile, waiting for that never-to-appear moment when Jim would be caught up on the projects that people needed right away. Until one day, tired of looking at the saw, Jim put his mind to fixing it. He salvaged a small disc from some other tool and set the new bellows on it, like an old-timey water pitcher sitting its basin. He cut a new piece of tubing and used a heat gun to attach one end of the new tubing to the bellows and the other end to the old tubing, saved because it perfectly fit the holder that aimed it at the saw. His creative solution worked perfectly. And when I asked him how much we would charge this customer who had waited so long for his saw,

Jim said, “Nothing.” Looking to the relationship with this customer, Jim said that because we’d made the mistake, we’d pay the price for it. When the customer came to pick up the saw, I told him what had happened and what Jim had done to recreate a bellows and tubing system that works. He understood how Jim’s creativity had made good on this project—a project that was supposed to have been a ten-minute job. Wisdom looks to the long term.

I think, too, that Jim gets real joy from thinking about how he could fix an item like a two-dollar watering can. I’ve seen his enthusiasm when he talks to clients about what they’ve brought in. He’ll spend 15 to 30 minutes—sometimes more—talking to clients about potential solutions to the problem, explaining the likely difficulties he’ll encounter as he tries to make the repair. Such conversations tend to revolve around items needed to get work done, like a cracked excavator bucket, but they can spring up too when a customer brings in a small hobby project. One fall morning, a woman brought in two lampshades. She said she wanted the rings in the skeleton of one lampshade redone in the style of the other lampshade so that the first would hold the same type of bulb as the second lampshade. Jim talked to the woman for at least 15 minutes that day to understand what she wanted and to work out how he could turn a new ring on the lathe and then weld that ring onto the old lampshade’s wire spokes. Another client brought in two silver teapots with jack-o-lantern faces drawn on them in black marker. She wanted Jim to cut out the faces so that she could put tea candles inside and have permanent jack-o-lanterns. The day the customer brought in the teapots, Jim again spent 15 or more minutes explaining the challenge of what she was asking him to do: As he cut the faces, he would have to shield the bottom and back of the teapots from the torch. The project intrigued him. But the teapots still wait in the pile.

That even small and futzy projects attract Jim’s creativity reveals in Jim another characteristic that Sternberg delineated when describing a consummate expert. Creativity-based expertise, he wrote, draws from the person’s strong analytical abilities, such as assessing what the tools at hand can do and improving upon earlier solutions to similar problems. Jim’s creativity came to the fore when a client brought in six hollow steel spheres, about 14 inches in diameter, and asked us to cut two round holes in each so that he could insert a fence pole through them. He planned to use them to display his Corvette at a car show. The spheres sat in the pile for a while as Jim pondered a solution to the problem: A 14-inch sphere will not fit into the waterjet. How to cut two holes exactly opposite when the globes won’t fit under the jet?

I watched Jim disassemble the waterjet’s basin so that a globe could fit underneath. Then, to solve the problem of making the holes directly across from each other so that they could hold a fence pole, Jim made a metal cone that would rest at the bottom of the basin. Once we’d cut one hole from a sphere, we could fit that hole on the cone and cut the second, which would be exactly across from it.

Before we started this unusual project, Jim asked me how I would solve the problems. I didn’t have the knowledge necessary to analyze the waterjet’s capacity to hold something other than a piece of sheet or plate. It never occurred to me that we could disassemble the basin to fit a 14-inch globe underneath the jet; my solution

involved a hole saw. And I didn't come up with an idea to make a second hole directly opposite the first before Jim told me his idea, but I doubt I would have come up with something so inventive. When I asked Jim how he came up with the solution, he pointed to an earlier, in some ways similar, project:

Jim: Well, that was going to be the easiest because I'd done bowling balls before. I've had to drill bowling balls. We made a dish for that. This way we just, okay, well we'll still have it, but we'll have a cone.

Jo: You drilled bowling balls?

Jim: Yeah.

...

Jo: But you came up with the idea of if you have a cone that'll hold it, and you can do it exactly at the same spot.

Jim: Right. Then you can flip it and have it-

Jo: The bowling ball isn't like that. But do you think the bowling ball gave you that idea?

Jim: That gave me, because I made a jig for the bowling ball to hold it. It wasn't the first time we'd ever- We've had to center up things enough times.

Jim transfers knowledge, gained through years of experiences, to creatively solve problems. And in this case, his creativity got six steel globes off the pile (Fig. 2.10).

Fig. 2.10 One of the six metal globes that we cut on the waterjet, using Jim's cone fixture to cut one hole directly across from the other



A Spectrum of Production Work

As I've described Howe's, I've stressed how infrequently we take on production jobs. It does happen, like the time Zach and I worked on the one hundred seed bins, cutting pieces of screen, bending them and the boxes that held them, and spot welding a piece of screen into each box. More commonly, we make a few of something rather than one hundred of something, like I did when I made six identical "stompers," punched pieces of ½-inch-thick flat bar welded together and used for soil research. But in stressing how most jobs that come into Howe's are unique, one-off repairs or fabrications, I fear that I may sound like I buy into the view that production work necessarily equals never-ending monotony. I've talked to enough people doing production work in the shops that I visited to know that's not the full story.

To be sure, manufacturers have systematized their processes such that a welder fabricating the same subassembly, or component, over and over again can do the task efficiently, without having to make a lot of extraneous movements, without having to make decisions about which step should come next, and without spending time building fixtures to hold together the unit's pieces for tacking. This regularization of processes in large-scale production work, wrote Justin Carone, "prevents the worker from pursuing or even considering an alternative outcome."⁵ Certainly larger manufacturers like Vermeer, but also medium-size facilities like Power Brace have analyzed and compartmentalized tasks so that workers can achieve, as the saying goes, maximum efficiency.

But as they've delineated very human problems that arise from such task siloing, scholars like Carone, Mike Rose, and Matthew Crawford have tended to treat production as a monolith. It's not. Even within Vermeer's literally mile-long campus of seven plants dedicated to industrial and commercial equipment for agriculture, mining, forestry, and landscaping, welders work in production that varies in the depth and breadth of knowledge, the expertises, it requires. On my visits to interview employees at Vermeer, John Deere, Quality, and Power Brace, I saw welders doing a kind of work that fulfills my mental image of factory welding—welding stacks of machined parts together into a subassembly in a prescribed order, churning out dozens or hundreds of an item day after day. And yet, spending sufficient time with the workers in these facilities, you see that even their tasks eventually change. Another component becomes a priority, and suddenly the welder works on a different item. There is, then, some semblance of variation within the repetition.

Production varies from the stereotypic image of the assembly line in other ways too. At Vermeer I talked to employees working in what's called a tub cell, a space devoted to making tubs for Vermeer's forestry grinders. As in any place where a process has been routinized, methods of efficiency are indeed clear. One worker explained, "And this tub is actually set up in a way that they can lift it up, they can rotate it, but then it can also spin 360 degrees too, so they can pivot it back on, or pivot it back around, so they can work the whole, inside and outside the

tub.” The tub’s rotation eliminated the need for out-of-position welds, simultaneously creating better ergonomics and higher quality welds. However, unlike work on smaller subassemblies, two workers in the tub cell work three days on just one tub.

Similarly, on my second visit to John Deere in 2022, I stopped where a welder fabricated axles, taking approximately one hour on each before sending the subassembly to a robot welder. The human welded the nooks and crannies, and the robot welded the rest. On an earlier visit to John Deere, I’d met a welder who made seven or eight chassis a day. Her job was to reach the joints the robot couldn’t reach. Like the workers at Vermeer, she welded flat; the chassis spun for her. As my John Deere guide told me, “Some jobs take a lot longer than others,” adding “some jobs take half a day to do one part.” In other words, while some workers fabricate smaller subassemblies one after the other, more clearly enacting that vision of factory production that I had in my head, others work through procedures that take longer. Yes, there is a repetitious beat, but the rhythm is slower.

Moreover, some welders in large manufacturing facilities work on tasks that take weeks to complete. In the mining division at Vermeer, my guide told me about equipment built for natural-gas installation: “So, their cells are set up entirely different than the other areas because they’re all true fabrication areas. You’re not going to see a lot of subassembly flow and fixturing. I’m building it from the ground up, piece by piece. So, most of the machines, so we saw that a large mower, we try to make two in a day, [but] one of these machines would take 45 days start to finish, for one.” Here then, the repetition beats even more slowly—once every month and a half.

Task variation becomes even more evident at small- to medium-sized production shops, where work tasks vary with client orders and bids won. As I visited facilities around Iowa, I spoke to fabricators who worked on the same product or subassembly—the same constructed part—for a few days or for week or two. For example, when I visited Sargent Metal Fabricating, they explained the company does custom fabrication, working from a client’s drawing or collaborating with the client to design the product, whether a grain shoot, a staircase and handrail, or a pipe support. They explained, “We’ve got a schedule that we use that lists all the active jobs. The jobs will get assigned kind of based on everybody’s skill level and experience. Stainless tig weld jobs, the number of people able to do those are fewer, aluminum jobs are fewer. The carbon steel, there’s more guys that do those.” When I looked at an example packing list at Sargent, I saw that the customer had ordered multiples of some items, just one of others.

Similarly, when I visited Custom Steel Service, employees were working several products. One project was explained to me as “dollies for pulling train cars around.” They described how they’d collaborated with the client on the design of the axle. I watched one of the workers there develop a fixture to facilitate the task of making the multiples the client had ordered. Fixtures hold pieces of metal together in a desired position so that they can be welded. For example, at Sorem Manufacturing, I watched workers use fixtures to hold together wire rings that when welded together would serve as fan guards.

At Howe’s, we create fixtures from items when we will make multiples of the item. For example, I worked for over a day creating a fixture for a lampshades

project because I had to make five lampshades. Unlike at big operations where salaried engineers typically design fixtures for assembly and welding, at smaller shops, people on the shop floor envision and design the fixtures. Thus, like at Sargent, workers at Custom produced multiples, but their task would soon change again, and they'd collaborate with clients to make something else.

Conclusion

In this chapter, I've introduced my boss, Jim Howe, the person I refer to throughout the book as I describe how expertises manifest and as I explore how Jim and my coworkers have aided my progress toward shop competences.

Work at Howe's develops breadth as well as depth of competences because, as a job shop, we grapple with a wide range of projects. Moreover, Jim's shop isn't simply a weld shop; it's a machine shop. So we all develop knowledge of machining too, especially in commonly used machines like the drill presses. This task variety often challenges us, posing unfamiliar problems and necessitating help from someone who has already developed greater expertise in the relevant domain of knowledge. However, I've also argued here that the tasks tradespeople in production shops carry out often deviate—sometimes greatly—from the stereotypical image of ceaselessly repetitive factory-line work. Production jobs, too, provide opportunities for developing expertises.

In thinking about developing both depth and breadth of expertise at Howe's, I explore in the chapters to come the ways less-expert people like me develop conceptual and procedural knowledge, entering more fully into a trades community while trying to avoid mistakes.

Notes

1. Gehr, "I Know I'm in a Floodplain."
2. Carone, "Fixing Value," 383.
3. Carone, "Fixing Value," 390.
4. Sternberg, "Four Kinds of Expertise," 424.
5. Carone, "Fixing Value," 386.

References

- Carone, Justin. "Fixing Value: History, Ethnography, and Material Ontologies of Deservingness in a Philadelphia Repair Shop." *History and Technology* 33, no. 4 (2017): 367–395.
- Gehr, Danielle. "I Know I'm in a Floodplain. That's My Problem": \$4.9 Million Flood Mitigation Project in Ames Could Result in Eminent Domain Use." *Ames Tribune*, January

- 26, 2021. <https://www.amestrib.com/story/news/2021/01/23/ames-iowa-4-9-million-flood-mitigation-project-could-result-eminent-domain-use/4172722001/>.
- Sternberg, Robert J. “Four Kinds of Expertise.” In *The Science of Expertise*, edited by David Z. Hambrick, Guillermo Campitelli, and Brooke N. Macnamara, 419–427. New York: Routledge, 2017.

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Chapter 3

Learning and Practicing



Abstract This chapter describes how learning takes place through one-to-one scaffolded interactions with a more-expert person and through deliberative practice. In a scaffolded learning interaction, a more-expert person like Jim helps a learner like me solve a problem that would have otherwise been beyond the learner's capability. In a scaffolded interaction, the teacher controls the parts of the task that are too difficult for the learner so that the learner can limit the scope of their concentration and focus on those task elements adjacent to their current competence. The chapter describes the six characteristics of a scaffolded interaction, including intersubjectivity, a shared understanding of the task, and interactivity, a joint engagement in the task. It then focuses on one of these characteristics, contingency, to explain how, critically, the task must build upon the learner's existing knowledge and fall within the learner's zone of proximal development, or ZPD. Then, the chapter explains the types of strategies that more-expert people use as they scaffold learning: instruction, cognitive scaffolding, and motivational scaffolding. It turns then to the importance of deliberative practice, as opposed to simple repetition. Deliberative practice requires concentrated effort, including analysis of process and results.

Learning a trade in the workplace isn't always, or even usually, ideal. Bosses and coworkers are busy and don't have time to devote 15 or 30 minutes at a time to walk a newcomer through a procedure or to explain some conceptual knowledge underlying a machine or process. Learners aren't perpetually motivated to learn something new or to practice with concentrated effort. Even though on-the-job trades learning isn't systematic, it's helpful to think about learning—its components—in a systematic way. That is, to understand how learning a skilled trade happens, you have to understand its characteristics.

More specifically, you have to understand the characteristics of scaffolded learning—in my mind the most important concept in teaching and learning. In a scaffolded learning interaction, a more-expert teacher (like Jim) helps a learner (like me) solve a problem that would have otherwise been beyond the learner's capability. In a scaffolded interaction, the teacher controls the parts of the task that are too difficult for the learner so that the learner can limit the scope of their concentration

and focus on those task elements adjacent to their current competence. For example, when first showing me how to use the lathe, Jim set the speed. All I had to do was concentrate on using two handles to move the carbide bit along the end of a spinning piece of square tubing.

A scaffold is an apt metaphor because it lends an image of people continuously adding more height to a structure that holds them, just as a teacher and learner co-construct the learner's knowledge. It's also apt because it generates an image of just a few people held aloft on the scaffold. And, indeed, research on learning strongly supports the utility of one-to-one interactions between a trained teacher and a learner, as opposed to a teacher and a classroom's worth of students.

Joanne Anania¹ and Arthur Joseph Burke,² students of Benjamin S. Bloom, a celebrated educational psychologist, revealed what Bloom called the two-sigma problem: that an average student engaging in one-to-one tutoring will advance about two standard deviations above an average student who is learning in a classroom setting.³ More recent research has added nuance to this two-sigma finding, revealing that student readiness, teacher training, and other variables play a role in one-to-one tutoring's effectiveness. Still, the continued use of one-to-one interactions in schools and workplaces, despite the resources that they require, indicates the value that researchers and practitioners perceive in them. Thankfully, a small shop like Howe's affords plenty of opportunities for one-to-one interactions or, nearly as good, one-to-several interactions. The latter occur when Jim decides to introduce all of us workers to some unknown-to-us tool, like his motorized pipe threader, or to some process, like twisting square-stock rods to create decorative fencing.

For scaffolded learning to occur, not just anyone will do as a teacher. First, the teacher must have greater knowledge than their student in the knowledge domain at hand. The teacher must also motivate the learner to persist in the task, even through frustration. The teacher has to be able to demonstrate and to explain the task, to provide targeted feedback, and to correct the learner's errors. In these pedagogic communicative acts, many tradespeople stumble. Critically, the teacher must make their interventions, that is, their demonstrations, explanations, and so on—dependent upon the learner's moment-to-moment progress in the conceptual or procedural knowledge domain. Clearly, much is asked of a teacher in a scaffolded interaction. But if a learner has such assistance, the learner will progress more efficiently than if they attempted the task unaided. For their part, however, the learner must participate actively; they cannot sit back and passively receive the teacher's input. They must *engage*.

Once when I was welding a new hitch onto a trailer, I had to weld ¼-inch square tubing into the existing tongue of the hitch. The radiused corners of the square tubing created a J-groove weld—something a little more challenging than a typical T-joint because slag—that byproduct of weld flux—can get trapped in the groove and thus weaken the weld. Jim told me that he wanted to see the welds I made on the outside of the tongue—regular T-joints—before he'd let me try the J-groove welds. In other words, he wanted to assess my level of readiness to attempt a J-groove weld.

My welds on the outside passed his inspection, so he let me try the more difficult welds. Before I started, he supplied instruction. He told me to maintain a 45-degree

angle and to keep the electrode in the front of the puddle. When I started, it was difficult to get weld to settle down; it seemed to bubble. Jim recognized my struggle and diagnosed the problem I was having. He moved the ground clamp from the end of the trailer arm to the tongue, much closer to where I was welding. Then he demonstrated a J-groove weld. Observing him, I noticed that he wasn't concerned about putting the electrode's heat onto the wall of the tongue, which I'd worried about for fear of blowing through its metal. On my next attempt, I tried to do exactly what Jim had just done. My imitation of his technique, along with the ground clamp's closer proximity, made the puddle settle down. I completed my weld. And while Jim's weld looked decidedly better—his being smooth and consistent—mine looked fairly smooth and fairly consistent. Jim had scaffolded my learning by diagnosing my level of readiness and targeting his intervention there. And looking from the other perspective, I was an engaged learner. For example, I didn't just *look* when I observed Jim weld his J-groove joint; I *analyzed* Jim's movements. In the next section, I examine the characteristics of a scaffolded interaction in more detail.

Not all my one-to-one interactions with Jim fulfill contain all six characteristics of a scaffolded interaction, but many of them do. And through these interactions, most often with Jim but also with my more-expert coworkers, my learning progresses.

Six Characteristics of a Scaffolded Interaction

A scaffolded learning interaction between a more-expert person and a learner will exhibit six important characteristics, according to educational psychology researchers Sadhana Puntambekar and Roland Hübscher.⁴ First, the teacher and the learner must have a shared understanding of the task. This shared understanding is called intersubjectivity, which makes sense when you break the word down: “inter” for between and “subjective” for personal. Both participants must understand what the goal of the interaction is. Second, the teacher must provide ongoing diagnosis. That is, they must assess the learner's progress during the interaction so that they can (and this is the third characteristic) make their responses contingent on the learner's current performance.

That's what Jim did when he intervened to help with my J-groove weld on the trailer arm. It's also what he did when we worked outside in Boone, Iowa, welding railroad tracks to the brackets that held them to a concrete base. Jim had won the job of installing new rails, intended not for real railroad cars but instead for hybrid pedal-motor carts. A new business, the Rail Explorers, had arrived in Boone. Its carts rode the same rails as trains, but the business needed new rails at the station that would divert the carts from the path of the trains and supply a place to park the carts.

As we worked on the new rails, welding them to brackets in turn bolted to the concrete base, Jim demonstrated how to do a multipass weld to fill in where two beveled ends of “track”—really 20-foot sticks of ½-inch-thick flat bar—came together. I observed him, paying attention to his placement of the weld passes on

the double V-groove joint. We'd practiced multipass welds in welding school after all, so I already had the conceptual knowledge of how to layer the passes. To that knowledge, Jim added that because we were doing a double V-groove, best practice said to move from one side of the rail to the other to evenly distribute the warpage of the metal that would come from the heat of the welding.

I tried a joint on my own, trying to imitate Jim. After I'd finished, I thought my work looked pretty good, that I'd pretty evenly distributed the weld passes. But when Jim looked at my weld joint, he saw that I'd not laid enough weld on the left side of the V-grooves. I had erred in how I'd placed the layers of my beads, such that they left an indentation on the left. I had to lay another pass on top of what I'd already done and then grind it down to flat. In doing so, I added more heat than would have otherwise been necessary. I'd exacerbated the heat affected zone or, as welders say, the HAZ. Jim's ongoing diagnosis led me to correct—to that extent that I could—my error and, hopefully, distribute the weld passes on my next attempt more evenly.

As indicated above, an effective teacher knows how to make their responses to a student contingent on the learner's performance. Of course, in many skilled-trade workplaces, including Howe's, no one has formal training in teaching that would give them research-based insights into how people learn and which teaching techniques work best. But while that's true, it's also true that the characteristics of a scaffolded learning interaction that I'm describing here stem from, or mirror, practices that teachers and learners have profited from for millennia. It's likely the case that interactions led by trained teachers manifest characteristics like intersubjectivity, ongoing diagnosis, and contingency more consistently than those interactions of pedagogically untrained tradespeople. Nevertheless, these ideas of how to help someone develop their expertise are, at least to some extent, intuitive. For example, people intuitively try to make their responses contingent upon a learner's contribution, whether that contribution constitutes something said or something done. In the next section, I return to the critical element of contingency and the strategies that teachers use to enact it.

Continuing with the delineation of the six characteristics of a scaffolded interaction, the fourth is interactivity. Interactivity relates to the social component of learning, articulated by researchers across disciplines, from Lev Vygotsky to Etienne Wenger, to Stephen Billett, to Selena Chan. In short, interactivity relates to what I highlighted before: that the learner, not just the teacher, must actively participate in the interaction. The learner cannot watch and listen to the teacher but instead must engage, for example, by trying to connect the information with existing conceptual or procedural knowledge or compare it to existing conceptual or procedural knowledge. It's easy to think when considering ongoing diagnosis and contingency that the teacher contributes more effort in the scaffolded interaction than the learner does. But interactivity says that for scaffolding to occur, the learner *must* participate. Depending on the domain and the task, the engagement will manifest in different ways.

Especially in situations where a learner develops embodied knowledge, where the body must know just as the mind knows, as in trades work, engagement manifests through varied responses to what the teacher says or does. A learner's response might

be nonverbal, such as handing over a pipe wrench when the teacher requests one, or nodding understanding during an explanation, or pointing to the cross-slide on the lathe when quizzed on its location. A nonverbal response might also be an action, such as closing the gap between your stick electrode and the weld puddle or adjusting your travel angle when directed.

A learner's response might also be verbal, as when a learner responds to a question, perhaps supplying the name of a tool, as when Jim asks me "What's this called?" and waits for me to spit out a response like "file card." Or depending on the question, the learner might respond with a description of how they'd approach the problem, such as "First, I'd center punch where I'm going to drill my pilot hole," or an explanation of a concept, such as "We use reverse polarity because it puts the most heat into the electrode." In these examples, the learner's reactions to the teacher's questions produce the interactivity that a scaffolded interaction requires.

But a learner also engages by raising new topics, typically through questions, such as "How do you decide on the height of the bit on the compound?" or "How long do you have to wait to use an acetylene canister if it's been laying sideways?" I commonly initiate topics, asking questions of Jim about conceptual knowledge like the reasons some lathes and mills rotate in opposite directions in high and low gears or the differences in metal types, such as the differences between 6061 and 5052 aluminum and 304 and 316 stainless steel. And I daily ask for procedural knowledge, such as how to choose a carbide bit and adjust its position, how to rotate the die on the press brake, and how to find a midpoint on the mill. My level of engagement when it comes to questions likely borders on nuisance.

That said, if someone were to record all the talk that occurs in Howe's on a given day, they'd find that Jim answers questions all day long and not just from me. All of us who work for him require his guidance occasionally throughout the day—even Adam. Along with questions during one-to-one interactions that are aimed at advancing learning, like "How do you decide on the height of the bit on the compound?," our questions also, in fact mainly, pertain to specific projects, as in "Do you want me to use the Enerpac to bend these?" and "Do you want this milled or stick?" and "Should I use a backing strip on this to close that gap?" When we ask questions like these, questions aimed at making it possible to proceed with what we're doing, we may not see ourselves as engaging in scaffolded learning, but we are. With our question, we've commenced a one-to-one scaffolded interaction, albeit a perhaps brief one. If we engage with the response to determine how and why it applies in a given project, we can perhaps transfer that insight to a future project.

Interactivity arises also through students' observations and imitations of teachers' demonstrations. These observations become fodder for verbal exchanges, including teachers' instructions and questions and students' responses and questions. After observing, students imitate teachers' actions, and these imitations spark feedback. Thus, imitation can serve as what Chan called "a catalyst" to "a reciprocal learning conversation" and can provide a basis for a learner's practice on their own.⁵

Finally, scaffolding includes two other characteristics that are less thoroughly discussed in research on one-to-one teaching and learning. Fading occurs when the teacher, diagnosing that the student understands the material, begins to transfer

control of the task to the student. It seems to me that two kinds of fading take place in skilled trade settings. The first type occurs within a single learning interaction, where the teacher might demonstrate some task, such as stick welding vertical up in a tight corner, telling the learner what to do and explaining the reasoning simultaneously. The teacher might combine the nonverbal instruction of demonstrating with the verbal instruction of the telling and the explaining. The teacher might also ask the student questions about what they're observing, such as "What travel angle am I using?" Then the teacher might watch as the student imitates how the teacher has bent the electrode to fit into the tight corner and how the teacher has used a five-degree travel angle, and how the teacher has moved somewhat slowly, letting the puddle wash into the edges of the corner's right angle. The teacher might provide instruction as the student welds, saying, "Go faster" or "Pause longer at the edge." With each of the student's attempts, the teacher's scaffolding subsides until, finally, the student can perform an acceptable weld in a tight corner. This reduction in the amount of tutoring imparted to the learner constitutes, if I might repurpose a term from linguistics, synchronic fading. Linguists use the term "synchronic" to describe a study that examines language at one moment in time. Synchronic fading occurs within one scaffolded learning interaction.

But we can also talk about fading across interactions. To borrow again from linguistics, we can analyze how a teacher fades diachronically, providing less intervention—fewer instructions, for example—each time a task being learned arises. For example, over at least a year, I observed Jim using the Hossfeld bender several times before I tried it myself by imitating what I'd seen him do (Fig. 3.1). In my first attempts, Jim watched me, diagnosing what I did right and wrong—how I'd placed the bender's pegs and bullnose—and supplying feedback. Eventually, I used the Hossfeld bender without him. First, I used pictures of the way he'd oriented the pegs and the bullnose to make simple 90-degree bends. Later, I didn't need to look at pictures anymore when my task was to copy the radius of a piece of flat bar bent into a U. Jim diachronically faded, eventually assigning to me a project with bends and leaving me to make those bends on my own.

The sixth characteristic of a scaffolded interaction comes from Janneke van de Pol, Monique Volman, and Jos Beishuizen's study of small-group learning in social studies classes.⁶ They counted checking back on a student's learning as a characteristic of a scaffolded interaction, through which teachers assess the learner's progression toward the goal. Checking back becomes critical when a teacher leaves an interaction but periodically comes back to diagnose the learner's progress and to once again offer a contingent intervention, such as instruction. In earlier research, I studied welding teachers' interactions with welding students. That study showed the importance of checking back on learners after they've devoted some time to practice. In the three welding programs that I studied, welding teachers rotated around the lab, booth to booth, observing students, demonstrating for students, and all the while offering feedback.⁷

In a work situation like the one at Howe's, checking back becomes less regimented than laps around a lab of welding booths. If Jim notices that he hasn't heard from me in a while, he'll check on me to assess my work, to answer any questions that I've

Fig. 3.1 Jim at the Hossfeld bender



been saving up, and to give me feedback. If he sees that I've made a mistake, a new task—rectifying the error—and a new scaffolded interaction begin.

Such was the case when Jim returned to my table to check on my progress tig welding chromoly caps onto tubes. The caps had been machined with slots that would allow them to fit into whatever machine the client used to pound the tubes—soil probes—into the ground to gather samples. I had asked Jim whether I could take on the project, even though I'd never welded chromoly before or used the associated ER80s-D2 filler metal. The word “chromoly” blends the names of its alloys, chromium and molybdenum. It costs more than mild steel but is stronger. Before I started, Jim issued instruction: “Don't back up. This filler will bubble, and you'll have to grind it out” and “Ease up at the end of the weld or you'll have a crater crack.”

When Jim returned to check on my progress, he wasn't satisfied with my work. He told me that he could see bubbles, so I must have gone backwards for an instant. He also saw crater cracks where I had not sufficiently eased off the pedal and filled in the end of the weld. Then we had to change tasks. Now the task was to fix my errors. Jim told me to grind out the spots with bubbles. He turned my gas flow up from 15 to 20 cubic feet per hour, or cfh, and he pushed my tungsten electrode farther back into its surrounding ceramic cup. He explained that these actions would give the puddle more protection from the atmosphere. These tricks sufficed. I was able to fix my mistakes, eliminating the bubbles and filling in craters. Jim's check of my progress, then, was critical to my learning and to successfully completing the task (Fig. 3.2).

Fig. 3.2 Ground out and rewelded joint on chromoly tube



As a part-time employee, I haven't had much opportunity to work on chromoly steel. The next time I do, I will need less intervention because I'll know that it requires—more than regular mild steel—a strong envelope of gas. The next time, then, Jim might be able to fade from the task sooner than he did on my first exposure to welding chromoly.

Contingency and the Zone of Proximal Development

As I mentioned above, the expert's scaffolds must be contingent on the how the learner performs, and the task should challenge the upper limit of the learner's knowledge. In this "region," the learner stretches just past their current level of competence. Education researchers David Wood and David Middleton called this the "region of sensitivity to instruction,"⁸ but most researchers have preferred the term "zone of proximal development," or its catchy abbreviation ZPD, which came from the work of Lev Vygotsky, a cognitive psychologist who studied learning assessment and instruction. Describing the ZPD, Vygotsky wrote, "Instruction is only useful when it moves ahead of development."⁹ Targeting an intervention toward the ZPD improves learning; in this way, the intervention balances the comfort and enjoyment of the known and the challenge and potential frustration of the new.¹⁰

In previous books, I've written extensively about the ways that a teacher can contingently scaffold a student's learning. With my friend and colleague Isabelle Thompson, I studied the language, specifically, the tutoring strategies, that expert

writing tutors used in conferences with writing students.¹¹ Later, studying the interactions between welding teachers and students, I again studied experts' strategies for advancing students' learning.¹² These strategies manifest in workplace learning interactions as well.

In responding contingently to a learner's performance, a teacher chooses among three main categories of tutoring strategies: instruction, cognitive scaffolding, and motivational scaffolding. With instruction, a teacher directs a student. The clearest case of this direction is telling, as in "Turn the amps down to about 150." Telling, suggesting, explaining, and describing are all verbal strategies for instruction. Because they are verbal, they combine well with the nonverbal instruction strategy of demonstrating. In that prior study of welding teachers' strategies, I used a research method called discourse analysis to closely analyze how the teachers combined demonstrating with describing and other verbal strategies to efficiently scaffold students' learning. Demonstrations (from the student's perspective, observations) fill in the gaps of language. As Selena Chan wrote in a study of observation in learning, "Sometimes the vocabulary to describe what is seen, felt, heard, tasted, or smelled does not exist."¹³

Besides the instruction strategies listed above, a teacher might use a cognitive scaffolding strategy to push forward a learner's understanding. These strategies are less direct than instruction. Instead, they prompt the learner to think about and articulate something about the task or some component of the task. Questions such as "What have we learned here?" "What would you use to bridge that gap?" "What should you do next?" or "What's the torch tip that you'd use?"—all questions Jim has asked me—are pumping questions. They pump a learner to think for themselves rather than being given the information via telling or explaining or some other more directive strategy. Pumping questions facilitate interactivity, that important characteristic of a scaffolded interaction.

A second cognitive scaffolding strategy that I identified in my research on welding teachers was referring to a previous topic.¹⁴ With this strategy, the teacher connects the concept or procedure currently being taught and learned to some prior, related occurrence. For example, as I constructed the fixture for my stainless-steel lampshades project, I wanted to create little steel shelves to hold the lampshade rings so that I could weld a lampshade's spokes to them. When I pondered how to get little shelves attached to my fixture, Jim said, "We used angle iron before," recalling a prior lesson in which we'd used a piece of angle iron as a support. With this prompt, I realized that I could put a small piece of 1-inch angle iron underneath the little shelves I'd cut to hold the shelves level as I tacked them on. When Jim remembers that he's demonstrated or explained something before, he lets me know in part to chide me for forgetting a prior lesson. But his reminders do cognitive scaffolding work as well.

The third category of strategies that teachers use during interactions aimed at scaffolding learning is motivational scaffolding. These strategies work on an emotional level, helping learners to persevere, even when they encounter frustration and setbacks. Motivational scaffolding includes showing concern, such as asking, "You doing ok?" It also includes giving sympathy, as in "It takes practice," being

optimistic, as in “You’ll get it yet,” and perhaps most important, giving praise, as when Jim once (and only once) said, “Outstanding.” That instance of praise followed my repair (with his occasional instruction throughout the task) of a lawn mower. A bit more commonly, I might get a “That looks dapper.”

A final motivational strategy is humor, which Jim uses not only during learning-focused interactions but just more commonly throughout the day. Shop humor includes kidding each other, joking around, and telling stories of dumb things we’ve done or dumb things other people have done. One of Adam and Zach’s favorite pranks, for example, is ringing the buzzer at the front counter so that I’ll trot across the shop into the front office to help a nonexistent customer. In scaffolded learning, humor helps to keep the mood light and to counteract the inevitable frustration that comes with stretching one’s knowledge.

I intend this delineation of tutoring strategies not to preview some linguistic analysis of interactions between Jim and me—that would be a very different book—but instead to give a sense of the kinds of talk that compose scaffolded learning, even when that scaffolded learning takes place unplanned in a repair and fabrication shop instead of in a school. Throughout this book, I refer to these strategies, particularly demonstrating, telling, explaining, and praise, because Jim and my coworkers use them, even though they weren’t trained as teachers.

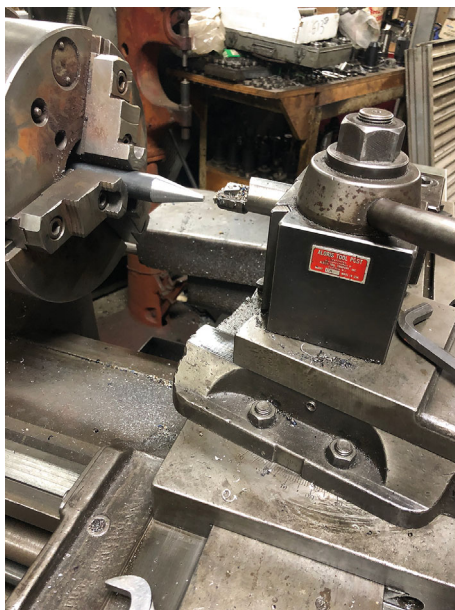
The Complexities of Practice

Scaffolding takes place during interactions between a teacher and a learner, such as when Jim built upon my existing (novice-level) knowledge of using the lathe. In earlier interactions, he had set the angle and height of the carbide bit himself. On this occasion, he demonstrated how to use an Allen wrench to move the bit up and down on the compound and a crescent wrench to change the compound’s angle to the work piece. I already knew how to move the bit along the lathe’s carriage and how to change the speed and direction, although I didn’t completely understand how to determine which speed to use. This time, making spikes for a trellis out of one-inch round stock, Jim demonstrated how to change the angle of the compound and thus adjust the angle of the spikes’ points.

Then, after demonstrating how to remove about one-sixteenth to one-eighth of an inch from the edge of the round stock soon to become a spike, he observed me as I finished the spike he’d started, telling me “You can dig it in there” to alleviate my fear of taking off too much steel at once and explaining how he uses old carbide bits to gouge out up to ¼-inch of metal when he’s turning big items (Fig. 3.3).

Such an interaction—one that involves observing, imitating, and feedback via tutoring strategies, equates to what the psychologist K. Anders Ericsson and his colleagues termed “deliberative practice.”¹⁵ Ericsson and his colleagues defined deliberative practice as engaging in activities that have been designed to improve performance in some domain. In one way, the one-to-one teaching and learning that goes on at Howe’s doesn’t constitute deliberative practice: When Jim teaches me how

Fig. 3.3 Making spikes on one of Jim's lathes. (Note the compound sits at an angle to create the angle of the spike's taper.)



to move the bit up and down or to change the compound's angle, he isn't working from a predeveloped lesson plan or a course syllabus on lathe operation. He's using a task-at-hand—one selected for me because it seemed to fall within or slightly beyond my level of competence—to scaffold my learning.

But in so many other ways, in my one-to-one scaffolded interactions with Jim, the characteristics of deliberative practice manifest. Deliberative practice requires five elements, according to Ericsson:

- (1) The learner must be motivated to improve.
- (2) The task must have a defined goal.
- (3) The task must account for the learner's current level of understanding. In other words, the task should target the learner's ZPD.
- (4) The learner must receive immediate and targeted feedback on their performance.
- (5) The learner must have ample opportunities for refining their performance through practice.¹⁶

Deliberative practice, you might notice, sounds a lot like the scaffolded learning that I described above, where a teacher diagnoses a learner's competence, sets a goal that falls within the learner's ZPD, and intervenes in the learner's effort with instruction, cognitive scaffolding, and motivational scaffolding. Indeed, Ericsson and his colleagues argued that deliberative practice works best when it is developed and guided one-to-one by a teacher. However, they also said that deliberative practice can continue when the learner thoughtfully practices on their own. After Jim observed me finishing up the spike he'd started and had given me feedback on how much steel to remove per pass, he left me to do two more spikes by myself. Although I was

left alone, a session of deliberative practice followed. I opened and closed the chuck that held the spikes, moved the carbide bit over each spike, growing more familiar with turning the handles in unison to drive the carbide bit where I wanted it to go. As I worked on the spikes, I tried slightly different depths of cut, keeping it within the range Jim specified. I also tried different ways of getting the spike out once I'd finished, checking how far I needed to move the cross-slide back to pull each 21-inch spike out of the chuck. In other words, I didn't simply repeat an action, or the same sequence of actions, over and over; I attended to how I was moving my body and, consequently, the lathe, and I was analyzing the effects of my actions. I aimed to imitate Jim, but I also tried to test the movement of the bit against the spike. This analytic approach, in Stanton's words, places "a heightened importance ... on the possibility of error, trial and improvement, and associating new information with prior learning" even as it fosters active learning.¹⁷

According to Ericsson and others who research expertise, certain constraints on deliberative practice exist, and these constraints clearly manifest in a workplace setting, where an employee's learning is usually not the most important goal. The first constraint on deliberative practice is what Ericsson called the resource constraint. In a shop setting like Howe's, the most important constrained resource is Jim or, more specifically, the time he can spend in one-to-one interactions aimed at scaffolding my learning. Besides trying to make me a better employee by developing my knowledge, Jim has to talk to customers, fix machines that break, replace components that wear out, and work on the many projects that lie outside the breadth and depth of my and my coworkers' knowledge. He also has to stop to answer questions about the projects that we, his employees, are working on. As I've mentioned, I'm not the only person who gets the benefit of Jim's scaffolded interactions. Other workers, especially ones with more novice-level knowledges, do as well. Even Adam, the employee with the most proficiencies besides Jim, requires Jim's time once a day or so to strategize a solution to a complicated or difficult project. In terms of learning, Jim is definitely the scarcest resource.

Moreover, the projects that come into the shop can constitute a resource lack. In an ideal world, the jobs that come into the shop would gradually increase in difficulty so that Jim's scaffolding of my learning could progress as if according to a course syllabus. Also in that ideal world, the jobs that I work on would vary such that I would receive regular challenges and refreshers on each of the machines and tools and procedures housed in the shop. That way, I wouldn't approach the mill thinking, "I haven't used this for two months. How do I set the x-axis again?" In such cases, I try to do the task myself first, but for fear of breaking something, I usually give up and ask Jim or one of my coworkers for help.

The randomness of the jobs that come into Howe's constrain my and my coworkers' opportunities, our resources, for deliberative practice. Even if I am motivated to advance my knowledge and skill in tig welding aluminum, if no such project comes into the shop, I don't get any practice, unless I practice after work. We have to work on whatever jobs the clients bring in, even if they are sometimes below our knowledge level and even if they are repetitive. For example, if I spend my morning

working on a long cut list, using the band saw to cut pieces of angle iron and tubing, I'm not advancing my learning.

Moreover, even if an aluminum tig project comes into the shop, the task might fall outside my ZPD; that is, it might be too difficult for my competence level and thus not assigned to me. For example, I've welded a few aluminum projects at Howe's: an aluminum ramp, an aluminum grill for a camper van, a bar that holds grow lights, and chock setters for the railroad (Fig. 3.4). But while I was working on a steel trellis project, another aluminum job came in—a radiator cased in aluminum. The client wanted a piece of aluminum angle welded onto the casing to use as a mounting bracket. As I looked at the project, trying to figure out whether I should stop work on the trellis to give this aluminum project a try, Jim explained the challenge for radiators lies in the epoxy used to affix the radiator fins. If you don't use a heat sink and if you weld too close to the epoxy, you'll have a huge mess of detached fins on your hands. Jim told me that whenever you weld a radiator, you've got to look at the directions of the fins to see whether they're vertical or horizontal. That way, you'll know where the epoxy is and where you have to use a heat sink, in this case a heat-absorbing putty. Although Jim seemed open to letting me work on this project and to scaffolding me through the procedure, I worried that the radiator project might lie a little too far outside my level of competence. I also wanted to finish the trellis project, which I'd been working on for a couple days. So I let this opportunity for deliberative practice pass me by. I probably made the wrong call on that, given that Jim seemed to think I could potentially handle it. As I noted before, for many jobs that come into the shop, there's no question that I simply don't have a sufficient level of competence. These tasks bypass me for my more competent—at least in that particular domain—coworkers.

In addition to the resource constraint on deliberative practice, Ericsson argued that a second constraint relates to effort, meaning the amount of deliberative practice a person can do. In research on violin players, Ericsson found that those who achieved the highest levels of proficiency were those who had engaged in an average of 10,000 hours of deliberative practice.¹⁸ In fact, Ericsson was the researcher whom Malcolm Gladwell cited in his best-selling book *Outliers*, inaccurately promulgating the idea that expertise requires 10,000 hours of practice.¹⁹ With this popularization, the number became a sort of folk wisdom, much like the old maxim that we humans use only 10% of our brains. Even Ericsson pushed back against this simplistic view that 10,000 constitutes some magical threshold where you shift from fumbling to refined, writing, “importantly, our research has never been about counting hours of any type of practice. In fact, it is now quite clear that the number of hours of merely engaging in activities, such as playing music, chess and soccer, or engaging in professional work activities has a much lower benefit for improving performance than deliberate practice.”²⁰ Ericsson wanted to stress that not only was 10,000 not a magic number but that the practice undertaken had to exhibit the criteria of deliberative practice listed above.

Another important, though faulty, take-away from Gladwell's analysis of Ericsson's research was that anyone who puts in sufficient effort (10,000 hours' worth) can achieve expertise. Of course, this idea that runs counter to what we intuit about

Fig. 3.4 The aluminum chock setters for the railroad that I repaired



all learned activities, both embodied like welding and machining and less embodied like reading a book: Nature and nurture don't provide each person with the same chance, no matter the hours of practice a person has put in, to reach an expert-level as a basketball player, violinist, chess player, or even as a welder. Some people will have greater potential in a given domain, and some will have less. It's more accurate to say that people are more likely to reach their potential if they engage in deliberative practice.

Of course, finding the opportunity to put in hours of deliberative practice is no simple matter. The effort constraint manifests at Howe's because it's difficult to find sufficient hours to develop expertise in the broad range of domains represented in the shop. If I wanted to develop expert-level conceptual and procedural knowledge only in mig-welding steel, I could get a different job and devote myself to that one domain. But trying to follow in Jim's footsteps means devoting hours to multiple domains across welding and machining (not to mention plumbing and wiring, which I've also seen Jim tackle). How to find the time to develop not only depth of competence, but also breadth of competence? The scope of domains bedevils.

Moreover, opportunities for deliberative practice in some domains, such as tasks using the lathe, the mill, or the rolling machines, come around more rarely than some other tasks, such as stick welding or punching holes. Therefore, getting the hours of sustained concentration and analysis needed to develop expertise will take longer—years. Take trying to develop competence in using one of the several metal-rolling machines in the shop. It's nothing to understand the basics of how the machine works: You can adjust the spacing between the rollers, and you can turn the machine off and on. In that sense, there's not much to it. But understanding how to make a

ring or semicircle of a particular size, that's an entirely different matter. You have to develop a feel for what a certain distance between the rollers means for the metal you're feeding into it. But the variables pile up: metal of different thicknesses, of different shapes, and different kinds. Stainless rod will react differently than mild steel because its less malleable. Some types of aluminum don't bend. Indeed, even seemingly identical rods or bars of metal can react differently if they come from different lots.

And even if you find time to put in the effort of deliberative practice, you'll find—if you're anything like me—that your concentration can only last for so long. Knowledge development blossoms in short bouts of deliberative practice. Paying attention to each detail—how to get the puddle started, how to move fast on stainless to avoid cooking out the chromium, how to let up on the heat when getting closer to the end of a bead when welding aluminum, how to fill in the end of a bead to avoid a crater (i.e., an unfilled spot that's susceptible to cracking), how to weave mig when welding vertical up—drains mental energy. A person can't concentrate like that all day.

Indeed, after bouts of concentration when I'm trying to learn something new, it's comforting to move to a task that's familiar and thus easier. Vygotsky wrote about this very idea. He didn't think that each task a learner encounters should fall within that learner's ZPD. Instead, he argued for thoughtfully intermingled tasks—challenging tasks that push the learner to develop and easier tasks that support the learner's motivation and provide a reprieve. Thusly, the learner progresses. As psychologist Mihaly Csikszentmihalyi discussed in his popular book, *Flow: The Psychology of Optimal Experience*, to sustain learning progress, we need to move from the challenge of the ZPD back to the safety of what we know.²¹ With this balance, we can progress without stressing ourselves out.

I've found that I often welcome an easy task, one that I can do without worry about making a mistake or, worse, breaking something, especially after I've completed a project that has stretched my ZPD. I once thought that that I was the only person who thought this way, but then Zach told me that he sometimes likes to do the repetitive job of punching circles out of 14-gauge steel. Our shop regularly provides hundreds of these one-inch circles to Happy Howie's dog food for use on display racks. And apparently Zach and I are not the only ones. On the welding subreddit, one welder titled their post, "F**k me. I am so sick of making these," with a photo of 17 or so of the 50 lowercase-h-shaped supports that they'd made. Another commentor responded:

Honestly, as irritating as that sounds I'd gladly take that job. They look like straight clean welds without a bunch of awkward weird shit to get in the way. And with 50, you can just zen out and you know what you'll be doing for the day!²²

Similarly, responding to the sarcastically titled post, "Anyone else have to do this tedious/repetitive beam work? It's just a blast!," another commentor responded:

That's what makes it good. Challenging tasks are also good, but sometimes just some easy stuff is nice.²³

Even tradespeople who avoid the repetition required to some extent by most production jobs, the comfort of some time spent doing a task for which you have already developed expert-level knowledge can't be denied.

Ericsson and colleagues discussed a third constraint on deliberative practice: the motivational constraint.²⁴ Anyone who seeks expertise must sustain motivation to continue, given that deliberative practice requires effort and often isn't pleasant. For example, when I tested different depths of cut on the lathe, I became nervous—nervous that I'd break the carbide bit, costing Jim money and embarrassing me in front of my coworkers. After all, experimenting leads to discoveries, but it can also break stuff. Expensive stuff.

Researchers talk about two main types of motivation: External motivation comes from factors outside the self, such as money, power, and fame. Internal motivation stems from our personal values. Daniel Pink, an expert on motivation, described three main internal motivators: autonomy, purpose, and mastery. Analyzing research on motivation, Pink found that while external motivators, like an hourly wage, certainly serve as a motivator, they don't foster creativity. For people to thrive at work, they need internal motivation. That is, they need to feel control over their workplace tasks; they need to feel like their work has meaning; and they need to feel like their job gives them space to learn.²⁵ These drivers—autonomy, purpose, and mastery—flourish in a shop like Howe's.

Howe's draws workers who want to solve new problems each day. Each project brings a new set of unique problems, like retrofitting an ATV so that it would hold an electric motor. And that constant figuring out and repurposing and making it work—all that creativity—scratches that itch for autonomy and generates internal motivation to continue to put in effort. Purpose flourishes at Howe's as well. Every day we repair and fabricate trailers and excavator buckets and augers and all manner of things that help people across industries get their work done. In central Iowa, farmers in particular come to Jim when a pin in the combine or tractor snaps or wears down. Working at a job shop like Howe's—where you even get to meet the clients—connects you to the work of others and lends meaning to your work. Finally, Pink argued that mastery—that need to improve—serves as an internal motivator. A job at Howe's cultivates both breadth and depth of expertises (or, rather, development toward them). Mastery at Howe's is the work of a lifetime.

As mentioned above, teachers—whether in a classroom or in a workplace—can play a role in sustaining learners' motivation. Teachers provide motivational scaffolding, such as praise, which impels learners to maintain their efforts. Tig welding aluminum used to frustrate me because I would stick the electrode in the puddle, contaminating the weld and the electrode. I would make this mistake as I was trying to attend to the distance between the electrode and the puddle but at the same time trying to attend to the amount of heat I was putting into the weld, the timing of dabbing the filler metal into the puddle, and the shape of the bead as the aluminum got hotter and hotter. During periods of frustration like this, I could feel my muscles tense, and I would start to feel like someone had set me, like a french fry, under a McDonald's heat lamp. Worse than these physical symptoms are defeatist thoughts: I wasn't born to do this; my eyesight and hand-eye coordination aren't sufficient; I

simply don't learn. Even now these declarations stream in the audio track of my brain, telling me I'm wasting my time and that I should just give up already. During my frustrations with aluminum tig welding, a kind "it's looking fine" from my proficient coworker, Adam, was enough to cool me off and keep me going.

To close this section on deliberative practice, it's important to note a point that Ericsson drove home repeatedly: Deliberative practice does *not* equate to performing an action over and over again. Erica Stanton, an expert dance teacher writing about practice, supported Ericsson's idea, noting the goals for dance technique "are not achieved through mindless repetition."²⁶ Improvements, whether in dance or in metal fabrication, come through thoughtful engagement with the task—analyzing movements and the results of movements, noting differences in what you see and hear and feel. Underscoring the ways that deliberate practice differs from mere experience or repetition, Ericsson used the example of tennis players, who "will not improve their backhand volley in tennis by playing more games."²⁷ Rather, they need challenges that sit at the edge of their competence, which a teacher (or coach) can provide. Similarly, welders, machinists, and others developing embodied knowledge need not just repetition but thoughtful, deliberative practice to advance their conceptual and procedural knowledge.

Conclusion

In this chapter, I've introduced the characteristics of a scaffolded learning interaction: intersubjectivity, ongoing diagnosis, contingency, interactivity, fading, and checking. I've also tried to introduce the types of strategies, such as demonstrating and explaining, that teachers use as they scaffold learners' knowledge. And I've also introduced the idea of deliberative practice, where the learner analyzes and critiques their performance to improve it. In the rest of the book, I draw upon these concepts to describe and analyze how—with the help of Jim and my coworkers, my community of practice—I've developed competences across knowledge domains, such as tig welding and using a lathe.

My next session on the lathe will almost certainly involve a one-to-one interaction with Jim and include instruction, cognitive scaffolding, and perhaps motivational scaffolding too. And further deliberative practice without Jim will follow. If I'm lucky, that next project will allow me to stretch my knowledge by working within my ZPD. I already know how to change the angle of the compound and how to raise and lower the cutting tool. Perhaps I'll be able to determine the cutting speed on my own. I have developed a little conceptual knowledge about the lathe's rpm (rotations per minute) already. I know that Jim's German lathes run twice as fast in reverse as they do in forward, a design feature intended to expedite tapping and threading. I know that the cutting speed, also called the surface speed, relates to the diameter of the item being turned. But this speed will also hinge on the hardness of the work material (for example, mild steel), the feed rate (that is, the speed of the tool toward the item), and the depth of the cut. It'll also depend on the tool being used. The

bit that you use to cut into metal could be high-speed (i.e., cutting) steel or carbide. This choice will change the rpm setting that you can use, as carbide can handle more rpm. I'm hoping I'll be able to apply this conceptual knowledge in the next lathe session.

But as I've noted in this chapter, in workplace learning like my learning at Howe's, these pedagogical concepts don't always—or even often—manifest in their idealized forms, as when a task I've been assigned falls squarely into my ZPD and Jim has the time to scaffold my understanding. But as I've mentioned here, workplace learning—perhaps especially at a job shop like Howe's—isn't always or even often ideal. In the next chapter, I explore in greater depth some of the challenges of on-the-job skilled-trades learning.

Notes

1. Anania, "The Influence."
2. Burke, "Students' Potential."
3. Bloom, "The 2 Sigma Problem," 4.
4. Puntambekar and Hübscher, "Tools for Scaffolding Students."
5. Chan, "The Reciprocity," 337.
6. van de Pol, Volman, and Beishuizen, "Promoting Teacher Scaffolding."
7. Mackiewicz, *Welding Technical Communication*, 20.
8. Wood and Middleton, "A Study of Assisted Problem-Solving," 181.
9. Vygotsky, *Mind in Society*, 212.
10. Csikszentmihalyi, *Flow*; Jackson and Roberts, "Positive Performance States of Athletes."
11. Mackiewicz and Thompson, *Talk about Writing*.
12. Mackiewicz, *Welding Technical Communication*.
13. Chan, "The Contribution of Observation," 443.
14. Mackiewicz, *Welding Technical Communication*, 82.
15. Ericsson, Krampe, and Tesch-Römer, "The Role of Deliberate Practice."
16. Ericsson, "Deliberate Practice," 991.
17. Stanton, "Doing, Re-doing and Undoing," 91.
18. Ericsson, "Protocol Analysis"; Ericsson, "The Influence of Experience."
19. Gladwell, *Outliers*.
20. Ericsson, "Training History," 534.
21. Csikszentmihalyi, *Flow*.
22. BrashPop, "F**k me. I am so sick of making these."
23. omega_86, "Anyone else have to do this tedious/repetitive beam work?"
24. Ericsson, Krampe, and Tesch-Römer, "The Role of Deliberate Practice."
25. Pink, *Drive*.
26. Stanton, "Doing, Re-doing and Undoing," 89.
27. Ericsson, "Deliberate Practice," 992.

References

Anania, Joanne. "The Influence of Instructional Conditions on Student Learning and Achievement." *Evaluation in Education: An International Review Series* 7, no. 1 (1983): 1–92.

- BrashPop. "F**k me. I am so sick of making these." Reddit, February 4, 2024. https://www.reddit.com/r/Welding/comments/1aj67e2/fk_me_i_am_so_sick_of_making_these/.
- Burke, Arthur Joseph. "Students' Potential for Learning Contrasted under Tutorial and Group Approaches to Instruction." PhD diss., The University of Chicago, 1980.
- Bloom, Benjamin S. "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring." *Educational Researcher* 13, no. 6 (1984): 4–16. <https://doi.org/10.3102/0013189X013006004>, 4.
- Chan, Selena. "The Contribution of Observation to Apprentices' Learning." *Journal of Vocational Education & Training* 67, no. 4 (2015): 442–459.
- Chan, Selena. "The Reciprocity of 'Imitative Learning' through Apprenticeship." *Vocations and Learning* 10, no. 3 (2017): 325–342.
- Csikszentmihalyi, Mihaly. *Flow: The Psychology of Optimal Experience*. New York: Harper & Row, 1990.
- Ericsson, K. Anders. "Deliberate Practice and Acquisition of Expert Performance: A General Overview." *Academic Emergency Medicine* 15, no. 11 (2008): 988–994.
- Ericsson, K. Anders. "Protocol Analysis and Expert Thought: Concurrent Verbalizations of Thinking during Experts' Performance on Representative Task." In *Cambridge Handbook of Expertise and Expert Performance*, edited by K. Anders Ericsson, Neil Charness, Paul J. Feltovich, and Robert R. Hoffman, 223–241. Cambridge University Press, 2006.
- Ericsson, K. Anders. "The Influence of Experience and Deliberate Practice on the Development of Superior Expert Performance." In *Cambridge Handbook of Expertise and Expert Performance*, edited by K. Anders Ericsson, Neil Charness, Paul J. Feltovich, and Robert R. Hoffman, 683–704. Cambridge University Press, 2006.
- Ericsson, K. Anders. "Training History, Deliberate Practice and Elite Sports Performance: An Analysis in Response to Tucker and Collins Review—What Makes Champions?" *British Journal of Sports Medicine* 47, no. 9 (2013): 533–535.
- Ericsson, K. Anders, Ralf T. Krampe, and Clemons Tesch-Römer. "The Role of Deliberate Practice in the Acquisition of Expert Performance." *Psychological Review* 100, no. 3 (1993): 363–406. <https://doi.org/10.1037/0033-295X.100.3.363>.
- Gladwell, Malcolm. *Outliers: The Story of Success*. Boston: Little, Brown, 2008.
- Jackson, Susan A., and Glyn C. Roberts. "Positive Performance States of Athletes: Toward a Conceptual Understanding of Peak Performance." *The Sport Psychologist* 6, no. 2 (1992): 156–171.
- Mackiewicz, Jo. *Welding Technical Communication: Teaching and Learning Embodied Knowledge*. Albany, NY: State University of New York Press, 2022.
- Mackiewicz, Jo, and Isabelle Thompson. *Talk about Writing: The Tutoring Strategies of Experienced Writing Center Tutors*. New York: Routledge, 2018.
- omega_86. "Anyone else have to do this tedious/repetitive beam work?" Reddit, April 25, 2023. https://www.reddit.com/r/Welding/comments/12y0qkc/anyone_else_have_to_do_this_tediousrepetitive/.
- Pink, Daniel. *Drive: The Surprising Truth About What Motivates Us*. New York: Riverhead Books, 2009.
- Puntambekar, Sadhana, and Roland Hübscher. "Tools for Scaffolding Students in a Complex Learning Environment: What Have We Gained and What Have We Missed?" *Educational Psychologist* 40, no. 1 (2005): 1–12.
- Stanton, Erica. "Doing, Re-doing and Undoing: Practice, Repetition and Critical Evaluation as Mechanisms for Learning in a Dance Technique Class 'Laboratory.'" *Theatre, Dance and Performance Training* 2, no. 1 (2011): 86–98.
- van de Pol, Janneke, Monique Volman, and Jos Beishuizen. "Promoting Teacher Scaffolding in Small-Group Work: A Contingency Perspective." *Teaching and Teacher Education* 28, no. 2 (2012): 193–205.

Vygotsky, Lev Semenovich. *Mind in Society: Development of Higher Psychological Processes*, edited by Michael Cole, Vera John-Steiner, Sylvia Scribner, and Ellen Souberman. Cambridge, MA: Harvard University Press, 1978.

Wood, David, and David Middleton. "A Study of Assisted Problem-Solving." *British Journal of Psychology* 66, no. 2 (1975): 181–191.

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Chapter 4

Challenges in Shop Learning



Abstract No fabrication shop devotes itself solely to developing its employees' expertise, Howe's included. For one thing, there's no set curriculum designed to scaffold knowledge development over weeks and months. Each workday isn't replete with one-to-one interactions with an expert. This chapter builds upon Chapter 3, exploring the limitations of learning in a workplace setting, as opposed to a classroom. First, I discuss imperfect projects for learning, those that contain too many tasks beyond my knowledge and that therefore prompt mistakes. I also discuss Jim's occasional impromptu lessons on unfamiliar tools and processes, lessons that almost always fail to target my ZPD and thus usually don't generate much learning beyond knowledge that the tool or process exists. Here I also discuss how, for someone with novice-, advanced beginner-, or even competent-level knowledge, it's difficult to envision a project's potential pitfalls; such envisioning accords with Jim's 7Ps doctrine: proper prior planning prevents piss poor performance. Finally, I explore how competence develops nonlinearly; during deliberative practice, setbacks invariably arrive after hope-inducing advances.

In the last chapter, I described qualities of a scaffolded interaction, focusing especially on the importance of contingency—the teacher's ability to diagnosis the level of the learner's existing knowledge and to build upon that knowledge—and working within the learner's zone of proximal development, or ZPD. In an ideal learning situation, the teacher and student work together, progressing stepwise through successively more difficult challenges. Moreover, in the one-to-one interactions covered in the research on scaffolding, *trained* teachers and tutors helped learners, choosing expertly among explanations, pumping questions, and other strategies. And in that ideal learning situation, the learner has sufficient time for deliberative practice and sustained reinforcement of the newly acquired knowledge.

But of course, as I discussed a bit in the last chapter, no working shop devotes itself to expanding its employees' expertise, Howe's included. For one thing, there's no set curriculum designed to scaffold knowledge development over weeks and months. In addition, each workday isn't replete with one-to-one interactions with an expert. Rather, opportunities for learning from someone more expert usually arise

in a moment of necessity, when you can't proceed without some intervention, such as a more expert person telling you what to do, explaining something that confused you, or asking you a pumping question like "What view would help to determine the angles of the ramps?" to help you consider what to do next.

Seeking out expertise once or twice per project doesn't pose too much of a problem, but projects that require near-constant supervision—babysitting—do in fact bring challenges. A project that involves numerous tasks beyond the worker's level of competence forces a more expert person to spend a lot of time teaching and supervising, which in turn pulls that person from other projects. Such projects can also demoralize the learner, making them feel like a nuisance.

Perfect and Imperfect Projects for Learning

The perfect project for learning at the shop is one that draws from current conceptual and procedural knowledge most of the time but that also occasionally pushes the learner into their ZPD. For example, when I worked on truck ramps made from C-channel and angle iron, cutting the metal and tacking the pieces together wasn't difficult. I didn't need Jim for that. But to start fabricating the ramp, I needed scaffolding to understand how to determine the angle to cut the C-channel so that the ramp would rest flat on the ground and so that the top of the ramp wouldn't bind against the back of the truck. After I had that, I could oxyacetylene cut the angles on the C-channel, clamp the pieces, tack them together, and then stick weld them. I didn't need Jim for any of that.

In that scaffolded interaction, Jim and I knelt on the shop floor in front of a large steel plate (Fig. 4.1). With a silver pencil in hand and using the plate as a drawing board, Jim demonstrated and explained how to make a template by measuring the 18 inches from the truck bed, where the ramp would attach, to the ground. However, Jim never explicitly said that we were drawing a side view, assuming that I understood the perspective he was drawing. But I didn't right away. It took me a few minutes as he drew a 63-inch line (the length of the ramps) from the top corner of the plate to the "ground," 18 inches from the top of the plate:

Jim: Right. But that's why we're going to use a piece of flat bar because we're looking at, basically our cut is going to be like so.

Jo: Yeah.

Jim: When we get our- This way we can take our flat bar. It's going to come- So if we take our 10- or 12-inch-long piece of 3-inch flat bar, we can strike that line onto it. This will still fit flush to the top, which is then flush bottom here.

Jo: Okay.

Jim: So this is the ground.

Jo: Yeah, I get it.

When I said, "Yeah, I get it," I wanted to indicate to Jim that I finally understood that we were looking at a side view and that the view showed us where to cut each

Fig. 4.1 Jim showing me how to measure the angle to cut off the ramp's C-channel sides



piece of C-channel. I didn't, however, yet understand the use of the 3-inch flat bar—that Jim wanted me to make another template from the flat bar. I was to lay the flat bar on top the C-channel to mark where the cut lines would be and then use it on each end of the pieces of C-channel. Doing so would make the cuts the same. Even though I didn't yet understand why Jim mentioned flat bar again, I tried to follow along. But my next question showed that I didn't yet grasp the purpose of the flat bar, which I'd need right away if I was going to proceed any further:

Jo: Do you really want me to cut a piece of flat bar now? Or should I just-

Jim: I would.

Jo: Okay. Can I just-

Jim: Just because then you can set the flat bar on there. Instead of trying to get this lined up, each one. It's going to be easier with the flat bar to set it on there, strike your line-

Once Jim stated explicitly that I'd need to set the flat bar on top of the C-channel, the idea of the flat-bar jig finally made sense:

Jo: I see.

Jim: Center punch it, torch it.

Jo: Ah, yeah.

Jim: Because otherwise you might get a little bit off on each one.

After a few more exchanges where Jim told me that I'd need to use a center punch to mark the lines and then oxyacetylene torch the cuts, Jim told me that I'd have to make a right and a left side for each ramp:

Jim: So when you're doing the template, that way you've got a flat bar because right now you'd have to do two upright and two the other way. The template's the same either way.

Jo: Right.

Jim: So then you just clamp it onto here. On the opposite, you flip the template and it's clamped over here. So that when you have your left and your right, if you make all rights, it's not going to work well.

Jo: But-

Jim: Because this one's getting torched here and the other one's back to that. It's the same cut. It's just one's left and one's right.

Jo: Right. Okay. All right. I got that.

Jim: Better?

Jo: Yeah, I got to go make my template. But yeah, I think so.

Even though I couldn't at that point envision flipping the template to ensure I had two lefts and two rights, I told myself that once I made the flat-bar jig and sat the C-channel on my worktable, I'd see what Jim meant. And I did.

Although this interaction revolved around what I think of as a perfect project for learning, it also reveals some of the challenges of learning at work. At the outset, Jim didn't explain what he was doing with the steel plate on the floor, so I didn't fully understand the goal of the task. In other words, intersubjectivity—that shared understanding of the learning goal—hadn't solidified at the outset. In a planned interaction in a school setting, the learning goal would be explicit at the outset. Also, I didn't recognize at first that Jim was drawing a side view of a ramp, and Jim didn't recognize my lack of recognition right away. So he missed a beat in ongoing diagnosis. And although Jim mentioned flat bar several times before the talk excerpted above, it wasn't until I asked a question that revealed my lack of understanding that he told me to set the flat bar on the C-channel to use as a guide for cutting. At work, we learn from people who haven't studied scaffolded learning, and as important, we learn from people who have other tasks to do besides scaffolding our learning.

Nevertheless, because this was a work task, I not only learned how to find the angles for the cuts and how to make a template for the cuts, I also got to carry out the rest of the tasks involved in the project. I set up the oxyacetylene torch and made the cuts myself. And I laid out the ramp pieces, clamped them down, checked for right angles, and tacked the pieces together with mig welds. This perfect project gave me time for deliberative practice in tasks that challenged me—cutting clean lines with the oxyacetylene torch in particular—but lay within my current knowledge level. Success in those tasks boosted my confidence. And that boost made it easier to take in Jim's feedback when he checked back on my progress as I stick welded the rungs onto the C-channel. He told me that I should rest at the sides of my weld bead a bit longer as I laid these 45-degree welds along the angle-iron rungs. He took the stinger and demonstrated what he meant. I observed, and then I tried to imitate his touch-longer pause at the sides. Even though his critique deflated me a little, it also motivated me to use the task as deliberative practice on 45-degree welds.

Of course, not all projects are perfect. Sometimes I end up working on a project that involves too many tasks beyond my competence, and I make mistakes. I think of the time when I worked on a sign that would sit in the lane of a bank drive-through when the lane was closed. The sign consisted of two triangles attached on the top by a bar and attached to a rectangle on the bottom. After I cut the pieces so that they fit perfectly together, I needed to prime and paint it, even though I'd never primed anything nor cut paint with paint thinner. In other words, the project involved several steps that lay outside my competence level.

After cutting the square tubing to the correct lengths, I tried to figure out on my own—without asking Jim—how to make the square tubing of the triangles meet evenly at the center to form the triangle point, but I didn't know how. I tried laying one piece of tubing on top of the other and drawing a line about where the other hit, but the goal was for the two to come together perfectly. As you might guess, laying one on top of the other and guesstimating where the two meet doesn't work. Jim came by my table and saw how I'd ruined the pieces of square tubing with the completely inaccurate cuts I'd made (Fig. 4.2, left). He looked horrified, actually. Trying to save face and deny my need for guidance, I told him I thought I could fill in the gaps by using a copper backing strip and bridging the gap between the two pieces. I was thinking then of Adam's maxim, "If you can step over it, you can weld it." But Jim would not abide my proposed solution. And having registered that I hadn't applied the necessary geometry on my own, he intervened. He demonstrated how to use a straightedge perpendicular from the middle of the triangle base to draw a line on each of the two pieces of square tubing where they would meet to form an acute angle at the triangle's top, explaining how doing this would create a line on each of the two pieces where I could cut to get the two pieces to fit together perfectly. In other words, Jim demonstrated how to use geometry to solve the problem. Then, I imitated what he did on new pieces of square tubing (Fig. 4.2, right). Jim diagnosed my knowledge level and made his intervention contingent on it, but in a practical sense, the scaffolding was too late. I'd already chopped up four pieces of square tubing. Nevertheless, after the demonstration and explanation of the geometry at work, I was ready to imitate what he'd done. Later, after I'd welded the pieces together—a step that lay at my competence level—I had to request more scaffolding from Jim and from Zach to help me through the multiple steps of operating the spray gun, priming, thinning paint, and painting.

The bank sign wasn't a perfect project because it involved several tasks requiring knowledge that I didn't have. After Jim helped me with the triangle geometry and after I'd finished the tacking and welding, Jim and Zach demonstrated, told, and explained the steps in the painting process. While these interactions aided my learning, they diverted Zach and Jim from their own projects, and research has shown that people, diverted from their own projects, incur substantial cognitive costs in switching from their original task to the interruption task (i.e., interruption lag) and back again after the interruption (i.e., resumption lag).¹ Interruptions can increase mistakes and, not surprisingly, increase the time needed to complete a task.² In short, switching between tasks requires effort and often generates negative outcomes. My need for scaffolded



Fig. 4.2 My mistakes on the bank-sign angles (left) and the bank sign with correct angle joints (right)

learning, at least in the short term, cost others time and cognitive effort and cost the shop money.

Impromptu Instruction

I'm lucky that I work for someone who wants to pass on what he knows to us employees. Stephen Billett, writing about challenges of on-the-job learning, wrote that more knowledgeable workers may be reluctant to guide less-expert workers for fear of being displaced from their jobs or of losing status.³ Jim has neither fear. Quite the opposite, he wants to introduce us to what's possible in fabrication. Every so often, then, he calls one of us—sometimes all of us—over to show some less-commonly used tool or some inventive solution to a problem. Once, he called me away from stick welding to show me how he'd revamped the waterjet basin to make room for a steel box with four tubes jetting out of it. He wanted to demonstrate and explain a jig he had made to find the center point between two tubes—the point where a new hole would be cut. I always find these impromptu instruction sessions interesting because they give me insight into what Jim considers noteworthy, but often integrating them into my existing knowledge often poses a challenge. These lessons don't arise from a task I'm engaged in, and because they are random, they tend not to target my ZPD in the relevant domain. Even so, I try to find some concept or procedure that I can transfer to a future task.

Transfer of learning, what's also called transfer of training, has for obvious reasons and for decades interested researchers who want to understand how people apply existing knowledge to new situations. In this case, the idea of using a jig to find a center point rather than repeatedly measuring between two tubes can apply to other cases of repeatedly finding a center point between two objects, such as when I used a jig to find the midpoint between rods when building a trellis.

That said, I did once by chance get to practice one of Jim's impromptu lessons about a month after he delivered it. Jim had called me and Zach over to watch him extract a broken-off bolt. Using about 60 amps, he tig welded a ball of filler metal onto the top of the bolt, being careful to keep the filler metal on the bolt and off the surrounding base metal. He then pounded the ball to give it a mushroom shape. Then, he could get a vice clamp on the now-mushroom-shaped filler metal. Jim told us that the heat from the tig torch would deactivate any thread sealant. It would also expand the metal of the bolt and break apart any rust that was holding it to the surrounding metal. Without much fuss, Jim unscrewed the stuck bolt.

Serendipitously, exactly one month after Jim demonstrated and explained bolt extraction, I had the chance to do it myself. As usual, I hadn't practiced extracting a bolt when Jim showed us how, so this was my first time trying it for myself. I was able to put a ball of filler metal on top of the broken bolt without getting the filler on the base metal, but I didn't make a good bond between the bolt and the ball. When I tried to use the vice grips on it, the ball popped right off. Seeing me struggle, Jim came over to intervene. He turned the piece over and told me that the bolt had mushroomed on the other side, making it impossible to unscrew. So this opportunity to apply the earlier impromptu lesson generated yet another; Jim used the drill to remove the bolt's center, easing the pressure on the threads and making it possible, finally, to unscrew it from the mushroomed bottom. Once again, though, I observed, but I didn't practice, let alone engage in deliberative practice.

As the saying goes, be careful what you wish for. About a year later, I got all the deliberative practice in bolt extraction that I could handle. A customer brought in a section of tubing for a pool. It consisted of two halves bolted together at a center flange. All the bolts were broken and stuck. Jim decided that rather than cutting off the bolts and drilling new holes, as Adam suggested, I'd get them all out. Thus, my bolt-extraction marathon began. On day one, Jim told me to try his brazer heater, which consists of two carbon elements hooked up to a car battery. As with the tig welding, the heat from the carbon elements expands the metal and that expansion cracks the stuff—in this case calcium—that holds the bolts. The carbon elements worked on the unthreaded bolts, but the ones with threads were far more difficult. I tried tig welding filler metal to them, but the vice grips just slipped around the balls I welded on. I gave up and went home. The next day, I started on the bolts again, but again I couldn't get them out. When Jim came to check on my struggle with the filler-metal balls and the vice clamps, he told me he had another trick. This time, he put the tig torch's tungsten directly on one of the bolts, and again, he got a bolt out. But at that point it was time for me to go home. After work, I wrote in my journal, "So he's shown me twice that it can be done. Now I have to do it."

When I returned to work on the third day of the bolt-extraction project, Jim had yet another plan. He cut off a small piece of 3/16 round stock, sharpened it into a point, and put it in a stinger (for stick welding), but he kept the machine on the remote setting so that he could use the foot pedal, as if he were tig welding. He used the sharpened round stock to heat up a bolt, making sure that the stuck bolt rested on the table so that the current followed a path through the bolt rather than heating up the tubing first. That creative solution worked. Still tasked with the remaining bolts, I imitated Jim's actions, and in an hour—but really after three days—I had all the bolts out. Responding to Adam's comment about this project being a waste of time, Jim said that, especially in retrospect, Adam had a point; drilling new holes would have taken a lot less time. But Jim had wanted me to learn how to get stuck bolts out, even the difficult ones that require several methods. And I did. Likewise, Jim wanted to do the best work possible, even when it's difficult to do. We'd made it possible to use the original holes rather than drilling new ones (Fig. 4.3).

As I've mentioned before, other times these impromptu lessons focus on tools that Jim wants to introduce to us. I always welcome these lessons, even when Jim interrupts what I'm working on, because for me they're excursions into the unknowns of fabrication. However, I usually find them even more difficult to connect to my existing knowledge than Jim's lessons about uncommon procedures. For example, one time Jim decided to demonstrate how to use a keyway broach to notch a channel in metal. As he pressed down on the handle of the arbor press, a tooth on the broach ate away a bit of the metal. But I haven't had to broach anything yet, so the lesson hangs in a sort of knowledge limbo, waiting for me to use it myself.

Fig. 4.3 Aluminum pool tubing with bolts extracted



Another time, Jim got me and Zach together to show us how his motorized pipe crimper works. He planned to use it to swage a piece of tubing, making one end's diameter smaller so that it would slide into another piece of tubing, like one piece of tent pole fitting inside another. He demonstrated swaging, explaining how the dies come together around the tube with up to 100 tons of pressure. Once again, because Jim had to get back to the project he was working on, I didn't get to set up and use the tool myself or get to engage in any deliberative practice. That is to say, I still can't use the pipe crimper on my own.

Planning a Project's Steps

To ensure that what you make is something that you're proud of, that you'd sign like a painting if you could, you've got to think ahead. Successful fabrication requires planning how you're going to carry out a project—what you're going to do first, second, third, and so on. When we're fabricating something from a drawing, we try to understand, for example, where the bends must be, how we're going to make them, and in which order we're going to make them. Toward this end, Jim likes to quote something he and his Navy buddies used to say: Proper prior planning prevents piss poor performance. The seven Ps. Jim likes to hit me with this saying when I've made a mistake that planning would have avoided.

But life in a metal shop like Howe's doesn't allow such easy passage down the 7Ps path. If in the domain of bending metal on the press brake or the box-and-pan brake you're still at the novice or advanced-beginner level, you might know which questions to ask, but you won't know the answers. Such was the case when I had to lay out bends on a 10-foot piece of 18-gauge steel that was to be a cover for a generator. The idea was to bend the sheet so that there'd be an offset X, making the sheet into a sort of dome (Fig. 4.4). We'd also bend a 1 ½-inch lip on each of the four sides. After we'd laid out the bends but before we had made them, we had to cut a 3-inch hole centered on the middle of the X. My level of development in layout and bending meant that I could determine where the cross of the offset X should be, but I didn't know which bends we'd make first—the X or the 1 ½-inch rims on each side. And I had no idea how we'd make the X.

After Jim had set up the knock-out punch for the 3-inch hole, he showed me how we'd use the hydraulic press brake to bend the X, checking the angle of each bend and measuring the dimensions of the sheet to ensure it would cover the generator. We had to use the press brake instead of the box-and-pan brake because the box-and-pan lacked sufficient room to fit the bends. That is, once we made the first bend, we wouldn't be able to make the second. Jim's knowledge of the capabilities and limitations of the shop's equipment allowed him to plan to use the press brake first and the box-and-pan second, which we would use to make the 1 ½-inch rim. Projects like these show me that you can't enact the 7P rule if your level of expertise doesn't allow it. If you don't have the required knowledge, you'll need scaffolding along the way, like I did.

Fig. 4.4 An X bend in a cover for a generator



In fact, Jim once recounted a story of an employee who had failed to anticipate the results of the bends he'd made:

Jim: I come in and he's got my [box-and-pan] machine torn apart. He didn't think it through, and he made the last bend hook, trapped it. He had to disassemble a machine.... I'll make this bend and then this bend. Don't make this bend because you're not going to get this bend.

Jim incanted the 7Ps again when I had doubts about a choice I'd made as I finished up a trellis project. Jim had told me that I needed to put gussets on the trellis so that the client could pound it deep into the ground. After I'd already welded the gussets to the bottom of the trellis, I asked Jim whether I had misplaced them. I thought perhaps that I had. Instead of connecting them to the spikes that the customer would drive into the ground, I'd connected them to the bottom of the trellis—that part that would sit above ground. Jim looked at me disbelievingly, wondering how on earth I had made this mistake. How was someone supposed to mow around this trellis with those gussets jutting out? How would someone not trip over them? Given that no good answers to these questions exist, I of course didn't have any. I'd heard Jim say that I should add gussets, but I hadn't thought about how people would interact with the trellis. I winced at this mistake particularly because it stemmed from my lack of attention to what people in my academic field call “the rhetorical situation”—the audience, purpose, and context of a text or, in this case, a trellis.

In addition, at Howe's I sometimes find myself working on projects without knowing what the thing I'm working on will look like in the end. Jim doesn't always have time to catch me up on the thinking he's already done about a client's project. When I show up, he might give me a task to do, like drilling holes, but I won't know

the end game. One of these projects materialized recently after a client had ordered 10 more aluminum boxes. Adam had already made one set of 10, and now the client needed more. Wanting to practice aluminum tig welding, I asked Jim to let me work on them. Jim acquiesced, but he told me that first I'd need to build a new stop for the cold-cut saw—an adjustable, sliding piece of steel that would stop the metal at the needed length. By saving me the step of having to measure each piece of C-channel for the aluminum boxes, the stop would allow me to cut the pieces more quickly.

I could tell that Jim had in his mind a vision of what the stop would look like, and he tried to describe it to me, but I didn't understand exactly what he wanted, except that it would consist of a square-tubing arm that would bolt onto the side of the saw. Realizing that I didn't fully grasp his design, he decided that he'd tell me what to do in short bursts. First he told me to cut four feet of 2-inch square tubing, two 4-inch pieces of receiver tubing that would wrap around it, and a 6×3 -inch $\frac{1}{4}$ -inch plate. Then he told me to use a template to match holes in the plate to the position of the threaded holes in the saw's base. With the holes drilled, I returned to Jim to ask him what he wanted me to attach to the receiver tubing as a stop. I understood the idea of the sliding stop, but I still didn't have a clear picture of what Jim wanted this preproject project to look like. And I didn't understand how the receiver tubing would stay in place on the stop's four-foot arm.

So Jim delivered more instruction. He said I'd drill a $\frac{27}{64}$ -inch hole on a corner of the receiver tubing, which would make the hole thicker than it would be if we drilled on a flat side. He told me to weld a $\frac{1}{2}$ -inch nut above this hole and then use the nut as a guide to tap the hole for a $\frac{1}{2}$ -13 bolt. The bolt would fasten against the arm, keeping the receiver-tubing stop in place. After I'd completed that step for both pieces of receiver tubing, Jim told me to weld eight inches of square tubing to one of the receiver-tubing pieces. That's the piece of receiver tubing that would act as the stop for the metal being cut in the saw. After I finished this step, I had a working stop to cut my aluminum C-channel on the cold-cut saw (Fig. 4.5). So in the end, the project succeeded. (That said, I still don't know exactly how the other piece of receiver tubing will function. Jim has told me that it will attach to an adjustable-height leg to further support the tubing arm. But I'm not sure what the leg will look like.)

But the saw-stop project could have been more efficient if I had understood the stop's design from the start. Jim had that picture. Indeed, he had made a several stops like this one before. If we had worked toward intersubjectivity at the outset, using a drawing to show how the pieces of tubing, the plate, and the nut came together to act as a stop, I would have been able to move through all the steps—the drilling, tapping, and welding—without returning to Jim multiple times with questions and more questions about what to do next. When you don't understand the end goal, you can't plan the steps yourself. You wait for the more expert person to tell you what to do.

Jim's catchy 7Ps acronym has a long history in British and US military branches, but it assumes that the recipient understands the goal and has developed the required level of expertise to anticipate what will happen and what will be needed. At Howe's,

Fig. 4.5 The sliding stop that I made for the cold-cut saw. The bolt on the bottom of the receiver tubing holds the stop in place



where I'm building both depth and breadth of competences, there's a strong likelihood my attempts at prior planning will miss the mark.

The Nonlinear Path Toward Competence

If my experience is any indication, knowledge development via scaffolded learning and deliberative practice advances and regresses and then advances again. You can perform a sequence of actions effectively one day, but the next day you might get it wrong. As I practice, I get overwhelmed by the details like maintaining the proper travel angle and easing up on the heat input as I travel along the length of the weld and trying to maintain a consistent weld size. These variables compound in out-of-position welds, such as welding around a piece of tubing.

Take, for example, a dining-room chair that I tried to repair and reinforce, thinking that my competence in tig welding thin materials had sufficiently developed to take on this project. The chair had been sitting in the pile for weeks. After walking past it for days, I decided I could tig weld the cracks and reinforce the non-welded joints without blowing holes in the thin, chrome-plated metal and making the chair's problems worse. Indeed, seemingly always looking for a new way to make me nervous, Jim told me that I could easily ruin the chair by blowing holes in the legs. To avoid a catastrophe like that, you have to provide enough heat to establish the puddle but not so much heat that you burn away the thin base metal. Deliberative practice involves



Fig. 4.6 The hole I burned in the chrome-plated chair (left) and my successful tig weld on the same chair (right)

figuring out where that sweet spot is. But when you're practicing on a customer's chair, you have to restrain your exploration of these parameters.

On my first attempt, I was able to fill a crack by establishing the puddle, gently dabbing filler metal into it, attaching filler metal to one side of the crack, and building a bridge to the other side. But as I got to the crack's end, the metal had become too hot and—voila—I blew a hole (Fig. 4.6, left). I'd have to decide later whether I was going to try to fix it or whether I'd leave it for Jim. Then, when I tried again on another crack, I got the weld started, bridged the gap, and lowered the amps as I got to the end. I had managed to fix the crack, if not beautifully, at least functionally (Fig. 4.6, right). I felt as if my body had, for once, joined my mind.

But when I returned to the chair the next day, it was as if that successful weld had never happened. I had trouble getting the puddle started, and I added the filler metal too soon, making an ugly pile of metal. All this extra metal required more heat to melt, so I had to put even more heat into the weld to establish the weld puddle. Afraid of causing damage, I played it too safe, but playing it safe ultimately led to the same result—too much heat. Frustrated and fearing that I was ruining the chair, and I asked Jim to fix my errors, which he did with ease.

This project drove home an important limitation of learning at work—the constraint of making a mistake that will ruin something. This worry doesn't only materialize when working on an object that belongs to a customer, like a chair or a lift arm off a loader, it also materializes when you've put a lot of time into fabricating something, like the bottom of a drain basket that I made for the athletics office of the local university. In that case, Jim and I had spent 30 minutes setting up the mechanical punch and setting the stops, and then I'd spent over an hour punching a bunch of holes in what were to be the sides and the bottom of the drain basket.

When it was time to bend ½-inch lips on the sides of the basket's bottom, I worried that one mistake on the press brake would ruin the entire thing, making waste of all the set-up and hole-punching time. In short, deliberative practice at work doesn't always or even often allow for safe exploration that decreases anxiety and facilitates learning.

Conclusion

Work in a job shop like Howe's brings ample opportunities for learning, but those opportunities won't necessarily match a learner's readiness or their need for deliberative practice. Projects don't line up to foster and reinforce learning. And while some larger fabrication facilities like John Deere and Vermeer run training programs where employees can for a few weeks concentrate on a structured curriculum, tradespeople must, for the most part, prioritize productivity goals over expanding and deepening their knowledge.

Tradespeople have to work with the tasks that materialize and have to take advantage of whatever opportunities for scaffolded learning and deliberative practice become available. To develop their knowledge, they need to advocate for themselves by asking for projects that will advance their cognitive and procedural knowledge. Projects that combine such advancement with the comfort of already acquired knowledge work especially well. They also need to take advantage of opportunities to work with people who can scaffold their knowledge.

And tradespeople can also practice on junk. The abundance of cheaply made crap in the world has one benefit: mountains of practice material in the form of tossed-aside tables, chairs, bike frames, drying racks, lawn art, truck grills, wheel rims, and broken tools. Practicing on discarded items removes the worry of ruining a customer's favorite thing. It lets you test limits, blowing holes in 18-gauge steel while finding a workable amperage. And if you end up fabricating something you like and want to keep, you've saved room in a landfill.

Tradespeople also need to cultivate and harness their curiosity about the tools, machines, and procedures around them: Why is copper a good heat sink? What are the rolling machine's limits? What's the difference between single- and three-phase welding machines? How do you make a scroll on the Hossfield bender? How do you straighten a bent auger? If you spend the workday curious, you encounter new information. Some of that information will become structured (i.e., incorporated into existing knowledge) and indexed (i.e., associated with its circumstances for use). And, unfortunately, much of it won't. But maybe it will tomorrow. Or the next day.

This chapter has explored the frequent mismatch between my projects at Howe's and my readiness to learn what those projects offer. In the next chapter, I explore another challenge to shop learning, especially in the United States—the absurdity of measurement systems.

Notes

1. Altmann and Trafton, “Memory for Goals”; Monk, Trafton, and Boehm-Davis, “The Effect of Interruption”; Trafton et al., “Preparing to Resume.”
2. McFarlane, “Comparison of Four Primary Methods.”
3. Billett, *Learning in the Workplace*, 90.

References

- Altmann, Erik M., and J. Gregory Trafton. “Memory for Goals: An Activation-Based Model.” *Cognitive Science* 26, no. 1 (2002): 39–83.
- Billett, Stephen. *Learning in the Workplace: Strategies for Effective Practice*. New York: Routledge, 2001.
- McFarlane, Daniel C. “Comparison of Four Primary Methods for Coordinating the Interruption of People in Human-Computer Interaction.” *Human-Computer Interaction* 17, no. 1 (2002): 63–139.
- Monk, Christopher A., J. Gregory Trafton, and Deborah A. Boehm-Davis. “The Effect of Interruption Duration and Demand on Resuming Suspended Goals.” *Journal of Experimental Psychology: Applied* 14, no. 4 (2008): 299–313.
- Trafton, Gregory J., Erik M. Altmann, Derek P. Brock, and Farilee E. Mintz. “Preparing to Resume an Interrupted Task: Effects of Prospective Goal Encoding and Retrospective Rehearsal.” *International Journal of Human-Computer Studies* 58, no. 5 (2003): 583–603.

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Chapter 5

Learning Arcanities



Abstract Not a few of my tribulations in advancing my conceptual and procedural shop knowledge have arisen from the absurdly arcane systems of measurement used in metal fabrication in the United States. In this short chapter, I relate a bit of the history behind the arcane systems of drill-bit sizes, thread counts and pitch, pipe sizes and schedules, and metal gauges that we—like many shops in the United States—use at Howe’s. Even though these systems cause head scratching, they persist as the units by which tradespeople in the United States conceptualize space. The chapter ends by discussing the waste and errors generated by maintaining these systems rather than using metric like every other country except Myanmar and Liberia.

Once early in my work at Howe’s, before I was to use the oxyacetylene torch to cut a ½-inch thick piece of steel, Jim quizzed me, asking “What number cutting tip would you use for this?” He was testing me on (1) whether I had any familiarity with the system used for differentiating cutting tips and (2) whether I knew the exact tip to use for ½-inch steel. I kind of knew the first part; I knew that the tips we have in our shop have numbers somewhere in the range of 1 to 10. I blurted out the first number I thought of—7. Of course, as anyone with any experience with torch tips knows, a 7 is for really thick metal—around 10 inches thick. Jim looked at me, astonished by my ignorance. I learned that day that the numbering system for torch tips is more complex than it needs to be. The scale begins at 000, which is for cutting metal 1/8-inch thick, and it moves through 00 and 0 before it hits 1. In our shop, we have a 7 tip, but I’ve certainly never used it.

A few months later, my task was to recreate a ski that the city road crew uses to cover the wheels on their rumble-strip maker. One of the steps in the project was to weld 5/8–11 bolts onto notched angle iron. When I went to Hokel’s Machine Supply, the guy at the counter gave me grade-8 bolts. At that point, I didn’t know that bolts come in different grades, although soon after I learned that a casual walk through the nuts-and-bolts aisle at a big-box DIY store would have alerted me to the existence of three bolt grades. As it turns out, grade-8 bolts don’t weld all that well because they become brittle in the heat affected zone. Jim had wanted me to get grade 5, not grade 8. “What’s the difference?” I asked him. He explained that the difference among the

Fig. 5.1 A grade-8 bolt stacked on a grade-5 bolt. The grade 8 has six lines on top, and the grade 5 has three lines



grades is their strength. The higher the number, the stronger the bolt. Clear enough. But then try to understand why a grade-8 bolt has six lines on top and why a grade-5 bolt has three lines on top and why a grade-2 bolt has no lines on top (Fig. 5.1). Why does the number of lines equal the grade minus two? When I returned to Hokel's, I asked them, but no one there could tell me. Surprisingly, my question also stumped Jim.

As I looked online through webpages explaining the system of bolt markings to ambitious home-improvement types, I found a 2020 blog entry by Dan Karpan, who works as a sales representative and estimator at Portland Bolt and Manufacturing. I emailed him to see whether he knew the reason why a bolt has two fewer line markings than its grade. He didn't, but he hypothesized that it might have something to do with the fact that the marking with lines doesn't start until grade 3. Of course, then I wondered why the lines don't appear until grade 3. And when I looked for an image of the less common grade-3 bolt, I found that it is marked with two lines, not one, as it should have if it were to follow the minus-two rule. You can't win.

In preceding chapters, I've talked about the process and challenges of developing competences in a trade. One thing I've failed to argue in my own favor, though, is that sometimes my skilled-trade tribulations have arisen from arcane organizational systems, such as torch-tip numbers and bolt markings—particularly in the United States. By using the metric system, the rest of the world avoids the unnecessary complications and errors brought on by the US customary system.

Drill-Bit Sizes and Thread Counts

Here in the United States, metal fabrication loves the obscurity of a quirky measurement system. Take, for example, the system that governs drill-bit sizes. Drill bits with the smallest diameters are numbered, starting with 107, which equates to 0.0019 inch, and going to 1, which equates to 0.2280 inch. At 0.2340 inch, the numbers stop and the letters begin, running from A to Z. At 27/64 inch, the letters stop, and you use just the fraction size (Fig. 5.2). This system stems from 18th-century wire-gauge sizes. You only have to look at comments on the tools subreddit to understand that I’m not alone in lamenting the US system for drill bits:

What happens when we run out of letters and need more sizes? Will we just start making emoji bits?¹

The system is obscure because it stems from the needs machinists had over 300 years ago. And as one commenter pointed out on the machinists subreddit, it could be worse. The numbers, this commenter wrote,

are just the wire gauge size. Letter sizes are the same thing in reverse: Sometimes with gauge sizes once they hit “0” they keep adding more 0s so you end up with things that are “0000” gauge or whatever. Instead of doing that, they started using letters instead. If they hadn’t started using letters, then an “A” drill would be “0” gauge, “B” would be “00” gauge, etc. A letter “J” drill would therefore be a “0000000000” gauge drill. That would be silly.²

Oh yes, *that* would be silly.

Fig. 5.2 Drawers of drill bits, ordered from smallest on the top (the numbered bits), through the lettered bits, to the bits identified by their actual size in fractions of an inch



If you understand how drill bit sizes work in the United States, you'll have a better chance of success in creating a threaded hole for a bolt. This process, called tapping, will send you to a chart to find the size of the hole you'll need—and thus the drill-bit size you'll need—for a given bolt diameter and thread count. In US customary, we measure bolts in threads per inch. So you could have a $\frac{1}{4}$ –20 bolt, which would have a $\frac{1}{4}$ -inch diameter and 20 threads per inch. That's an example of a course thread. You could also have a $\frac{1}{4}$ –28 bolt, which would be a fine thread: 28 threads per inch. Whether you want course or fine threads makes a difference for the size of the hole you'd drill— $\frac{13}{64}$ for the course and $\frac{7}{32}$ for the fine. In the logical world of metric, you'd use thread pitch instead. You measure between the points of the threads in millimeters, so you could have an M8-1.0 bolt: eight millimeters in diameter with one millimeter of pitch. Added on to either US or metric is the bolt's length, such as a $\frac{1}{4}$ –20 $\times$ 3 (three inches in length) or a M8-1.0 $\times$ 20 (twenty millimeters in length).

When I first started hanging around Howe's with the idea of studying the written genres used and produced in skilled trades, I asked Jim about the drill-bit/tap size posters that he'd tacked and taped around the machining area of the shop. "How often do you go to these posters as a reference?" I asked, trying to determine the extent to which these texts played a role in his work. Jim, failing to recognize my utter lack of knowledge in this domain, launched into an explanation of drill-bit sizes and the complication of using a US drill bit for a metric diameter and thread-pitch bolt. Jim's answer to my question was—through no fault of his—far beyond my ZPD. He didn't know that I had no idea what tapping was, let alone why you might have to convert between US and metric.

I've tapped holes a few times at Howe's, but only manually. Jim taught me how to use a spring-loaded centering bit in the drill press to keep the tap perpendicular to the metal's surface. You turn the tap, "breaking" it every half turn or so. Breaking means turning it in the opposite direction to let the metal pieces you've sheared out fall into the tap's flutes. You also have to pay attention to whether you're using a starter tap or a plug tap or a bottoming tap and whether you're tapping a blind hole or a through hole. Learning how to drill and tap holes, even though I have only done it manually, with the tap handle and a lot of muscle, makes me feel like I've taken a step into a machinist community of practice.

Pipe Sizes and Schedules

If only the drill-bit measurements were the shop's sole arcany. Instead, a newcomer like me soon realizes that little about pipe size makes any sense to the uninitiated. When I started at Howe's, one of the first things I learned was that tubing and pipe are different. Like René Magritte suggested in his famous painting, you have to know what a pipe is and what it is not. Most important, pipe differs from tubing in that it has been tested for the internal pressure it can withstand. That's because its job is to carry gases and fluids. In contrast, tubing is structural. Also, pipe differs from tubing in how it's measured. It's measured by its ID (inner diameter); tubing is measured

by its OD (outer diameter). Customers will come in asking for pipe because that's the word they know but, usually, they need round tubing instead. Finding the tubing size they need is easy because tubing's OD measurements are exact. A 1 ¼-inch tube will be exactly 1 ¼ inch in diameter. But that's not the case with pipe.

Pipe works on another system, called nominal pipe size, or NPS, and it too is wacky. For example, a 1-inch, schedule 40 (more on schedule in a bit) pipe has neither a 1-inch ID nor a 1-inch OD. To find the dimensions of a 1-inch (or any other) pipe, you have to memorize the ID and OD or, more likely, consult a chart. A 1-inch, schedule 40 pipe's ID is 1.049 inch (quite close to 1-inch) and its OD is 1.315 inch. And complicating matters further, the mismatches between nominal and real ODs end at 14-inch pipe. From that size on, the nominal and the real ODs exactly match. I haven't cut nearly as much pipe as I have tubing, but in my limited experience, when someone comes into the shop looking for pipe and confirms that they want pipe, not tubing, they tend to know what size and schedule they're looking for. And I'm glad for it because I worry I'll steer them wrong.

And then there's the issue of the pipe's schedule. As you might have known or surmised, schedule refers to a pipe's wall thickness. For example, it's possible to have a 1-inch, schedule 40 pipe or a 1-inch, schedule 80 pipe. (The schedule numbers go higher, but schedule 40 and schedule 80 are what we keep in the shop.) The wall thickness and the ID of the two 1-inch pipes would differ, but their ODs would be the same. So why the word "schedule," and why the seemingly arbitrary numbers were questions I asked myself. The word "schedule" can mean, according to part c of the *Oxford English Dictionary*'s second entry for the noun, "any tabular or classified statement, esp. one arranged under headings prescribed by official authority."³ So it's a use of the word that's a little less common, but a similar sense shows up in classifications of drugs according to their medical use and their capacity for abuse, as in a schedule 1 drug. More important than the word's denotation is its use. It turns out that the numbers 40, 80, and so on, result from an equation:

$$\text{Schedule} = (1000) \times (P/S)$$

P equals the internal pressure of the pipe, and S equals the amount of stress the pipe can withstand, both measured in pounds per square inch, or psi.

In the shop, I haven't had any reason to deal with pipe measurements of even more complexity, but more complexity there is. For example, the schedules standard, extra heavy, and extra extra heavy also exist. Schedule 40 and schedule 80 are the same as standard and extra heavy, respectively, up to 8-inch pipe, but then their dimensions diverge. Oh, and stainless-steel pipe comes in schedules 5, 10, 40, and 80, schedules that either don't exist for regular steel pipe or that diverge at larger sizes. In any case, you can understand how this obscure knowledge, minutiae perhaps to some but also critical to the built world, can signal a shared group membership. As one commenter said in response to a question on the home improvement subreddit:

There's a reason plumbers make the big bucks. It's because their naming and measurement system is absolutely fucking insane. It's not a good reason, but it's a reason.⁴

Metal Gauges

The system of measuring the thickness of metal sheets, called gauge, constitutes another professional hazing of sorts. Gauges run backwards. The smaller the number, the thicker the metal sheet, so an 8-gauge steel sheet is thicker than an 18-gauge steel sheet. However, an 8-gauge sheet is not two times the thickness of a 16-gauge sheet. That would be too easy.

The metal gauge system that tradespeople use today has its roots in wire drawing, which was an industry as far back as 1200 in Germany and 1435 in England. In this process, metal was drawn through a cone-shaped hole in a plate, and then through another, and then through another. Each plate thus served as a die, or gauge. The number, like 22, referred to the number of gauges the metal had been pulled through. As the industry progressed, different gauge systems emerged but, eventually, with the increase in international commerce, the need for standardization became clear. In the 1880s, a “battle of the gauges” was fought, with different industries in different countries advocating for their own system.⁵ As a result, some standardization did occur, but even today the American Wire Gauge system differs from the Standard Wire Gauge system (i.e., the British system). However, the American Wire Gauge system equates to the system used for sheet metal, called the Brown and Sharpe sheet-metal gauge, which is our concern at Howe’s (as opposed to wire gauge).

Close to the shears, we keep two circular metal gauges⁶ hanging on a piece of wire; one is for ferrous metal, namely mild, galvanized, and stainless steel.⁷ The other metal gauge we use on nonferrous metal, which at Howe’s is mainly aluminum (Fig. 5.3). It took over a year into my time at Howe’s to realize that there are slight differences among metals assigned the same gauge number. For example, 11-gauge mild steel equals 0.1196 inch, or a bit under 1/8-inch. Galvanized 11-gauge is 0.1233 inch, just a smidge less than 1/8-inch. A stainless 11-gauge sheet is 0.125 inch, or exactly 1/8-inch. An aluminum 11-gauge sheet is 0.0907 inch, thinner than the others.

Jim doesn’t ask us to memorize these metal gauges, obviously. Some do stick in the mind, though, like 11-gauge being about 1/8-inch. But choosing the correct metal gauge and using it properly were two easy-to-master skills I learned right away. Knowing how to determine metal gauge also gives me something to do during any downtime at Howe’s. Besides cleaning up the shop, I can go through drops from the shears, measure the gauges of the leftover pieces, and write the gauge on the corner with a paint pen. The idea is to help the next person find what they need more quickly.

Converting Between US Customary and Metric

I vaguely remember back when I was a Catholic-school kid in northern Wisconsin, my school briefly emphasized the metric system. We learned the base-10 system and were told it would be critically important to all things science and engineering. These lessons stemmed from the Metric Conversion Act, passed in Congress in

Fig. 5.3 The gauges for ferrous and nonferrous metal that we keep near the drops of steel and galvanized steel



1975, and the United States Metric Board that it created. Forward-thinking members of Congress and President Gerald Ford wanted us kids to join the rest of the world in thinking about distances in kilometers, thinking about the temperature in Celsius, and thinking about our weights in kilos. Signing the bill in December 1975, Ford pointed out that our continued use of miles, Fahrenheit, and pounds had created “an island in a metric sea.”⁸ There was problem though: These forward-thinking leaders made conversion, in the words of the Act, “completely voluntary.”⁹

So then we pretty much forgot about it. Or at least, many of us did. President Ronald Reagan disbanded the Metric Board in 1982. And while some of us took up metric again in pursuit of careers in science and engineering, others like me thought about it only occasionally, like when running a 10-kilometer race. Now, working at Howe’s, I very occasionally see a metric technical drawing and then just as clearly recognize the additional cognitive effort, the potential for error, and the additional cost that the use of two systems creates for everyone in fabrication.

To be clear, because we’re a small metal shop, most of the fabrication jobs we get at Howe’s use US customary, which is—not to be pedantic—the more accurate name for what’s sometimes called the British Imperial system. (The two differ in terms of volume measurements.) In any case, Howe’s clients, local businesses and municipalities, mostly use the US system, so I haven’t had to do a lot of converting myself. I’ve seen Jim do it though, and it’s made me wonder how much time has been devoted to this unnecessary mathematical gymnastics.

A poll on the machinists subreddit asked US tradespeople whether they use metric or US in their workplaces. A majority used one or the other: 133 used metric, and 130 used US customary. Others used both—whether or not they wanted to. While 76

of 412 respondents said that they moved “fluidly” between the two systems, another 73 people said they converted between the two “begrudgingly.”¹⁰ One commenter wrote, “We convert most of the time but not because we want to. Look the metric system is better but most of my legacy analog measuring equipment is IN.”¹¹ One commenter described the tribulations of their then-current task:

I’m currently working on a mounting plate that’s 4.5”x8” that needs a 40 mm bore 1/2” deep located 75 mm from the edge with m10 tapped holes and two 1/4-20 set screws tangential to the bore. Please kill me.¹²

A few commenters pointed to mistakes that made the news, such as the case of the Mars Climate Orbiter. In 1998, an error from a failure to convert from US to metric famously destroyed the craft by sending it too deeply into the atmosphere of Mars.¹³

Trying to determine how much money US companies lose each year by working in or accommodating both systems would involve calculating losses from:

- International jobs lost because international companies assume US companies can’t or won’t work in metric.
- Buying and maintaining two sets of tool and part inventories.
- Mistakes caused by conversion errors.

These are just a few of the important costs that Pat Naughtin, managing director of Metrication Matters, delineated in his 2007 essay, “What Is the Cost of not Going Metric?” And since that time, the expense of maintaining this two-system limbo has continued to grow.¹⁴

Conclusion

So why does the United States cling to the past? Mostly, I suppose, because nothing—including the lack of fangs in the Metric Conversation Act—has forced its organizations to change, except for those companies like John Deere that need to operate within a global economy. And while I think that’s the main reason many tradespeople have stuck to US customary, I do think other sorts of benefits might be at work. I wonder whether US tradespeople remain fond of these arcane systems because they connect us to the past. The drill bit sizes and pipe schedules and metal gauges we use at Howe’s reflect the ways centuries of skilled tradespeople organized their work. Our arcane systems echo their processes and their achievements. Similarly, these arcane systems bind tradespeople together, highlighting in-groupness, much like a shared technical vocabulary does. Indeed, writing about machinists in 1950s Finland, Jussi Turtiainen and Ari Väänänen pointed out this role of shared language: “The occupational group defined itself using factory slang and trade names of tools and machines. The names of tools contained a long history of craftsmanship and the names of machines embodied modes of work.”¹⁵ At Howe’s, we’ve all learned to follow Jim’s lead in how we refer to the shop’s machines: The small press brake is the Enerpac; the older press brake is the Inoue. The main hydraulic ironworker is the

Peddinghaus. Like a shared vocabulary, I think the complexity of the US systems and the complications of converting them grant them a bit of cachet not possible with the logic of metric. These arcanities are like a password. Learning them—or beginning to—has granted me a bit more access into the club.

Notes

1. Smoke_Stack707, “What happens when.”
2. comfortably_pug, “It is simple.”
3. *Oxford English Dictionary*, 2023, s. v. “Schedule.”
4. Cecilkorik, “There’s a reason plumbers make the big bucks.”
5. Pöll, “The Story of the Gauge,” 580.
6. It has not escaped me that we use the word “gauge” both for the tool itself and the metal thickness—the “gauge” that it measures.
7. Stainless steel is, however, a bit complicated. It contains iron, which means technically it’s ferrous, but because it also contains chromium, it’s resistant to corrosion and is sometimes treated as nonferrous.
8. Rothman, “The Long.”
9. U. S. Congress. Metric Conversion Act of 1975.
10. Csmart01, “Metric or inch.”
11. nerve2030, “We convert most of the time.”
12. Keilik, “I’m currently working on a mounting plate.”
13. Hotz, “Mars Probe Lost Due to Simple Math Error.”
14. Naughtin, “What Is the Cost of not Going Metric?”
15. Turtiainen and Väinänen, “Men of Steel?” 456.

References

- Cecilkorik. “There’s a reason plumbers make the big bucks.” Reddit, November 30, 2015. <https://www.reddit.com/r/HomeImprovement/comments/3urraw/comment/cxhpad/>.
- comfortably_pug. “It is simple. They are just the wire gauge size.” Reddit, March 11, 2021. <https://www.reddit.com/r/Machinists/comments/m20ni4/comment/gqkzc3h/>.
- Csmart01. “Metric or inch.” Reddit, January 20, 2022. https://www.reddit.com/r/Machinists/comments/s8xg2u/metric_or_inch/.
- Hotz, Robert Lee. “Mars Probe Lost Due to Simple Math Error.” *Los Angeles Times*, October 1, 1999. <https://www.latimes.com/archives/la-xpm-1999-oct-01-mn-17288-story.html>.
- Keilik. “I’m currently working on a mounting plate.” Reddit, February 18, 2023. <https://www.reddit.com/r/Machinists/comments/114z9ts/comment/j914mg5/>.
- Naughtin, Pat. “What Is the Cost of not Going Metric?” *Nonpartisan Education Review* 3, no. 3 (2007). <https://nonpartisaneducation.org/Review/Essays/v3n3.htm>.
- nerve2030. “We convert most of the time but not because we want to.” Reddit, January 20, 2022. <https://www.reddit.com/r/Machinists/comments/s8xg2u/comment/htjdrea/>.
- Oxford English Dictionary*. 3rd ed. Oxford: Oxford University Press, 2024.
- Pöll, Johan S. “The Story of the Gauge.” *Anaesthesia* 54, no. 6 (1999): 575–581.
- Rothman, Lily. “The Long, Tortuous History of the U.S. and the Metric System.” *Time*, June 4, 2015. <https://time.com/3908881/history-us-metric-conversion/>.
- Smoke_Stack707. “What happens when we run out of letters and need more sizes?” Reddit, September 13, 2018. <https://www.reddit.com/r/Tools/comments/9fhtmn/comment/e5wn4z4/>.

- Turtiainen, Jussi, and Ari Väänänen. "Men of Steel? The Masculinity of Metal Industry Workers in Finland after World War II." *Journal of Social History* 46, no. 2 (2012): 449–472.
- U. S. Congress. House. Metric Conversion Act of 1975 [Public Law 94–168], <https://www.govinfo.gov/content/pkg/COMPS-1851/pdf/COMPS-1851.pdf>.

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Chapter 6

Learning from Mistakes



Abstract In this chapter I categorize and describe my many mistakes. I begin by describing and exemplifying what I call dope-slap mistakes, embarrassing errors that even someone walking into the shop from off the street would likely have avoided. I follow up with communication mistakes, gaffs brought on by both written and spoken miscommunications. Perception mistakes, I argue, stem from an insufficient ability to perceive with expert senses, such as failing to recognize a weld defect. Knowledge-of-what mistakes arise from insufficient conceptual knowledge, such as my lack of knowledge about tungsten size and the ways it impacts tig welding. Knowledge-of-how mistakes, on the other hand, relate to procedural knowledge—how to do something. My days at Howe’s would overflow with such mistakes if I did not have recourse to Jim and my more-expert coworkers.

Even though I try not to compare myself to the people I work with, I feel like I’ve made a lot more mistakes than any of my coworkers. My brain tells me that can’t be true; my full-time coworkers put in more hours than I do. They’d have to have made as many mistakes as I have. But my gut tells me it is true—that I make more mistakes because I don’t readily learn the shop’s conceptual and procedural knowledge. In any case, when I look through my daily journal entries, I relive the frustration and embarrassment I felt with each mistake. These entries lamenting my errors have added up during my years at Howe’s.

Research on workplace mistakes has shown that businesses tend to exhibit what’s been called the “error paradox.”¹ On one hand, as education researchers Andreas Rausch, Jürgen Seifried, and Christian Harteis pointed out, errors increase costs and lower customer satisfaction. Moreover, in a fabrication shop, errors can also damage equipment or cause injuries. On the other hand, fastidiously guarding against errors can hinder productivity and employee learning.² In a small workplace like Howe’s, we manage this paradox on a microlevel. Unlike in a large production-focused shop, Jim daily considers the level of difficulty of each client’s project and checks it against the competences of each employee. Adam does the most difficult projects because he has the greatest depth and breadth of expertise and requires almost no babysitting. As my learning has progressed, I’ve been given more complex projects, and I’ve

been expected to complete them more efficiently and with less help. But even as I have developed sufficient breadth and depth of competence to fabricate some items myself, I've made many, many, *many* mistakes of various types along the way. I've already recounted a few, such as my errors creating the acute angles of the bank drive-through sign (Chapter 4). In this chapter, I analyze my mistakes, attempting to categorize them. My goal here is to help other learners understand—and perhaps make peace with—the errors they might make along the way to competences.

Dope-Slap Mistakes

I'm embarrassed to say that I've made mistakes that a person completely new to the shop—a true newcomer—could likely have avoided, but for whatever reason, I did not. Here's an example of what I mean. Jim told me to use an old mig welder that typically sits unnoticed and unused in a cluster of spot welders and Pullmax dies. Before I could use it, I had to disentangle it from the other items that hemmed it in and then use compressed air to blow the dust and grime from its outside and inside. Then, I carefully threaded a new spool of wire through the hose to the gun like I'd learned to do in welding school. If you've installed the new spool correctly, when you press the gun's trigger, the wire eventually appears at the tip. But I couldn't get the gun to work. I pressed the trigger, but no wire. I checked the wire tension of the roller that pushes the wire through the hose to the gun. It seemed fine. Then, my coworker Jessie walked by and saw right away what the problem was: The gun wasn't plugged into the welding machine, so it wasn't getting any power. Jessie certainly was no novice to welding, but I think even someone who had never touched a mig welder before would have noticed the plug dangling there. I think of such an error as a dope-slap mistake. Its cause is obvious.

Even worse are the days when I make a dope-slap mistake first thing because then it haunts me the rest of the day. That happened the day Jim asked me to mig weld the bottom back on to a rather cheap, thin-walled safe. The customer had cut the bottom out of the safe because they had forgotten the combination. I used a flapper disc to put a slight bevel on the square hole's edges and on the cut-out square itself. Jim told me to step weld the thin metal, meaning you weld about an inch at a time and distribute those short weld beads around the piece. Doing this, you distribute the heat and reduce warping. Jim also gave me some super-heavy heat sinks to place under the thin steel of the safe's bottom. These would capture some of the heat from the welds and further reduce warping. I had to use long-armed clamps that could reach to the back of the safe to hold the heat sinks under the square of steel I was welding back into place.

Before I started welding, I made a couple practice welds on a piece of scrap to see what the welds looked like. Like every other time I'd used the little Lincoln 100 welder, my beads looked too convex and wormy, no matter how I adjusted the wire speed and voltage. I decided to find Jim to ask whether the welds I was getting with my settings would be good enough to do the job. But when I took off to find Jim,

I left the mig gun with the trigger side down. When I returned with Jim in tow, we found a nest of hot wire that had spooled out of the gun. I'd wasted at least 20 feet of it.

I felt my face getting red, and I spat out that I would of course pay for a new wire spool to replace what I'd wasted. Jim told me that he didn't want me to pay for it but, given that we were talking about my mistakes, I should know that I'd forgotten to turn off the argon on the welder that I'd used the day before. I had kept telling myself over and over to turn off the gas as I worked on my lampshades project, but just after I'd decided to quit for the day, I changed my mind and made one last weld. And then I promptly forgot to turn off the argon. Knowing that I'd made wasteful mistakes two days in a row made me want to solve the problem with money. But like all other times I've generated waste or caused damage, Jim told me that he'd rather fire me than take my money. "You're going to have mistakes," he told me later when I asked him about this incident and other times I'd made costly errors. The losses, he said, are the cost of developing an employee's expertise, "part of being in business," as he put it. Although sometimes I think I'd prefer to simply assuage my guilt with money, I appreciate his wisdom-based expertise.

These dope-slap mistakes hurt because their causes are obvious. Of course you check to see that the mig gun is plugged in. Of course you don't lay the mig gun with the trigger pushing against the table. It's the common-sense element that makes these errors embarrassing. And worse, they're discouraging because they signal that you're no more competent than a person who walks in off the street.

But obviousness exists on a spectrum. Sometimes, the causes of my mistakes stem from my lack of a background in mechanics. I wrote earlier about how Jim grew up steeped in repair work and surrounded by tools. I didn't. That's part of the reason why, as I discussed in Chapter 2, I failed to recognize that inside the Craftsman scroll saw lay a rubber bellows that would melt with the heat of a tig weld. I destroyed the bellows, which as it turned out was a discontinued part. This mistake—not recognizing that scroll saws have at least one rubber component inside them—is another variety of dope-slap mistake in that it's obvious after the fact. Without that knowledge of scroll saws, I generated a problem that would take over a year to solve (Fig. 6.1). Of course, the scroll-saw fiasco also involved an even more egregious dope-slap mistake: I should have noted the rubber hose running from the top of the metal casing to the front of the saw. That is, I should have at least thought to remove the rubber tubing, but I didn't. Thus, I complicated the repair further because Jim had to repair the tubing in addition to the bellows.

Along with my quite specific lack of familiarity with scroll saws, my general lack of experience with tools and machines, while becoming less and less of a problem the longer I work at Howe's, has also contributed to my mistakes. Just after I began to work at Howe's, Jim assigned to me the repair of a large tractor hitch (Fig. 6.2). The hitch was worn away all around, but particularly on the front where friction had eaten away the metal. Jim wanted me to build up the hitch by stick welding bead after bead. But to save some time, he had me oxyacetylene cut a disc that would keep me from having to lay as many layers of weld beads as I otherwise would have had to do. I began welding in the disc, enveloping it in weld beads. But when Jim came

Fig. 6.1 Jim assembling the repaired scroll saw



by my table to check on me, he pointed out that the disc was sitting too high up on the hitch. Because it sat higher than the rest of the hitch, it wouldn't fit below the tractor anymore. The sticking-out disc would get in the way.

Fig. 6.2 Nearly finished hitch, built-up again with a steel disc and with stick welds



Because I hadn't yet learned how to carbon-arc gouge, Jim had to spend his time doing it for me. As he erased my welds, I felt myself getting hot with embarrassment yet again. After he'd finished, I had to grind out all the carbon, prolonging the project even more. The lesson, Jim told me after he'd finished carbon-arcing, was to check your fit before you weld. Certainly, I made my mistake worse by completely welding the disc in rather than tacking it in and checking the fit. However, my mistake stemmed from a failure to consider fit-up at all, and this failure arose, at least in part, from my lack of familiarity with tractors and their hitches. As I had welded the disc onto the hitch, it didn't occur to me to ask about how it would fit on the tractor. Since then, I've tried put this lesson into practice by checking fit up, checking squareness or angle correctness, and then tacking pieces together rather than simply charging ahead with welds. In this case, I got the instruction I needed after I made the mistake.

Another time, also right after I'd started at Howe's, I chipped a die while using the ironworker. These dies aren't cheap. A quick glance online for an Enterpac 9/16 punch and die set says the current price is \$278. That day, I was punching 100 reinforcement pieces for jersey barricades that would eventually sit on Interstate 80. While I had sufficiently tightened the nuts on the ironworker's die holder, I didn't recognize that repeatedly punching 7/8-inch holes into 1/4-inch steel with over 17 tons of force would eventually loosen the nuts and bolts holding the punch and die in place. After about 50 holes, the ironworker made a strange sound. Jim came down from the office to see what had happened. He looked at the die, saw the chip, and then checked the nuts on the die holder, which were, of course, loose. Once again, I offered to pay for my expensive error. But rather than taking my money, Jim demonstrated how to slip a piece of tubing or pipe over a wrench to get more torque as you tighten nuts on machines like the ironworker and, as important, to use the extender again to loosen them. And he told me to check them every so often to make sure they're still tight—something he wouldn't have needed to say to someone who had been around nuts and bolts more than I had before I found Howe's.

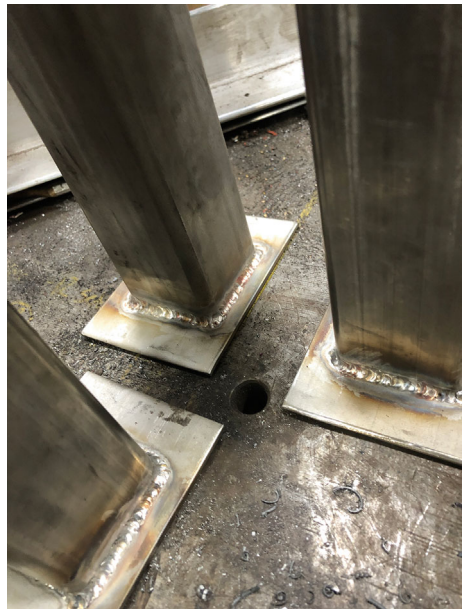
I've also made dope-slap mistakes when I've concentrated so much on all the variables involved in doing a task correctly that the easy steps slipped by me, as if crowded out by all the other input. Researchers call this phenomenon cognitive overload, and it happens when someone with novice-level or advanced-beginner knowledge of the domain, such as tig welding stainless-steel tubing, encounters a complex task. As Faizal A. Haji and colleagues wrote in their study of medical students learning lumbar puncture, "Novices may not have sufficient cognitive resources to meet the information-processing demands associated with these complex learning tasks."³ One clear and incredibly embarrassing example of cognitive overload occurred when Jim assigned a table-leg-extension project to me. These leg extensions were made from stainless square tubing. My job was to weld rectangular caps onto each end. What's important to know about stainless is that it's more difficult to weld than regular steel. If you put too much heat into it, you burn out the anticorrosive properties, such as chromium and nickel, and the metal goes from shiny to dull gray. You also run the risk of sugaring, or oxidation, on the back of a weld. Stainless is susceptible to sugaring because it oxidizes quickly at elevated temperatures. Using a heat sink, such as a piece of aluminum or copper, helps to dissipate the heat and mitigate the

risk. So as I welded, I was under pressure; I had to establish the puddle but then get moving so as not to keep the heat in one location for long. I also had to keep in mind that I needed to leave a small gap somewhere on one of the tubing's ends so that the hot air could escape. I would wait until the next day, when the welds had cooled, to seal up the gap. Finally, I had to make sure that I securely clamped the rectangle caps to the table to minimize the warping that would occur as I put heat into the metal.

I finished the job, thinking that my welds looked pretty good (Fig. 6.3). They were rainbow colored. A perfectly unoxidized weld on stainless will look just like stainless—shiny and silver. But that result is difficult to achieve without a gas lens on the tig gun to more thoroughly diffuse the protective argon. A weld with a bit of oxidation will be straw colored. A weld with a bit more oxidation will create a rainbow—sometimes deep blue and magenta and really beautiful. I was using just a regular tig-torch set-up, and my rainbow welds were acceptable. When I returned to work the next day to weld the little gaps I'd left on each extension, I saw my dope-slap mistake: On one leg, I'd welded the rectangle caps to the tubing in different directions. That is, I'd welded all around the tubing without noticing that one cap faced the wrong direction.

To fix my mistake, I had to carefully cut off the errant rectangle to save the stainless (and expensive) tubing, and then I had to grind off the rest of the rectangle until I could see the line of fabrication. All this took over an hour. I wrote in my journal that day, "I really don't know why I keep doing dumb things. And I'm not just beating myself up. I truly am wondering why." Looking back, I think that "dumb" mistake arose because, like other learners who have not yet routinized relevant knowledge, I

Fig. 6.3 Finished table-leg extensions



skipped an easy step—the fit up—while occupied with a barrage of other concerns. Unlike someone with expert-level knowledge of welding stainless, I struggled to control all elements of the task, especially travel speed. When nothing in your task is yet routinized, easy steps can slip through the cracks.

Communication Mistakes

Plenty of researchers have examined the mistakes, even catastrophes, that occur when communication breaks down. Risk communication researcher Carolyn Boiarsky, for example, examined how writers trying to communicate risk or crisis failed to consider the context in which their audience would read the message. Her book *Risk Communication and Miscommunication* examined the communication involved in such events as the Chicago flood, the Columbia accident, and the British Petroleum oil spill. She wrote about the communication leading up to these tragedies, “Readers might have recognized the problems and the potential for disaster if the messages had been clearer, the material had been organized in another pattern, the tone had been different, the focus had been on another aspect, or additional information had been included.”⁴ Communication mistakes at Howe’s are far less dramatic and tragic than those Boiarsky covered, but they nonetheless waste time and money.

I wasted money the day Jim told me to cut “five and a half” of a $6 \times 4 \times \frac{1}{2}$ -inch stick of rectangular tubing as he hurried across the shop to answer the phone. He didn’t say inches or feet and, without asking, I used the hoist to move the heavy stick to the band saw. I cut 5 $\frac{1}{2}$ feet. As I learned when he returned from the long phone call, he wanted 5 $\frac{1}{2}$ inches. Although he didn’t yell, I could tell he was upset. A 20-foot stick of that rec tubing costs roughly a thousand dollars. In cutting a big chunk off, I’d decreased the stick’s utility. What if someone came in wanting 16 feet of it?

The obvious communication error of failing to say and failing to ask for the unit of measure was one problem. But another, more interesting, communication problem fed this mistake: the failure to communicate and to ask for an explanation of what we were making. I discussed such a failure of intersubjectivity in Chapter 4, when I described the mismatch between Jim’s idea for a cold-cut saw stop and my own piecemeal understanding of what he envisioned. As Stephen Billett wrote, “Learners also need to be able to visualize and understand the desired outcomes of their work in order to develop goals for performance.”⁵ Jim had in his mind what the 5 $\frac{1}{2}$ -inch piece of rec tubing would become: a casing for a pulley. I didn’t know what he was working on, so when I heard 5 $\frac{1}{2}$, I assumed (yes, I know the saying about that word), given the large size and wall thickness of the tubing, that he wanted feet, not inches. Because I could tell he was harried from having too much to do, I didn’t want to bother him with questions, as I should have.

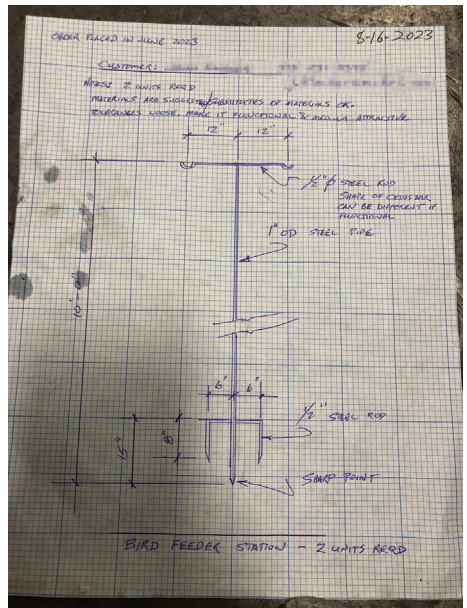
Mistakes found in written communication also complicate trades work. Because Howe’s specializes in one-off jobs, as opposed to production, we employees interact with a lot of by-hand technical drawings. These drawings range in sophistication from

precisely rendered drawings like the one in Fig. 6.4 to hastily drawn sketches. We also, of course, receive computer-generated technical drawings from other businesses or researchers at the local university. No matter the level of sophistication, these drawings usually raise some questions and require discussion with the client. For example, Jim talked to the customer who wanted us to build two 10-foot shepherd’s hooks for bird feeders, focusing on the length of the spikes that would go into the ground. The customer’s drawing showed just 8-inch and 15-inch spikes, but during his conversation, Jim convinced the customer they’d need to have more metal underground to ensure that the 10-foot poles would remain upright. Indeed, Jim often modifies client’s drawings as he learns through these conversations the customer’s aim and the fabricated item’s purpose and context.

Sometimes, technical drawings that we receive omit critical information, driving us to call the client upon discovering the flaw. For example, I was once ready to cut a piece of sheet metal with an angle cut out from one side to the other when I realized that the customer’s drawing didn’t indicate how wide the piece was supposed to be. At first, I thought I could use my tenth-grade geometry to figure it out from the other dimensions, but Jim explained that without the length of the angled cut, we couldn’t know the width. We’d need to call the client.

In short, there’s much potential for miscommunication—both oral and written—at a busy job shop, where workers might not be privy to the end goal of each project and where conversations and drawings intermingle.

Fig. 6.4 A customer’s quite precise drawing for a shepherd’s hook



Perception Mistakes

In her book *Visual Intelligence*, Amy E. Herman wrote about the ability to perceive what others miss, “the opportunity, the solution, the warning signs, the quickest way, the way out, the win.”⁶ She argued that we can train ourselves to perceive what’s not readily apparent and thus understand the world in new ways. In making this argument, she cited Leonardo da Vinci, who called this ability “saper vedere,” which means “knowing how to see.”⁷ Similarly, I argued in my last book that learning a trade like welding requires learning how to perceive as an expert does. Developing expert perception, I argued, involves not just developing your ability to see, but also to develop your ability to hear, smell, touch, and taste.⁸ Trade expertise arises, in part, from multisensory perception at an expert level.

A person who has developed expert perception will recognize the flaws in their work. For example, when Jim and I were working at the Boone and Scenic Valley railroad, we spliced together flat bar to make rails for the pedal cars. I had mainly welded the smaller brackets that held the rails to the concrete (Fig. 6.5, left), but Jim let me do a few of the splices—the place where two pieces of flat bar came together. I beveled the ends of both pieces and set about my multipass welds on either side, as I discussed in Chapter 3. After I’d finished, Jim pointed out that my splice wasn’t straight, which in turn meant that the rail wasn’t straight (Fig. 6.5, right). I’d been so concerned with evenly filling in the double V-groove of the splice and not weaving the electrode back and forth excessively that I had once again failed to check my fit-up. In fact, I hadn’t perceived that the splice wasn’t straight until Jim pointed it out. Once he did, the mistake was obvious. Jim had to cut through my weld and redo the splice, which was, like always, embarrassing.

Through one-to-one scaffolded interactions, Jim has taught me how to perceive more expertly. Early in my work at Howe’s, Jim assigned a fence-pole project to me. My job was to use a weld positioner—a sort of turntable for welding around tubing or pipe—to weld fence poles onto square bases. After I’d welded about 15 of the poles, struggling to keep the electrode at the correct angle while spinning the pole with the positioner, Jim came over to check on me. He said that my welds had undercut, a spot where the base metal has melted away but has not been filled adequately with filler metal (Fig. 6.6). A weld defect, undercut weakens the joint, leaving it prone to failure. When Jim pointed out the groove at the top of my welds, he highlighted it for me, differentiating it from the rest of the environment—the weld face, the pole, the base, the slag I’d partially chipped away. Then, he coded that phenomenon, imbuing it with meaning. In this case, he told me the name of the defect, undercut, and then explained why it was a problem that required fixing.

Motivated by the need to make me capable of welding 25 more fence poles and of fixing the ones I’d already messed up, Jim decided to devote some time to scaffolding my learning. First, he demonstrated how to do the weld successfully, describing as he went along how he kept the electrode close to the joint and let the weld puddle fill in the entire joint. After he’d highlighted and coded what he’d just demonstrated, he told me that it was now my turn; he’d observe me and give me feedback as I



Fig. 6.5 A bracket on the new pedal-car rails (left) and my double V-groove splice that wasn't straight (right)

Fig. 6.6 One of my stick welds with undercut around a fence pole



tried to coordinate my hands and arms and my foot controlling the speed of the weld positioner's turntable. As he did, he used my iPhone to videorecord my weld. With the video, the process of highlighting and coding happened again as he pointed out the flashes that occasionally burst from the space between the electrode and the joint. Those flashes, he said, occurred when I moved the electrode too far away from the joint, which is called long-arcing. Creating a too-long arc increases the voltage, generates more heat, and leaves the weld susceptible to undercut, in addition to other problems. Indeed, because I had long arced as I welded these fence poles, I had also on one occasion generated enough heat to blow through the tubing.

Of course, a lot of deliberate practice is necessary for a task that brings an extra variable, like using your foot to control a weld positioner. And as anyone who has

stick welded knows, people with novice- and advanced-beginner-level knowledge need practice to avoid affixing the electrode to the work piece. Sticking the stick electrode generates another problem: detaching it without losing too much of the flux. Even though I needed more deliberative practice, with Jim's instruction, especially his use of a video to demonstrate what I was doing wrong, I was better able to recognize a critical flaw in my work.

Knowledge-of-What Mistakes

Just as developing the ability to perceive expertly comes through continuous learning and practice, developing conceptual knowledge—knowledge of what, as opposed to how—requires sustained effort as well. Some of my mistakes at Howe's have stemmed from insufficient conceptual knowledge. For example, one day when I was working on the weeks-long lampshade project, I was trying to weld together the two ends of a ring that I had rolled on one of Jim's rolling machines (Fig. 6.7). When I started tig welding, I immediately blew through the metal that I'd beveled to make room for a weld. I must have yelled, because Jim hustled over to see what had happened. He looked at my tig-torch set-up and told me that I was using a way-too-big tungsten electrode for the thickness—or rather thinness—of my stainless-steel ring. I knew that Adam and Jessie sometimes switched out the tungsten when they tig welded, but I didn't know why.

Fig. 6.7 One of the stainless rings that I rolled and tig welded for the lampshade-frame project



Jim explained that you choose a tungsten size according to the thickness of the material that you're welding. So if you're welding something thin, you might use a 1/16-inch tungsten. If you're welding something thicker, you'd use a 3/32- or a 1/8-inch tungsten. He said that that tungsten needs to heat up, and by the time a thick tungsten heats up, it can blow a hole in thin metal. Jim replaced the 1/8-inch tungsten in the torch with a 1/16-inch tungsten. He also told me that my welding school should have taught me this. In my teachers' defense, I can understand why we students didn't practice with differently sized tungstens. Our teachers wanted us to practice laying beads in different positions—flat, horizontal, vertical—on different metals—steel, stainless, and aluminum. It's difficult enough to lay a decently consistent bead when you're just starting out, let alone switching tungstens to practice on super thin metal, such as a soda can. For class, we students were told to buy 3/32-inch tungstens, and we used those to practice on 1/8-inch and 1/4-inch coupons. Even so, although I understand why we didn't switch out tungstens in class, I think it would have been helpful to impart the conceptual knowledge that tungstens come in different sizes for different metal thicknesses. Indeed, as I continued tig welding at Howe's, I developed an interest in tungsten—not just the different sizes but also the different types. The difference among the types lies in which elements are added to the tungsten and in what quantities. Jim uses thoriated tungsten almost exclusively, but many people switch types for different purposes. I started using 2% lanthanated tungsten because it works with both AC and DC welding and because it works across metals. Looking back, I cringe to recall that I hadn't yet developed this basic conceptual knowledge about tungsten size when I started to work at Howe's.

Developing conceptual knowledge in a metal shop also involves developing an understanding of how the machines in the shop work. As Jim said of my coworker who had to tear apart the box-and-pan brake to dislodge what he was working on, "It's like, dude, you got to think these things through because know your machine. What can it do?" As a novice, you use machines like the box-and-pan without understanding their mechanics or their settings. You use them to repeat the actions that a more expert person has demonstrated, doing what they've told you to do without understanding why. But as you advance toward competence, you develop conceptual knowledge of, for example, the four types of mig welding: short circuit, globular, spray arc, and pulsed spray transfer. You'll also develop conceptual knowledge of what's going on inside the shop's machines, the gears that drive the drill press, for example, as well as competent perception of the sound the machine makes if it's not in gear. A lack of conceptual knowledge—combined with a failure to ask for expert help—can lead to potentially costly mistakes.

My worst day ever at Howe's—at least so far—involved breaking not one but two ironworkers—the main one and the back-up. Well, to be fair, I was likely the person who happened to be using the main ironworker when the switch on the pedal shorted out. When I pressed the pedal to punch a piece of steel, the punch stopped midway, and the machine turned off. After testing the wires from the pedal, which were attached via a cable to the ironworker, Jim got the machine to turn on, but the punch and blade wouldn't move because, Jim thought, a wire to the pedal was bad. So the ironworker we use all the time died (for a time) on my watch. Months later,

during a conversation about breaking things, Zach told me that the ironworker had been acting funny for weeks; I just happened to be the unlucky one who was using it when the wire finally went bad.

But as if that weren't enough, about 30 minutes after the ironworker died, I actually made a mistake that broke the shaft on the back-up ironworker that Jim keeps tucked away at the side of the shop. An ironworker has a shaft that comes down and presses a punch through the workpiece and into a die, but in the ironworkers at Howe's, that shaft doesn't come into direct contact with the punch. Because Jim mixes punches and machines when he buys used punches and dies at auctions, we have to insert a metal slug between the shaft and the punch to bridge the gap. If you forget the slug, the punch will come down farther and embed itself into the threads on the nut that holds the punch.

After the drama of the main ironworker, I was a little shaken up. Also, I had never used the back-up ironworker before. When I went to set it up, it seemed to me that there wasn't enough space for a slug between the top of the punch and the shaft, so I assumed (again, that word) that this ironworker didn't need a slug. And that assumption generated my mistake. Sure enough, the shaft embedded itself into the retainer nut, making both unusable. Jim wasn't so concerned about the nut, but he was concerned about the damaged shaft because now, with the back-up ironworker out of commission, we had no easy way to cut flat bar. This being a metal shop, that was a big problem. Thankfully, Jim could fix even this horror show of an error. He machined the shaft on a lathe until the implanted metal was gone. But my mistake cost him time that he should have spent doing something productive.

About a year after my worst day at Howe's, my coworker Regen told me that she had forgotten to put a slug in the ironworker when she set up to use the punch. At the very least, I was able to tell her that she's in excellent company, as I had done the same thing. I've noticed this sort of empathy among my coworkers. When I lament yet another mistake, my coworkers are quick to bounce back with a "You should see what I did" story to make me feel like I'm not alone. These shows of empathy serve as motivational scaffolding, those verbal strategies that encourage us to continue in our efforts, despite our mistakes.

Knowledge-of-How Mistakes

When you learn in a place where embodied knowledge drives success, you're bound to make mistakes that stem from a lack of procedural knowledge, knowledge of how. I've made hundreds. Seriously. Working underneath a trailer for the first time, I had to do vertical-up stick welds while lying on my back. It was difficult to get my hood positioned so that I could see, and it was difficult to keep my weld beads consistent when I had nothing to rest my arms on to hold them steady. When Jim came by to check on my progress, he told me my welds weren't super pretty, but they'd at least hold. My not-so-pretty welds arose in part from my lack of know-how, such as how to use a hoist to make more head room underneath a trailer and how to use a bolster

to steady my arms. I also needed more deliberative practice—more time spent doing and assessing vertical-up welds in general and in tight spaces in particular.

Sometimes mistakes arise when you try to operate within your ZPD without any expert support. One day just after Zach and I had been hired, I helped Zach build a ramp for a trailer. He'd already cut the angle iron for it and was laying it out when I arrived. I helped him to space out the rungs, and we tacked it together. Zach wasn't sure whether we should start welding without Jim's say so, but feeling uncharacteristically confident, I told him that we could do it. My welds looked good; they were fairly consistent and flat instead of wormy. I got cocky, though, and decided that I was going to try to weld one of the corners on the last rung. It was a tight fit to do the vertical-up weld, and I immediately goofed it up. Rather than sitting flat against the T-joint angle, my weld bulged out at the bottom, as if it had, in the words of a welding teacher I interviewed for my last book, a beer belly.⁹ When Jim came by, he filled in my ugly weld and made it look passable. Then, he showed me how you can bend a stick electrode to fit in a tight spot and maintain the travel angle that you want. Later, I realized that I also could have simply flipped the ramp on its side to position the joint for a horizontal instead of a vertical weld. Because I was champing at the bit to push my procedural knowledge rather than wait for the scaffolding I clearly needed, I made a (thankfully fixable) mistake.

Development of procedural knowledge requires—at least in a welding and fabrication shop—continual opportunities for scaffolded learning and deliberative practice. Even with these opportunities, people learning on the job and thus facing all the limitations of workplace learning will make numerous knowledge-of-how mistakes because they will continually encounter tasks that demand greater levels of competence than they possess.

Conclusion

Mistakes are inevitable, especially when learning in a workplace. In this chapter, I've attempted to categorize my mistakes, detailing dope-slap mistakes, communication mistakes, perception mistakes, knowledge-of-what mistakes, and knowledge-of-how mistakes. My goal here has been to help other learners, particularly other learners of skilled trades, understand the blunders and oversights that will surely arise as they navigate the path of developing their competences while getting things done in the workplace.

I hope, too, that this chapter reveals my empathy with other learners as they grapple with the frustration and embarrassment that accompany mistakes, unavoidable and natural as mistakes are. As Mark H. Anshel wrote in his book *In Praise of Failure*, "We need to interpret our inevitable less-than-perfect performance outcomes as what separates humans from machines. Errors give us our humanity and fulfill our inherent need to achieve."¹⁰ I love this idea that mistakes constitute an integral part of humanity's inquisitiveness. But it's difficult to perceive mistakes in this way when you've used an entire morning at work to build a fixture for an aluminum-box

project, only to find that your fixture isn't square and that you have to grind out your welds.

As I've noted in this chapter, when embarrassment and frustration arise, it helps to have coworkers who readily offer the solace of empathy. In a study of communication after embarrassing incidents, Sandra Metts and William Cupach found that observers of the embarrassment offered empathy 19% of the time "to de-individuate the embarrassed person" and remind them that the incident "is not unique" and "happens to others."¹¹ Empathy was the second-most frequent observer response to an embarrassing incident, after support, such as placing a hand on the embarrassed person's shoulder. As I noted in this chapter, my coworkers have supplied me with empathy, a type of motivational scaffolding, numerous times. And this kindness is apparent too in online forums devoted to trades. For example, when an apprentice steam-fitter bemoaned their daily "stuuuupid" mistakes on the skilled trades subreddit,¹² more-expert others responded with empathy, sympathy, and optimism:

- You'll get the hang of it, took me a few years to get my shit together.¹³
- Our trade covers such a broad spectrum of piping applications and systems. It takes time to master our craft.¹⁴
- You learn by fucking up.¹⁵

Nevertheless, workplaces can do more to acknowledge the inevitability of mistakes in learning, particularly in shops where projects and the concomitant problems they pose change frequently. Workplaces that fail to acknowledge the certainty of mistakes risk generating a culture of turn over, where tradespeople leave because they feel demoralized. Workplaces that don't acknowledge that mistakes are inescapable also can inhibit people's willingness to express and try potential solutions. Shops like Howe's run on creativity-based expertise—that ability to build upon earlier solutions to similar problems. Learners in such workplaces strive to develop the ability to tackle novel problems creatively, but lacking sufficient conceptual and procedural knowledge, workers like me are bound to make mistakes as we stumble toward creative, but not necessarily viable, solutions. All workplaces—but especially those that consistently expect creative problem solving—should expect and even welcome mistakes.

Notes

1. Weingardt, *Fehler Zeichnen uns Aus*.
2. Rausch, Seifried, and Harteis, "Emotions, Coping," 374.
3. Haji et al., "Thrive or Overload?" 956.
4. Boiarsky, *Risk Communication and Miscommunication*, 4.
5. Billett, *Learning in the Workplace*, 88.
6. Herman, *Visual Intelligence*, 5.
7. Herman, *Visual Intelligence*, 6.
8. Mackiewicz, *Welding Technical Communication*, 34.
9. Mackiewicz, *Welding Technical Communication*, 91.

10. Anshel, *In Praise of Failure*, x.
11. Metts and Cupach, "Situational Influence," 157.
12. glenthedog, "Am i ever gonna stop making silly mistakes?"
13. The_Snailman, "Stop and think."
14. Hippyfitter, "You'll still be learning."
15. randygiesinger, "Just some food for thought."

References

- Anshel, Mark H. *In Praise of Failure: The Value of Overcoming Mistakes in Sports and in Life*. Lanham, MD: Rowman & Littlefield, 2016.
- Billett, Stephen. *Learning in the Workplace: Strategies for Effective Practice*. New York: Routledge, 2001.
- Boiarsky, Carolyn R. *Risk Communication and Miscommunication: Case Studies in Science, Technology, Engineering, Government, and Community Organizations*. Denver: University Press of Colorado, 2016.
- glenthedog. "Am i ever gonna stop making silly mistakes?" Reddit, September 16, 2019. https://www.reddit.com/r/skilledtrades/comments/d59txl/am_i_ever_gonna_stop_making_silly_mistakes/?rdt=56353.
- Haji, Faizal A., Jeffrey J. H. Cheung, Nicole Woods, Glenn Regehr, Sandrine de Ribaupierre, and Adam Dubrowski. "Thrive or Overload? The Effect of Task Complexity on Novices' Simulation-Based Learning." *Medical Education* 50, no. 9 (2016): 955–968.
- Herman, Amy E. *Visual Intelligence: Sharpen Your Perception, Change Your Life*. New York: HarperOne, 2016.
- HippyFitter. "You'll still be learning once you turn out." Reddit, October 10, 2019. <https://www.reddit.com/r/skilledtrades/comments/d59txl/comment/f36oni4/>.
- Mackiewicz, Jo. *Welding Technical Communication: Teaching and Learning Embodied Knowledge*. Albany, NY: State University of New York Press, 2022.
- Metts, Sandra, and William R. Cupach. "Situational Influence on the Use of Remedial Strategies in Embarrassing Predicaments." *Communication Monographs* 56, no. 2 (1989): 151–162.
- randygiesinger. "Just some food for thought: You learn by fucking up." Reddit, September 17, 2019. <https://www.reddit.com/r/skilledtrades/comments/d59txl/comment/f0lgxer/>.
- Rausch, Andreas, Jürgen Seifried, and Christian Harteis. "Emotions, Coping and Learning in Error Situations in the Workplace." *Journal of Workplace Learning* 29, no. 5 (2017): 374–393.
- The_Snailman. "Stop and think about the possible outcomes." Reddit, September 17, 2019. <https://www.reddit.com/r/skilledtrades/comments/d59txl/comment/f0lw3fo/>.
- Weingardt, Martin. *Fehler Zeichnen uns Aus: Transdisziplinäre Grundlagen zur Theorie und Produktivität des Fehlers in Schule und Arbeitswelt*. Julius Klinkhardt, 2004.

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Chapter 7

Learning Health and Safety (and Danger)



Abstract Fabrication work, welding in particular, exposes workers to a long list of potential injuries and chronic health problems. The potential injuries include burns, cuts, and crushed fingers and toes. The chronic health problems include respiratory conditions and cancers. How fabrication workers live with and respond to these risks depends largely on the conventions of their community of practice. Newcomers integrating into a shop acquire its safety and health practices—what’s expected and what’s avoided to ensure employees’ well-being. In this chapter, I examine how learning, such as the learning of safe practices, goes on outside of scaffolded interactions. Viewing health and safety practices as signals of membership within a workplace community, I discuss how workers’ practices arise through their everyday workplace observations and how workers may disregard safe practices to get along and fit in—at least until a workplace environment generates enough worry that an employee is compelled to take some action.

Fabrication work, welding in particular, exposes workers to a long list of potential injuries and chronic health problems. The potential injuries include burns, cuts, and crushed fingers and toes. The chronic health problems include respiratory conditions and cancers. How fabrication workers live with and respond to these risks depends largely on the practices of their shop communities. New workers integrating into a shop acquire its safety and health practices—what’s expected and what’s avoided—through interactions with the community’s old timers. In their highly influential work, *Situated Learning: Legitimate Peripheral Participation*, Jean Lave and Etienne Wenger, anthropologists of the workplace, wanted to differentiate this process, what they called “legitimate peripheral participation,” from intentional teaching and learning, like that of the one-to-one interactions between me and Jim that I described in earlier chapters. They wrote, “Learning through legitimate peripheral participation takes place no matter which educational form provides a context for learning.”¹

Basically, they were pointing out the obvious: People learn in and from all sorts of observations and interactions, not just when they’re engaged in interactions with the goal of teaching and learning. This approach to learning complements the process I

described in Chapter 3, where a teacher scaffolds the learning of a student. It expands what we mean by “teaching” and “learning” to include our unconscious practices and helps explain the cultural transformations brought about by the integration of newcomers into a community of practice.

We all belong to communities of practice inside and outside of work. Before the pandemic, I swam at the local gym at 5:00 a.m. every weekday for over five years. The people who got themselves out of bed and into their swim gear before 5:00 a.m. everyday formed a community of practice. We had shared ways of greeting, of determining who gets which lane, of determining who gets a lane to themselves unless the pool becomes especially busy, and of determining who should share a lane, and of saying goodbye at the end of a swim. We didn’t explicitly talk about our ways, but when a newcomer came along at 5:00 a.m., we expected that person to learn our practices and accord with them. Lave and Wenger’s approach to learning would help explain how a newcomer adopts the existing ways and how a newcomer might change the existing practices, such as the practices at the pool. In a later book, Wenger attempted to further explain this idea:

Such a concept of practice includes both the explicit and the tacit. It includes what is said and what is left unsaid; what is represented and what is assumed. It includes the language, tools, documents, [etc.]. But it also includes all the implicit relations, tacit conventions, subtle cues, untold rules of thumb, [etc.]. Most of these may never be articulated, yet they are unmistakable signs of membership in communities of practice and are crucial to the success of their enterprises.²

Viewing learning as not solely acquisition of conceptual and procedural knowledge through various stages like advanced beginner helps explain how people entering a community of practice adopt—or sometimes push back against—the community’s health and safety practices. That’s the idea I explore here in this examination of the ways that welders and other metal workers grapple with the risks of their work.

Promoting (and Ignoring) Safe Practices

Personal protective equipment, or PPE, mitigates some of the safety and health risks in metal work, but workplace communities vary widely in how often and well workers use PPE, how well they enforce its use, and how well they supply workers with equipment, such as ventilation and fume extraction, face, eye, and ear protection, gloves, and footwear. In my visits to ten fabrication facilities of various sizes, I saw that the two largest companies, John Deere and Vermeer, have systematized health and safety practices; they’ve mandated it. For example, they provide safety training and refresher classes. At Vermeer, workers discussed safety at the department meet-up at the start of a shift; I asked what those sessions cover and was told, “Pinch points, be careful, hoist, rigging, it’s a dangerous job, it can be for sure, so we don’t want to get hurt at work.” At John Deere, I spoke to people who conduct the training, and they explained how they determine what’s included:

We've been going through all of the corporate standards, what's required, when it's required, how often it's required. And we go through, we cross reference what was required for corporate, what's required through OSHA and then as far as the content, we get it wherever we can get it. We benchmark other factories. We get it on the internet, we get it off research.

In addition to the folks who run the training sessions, union safety representatives work with the company administration to ensure that OSHA's requirements are met and to determine where the training could expand from those basic requirements. Employees have to attend one training session a year, but the sessions are offered each month. Session leaders cover waste, machine guarding, forklift safety, pedestrian vehicles, confined spaces, and lock out/tag out. Trainers try to keep these sessions fresh:

One thing that we've done to keep it fresh like you ask is, within the last few years, we've been really trying to figure out how to tell the stories that happen at work, at home. Okay. So adjust your machine guarding. Why do we have machine guarding? To keep your hands and fingers away from this thing. Why is machine guarding important? Because we have a 10-ton press.

Besides training, big- and medium-sized companies have developed systems to analyze workers' near-miss reports. I discuss near-miss reports in more depth in Chapter 9, but briefly, a near-miss report relates an incident that could have led to an injury if the time or position had been slightly different than it was. For example, an employee in a shop I visited told me that they wrote a near-miss report after the chains and hooks of two hoists collided, causing each hoist to carom and nearly miss employees working nearby. Employees can usually file near-miss reports anonymously, although the safety experts told me that follow-up is easier when they know the employee's name. The reports range from the grave to the concerning with an occasional seemingly minor problem tossed in:

- THE THREAD ALL FELL OUT ON TO THE FLOOR AND ALMOST LANDED ON MY LEG FROM THE BUSHING PUSHER
- the press spring shot out of the press
- parts delivered on pallets are everywhere causing trip hazards. no room to store the alt packaged parts

In addition to describing situations ripe for accidents, these reports seem to act as a way to report another employee's error without directly naming the employee who made the mistake:

- FORKLIFT OPERATOR WITNESSED NOT STOPPING AT STOP SIGN GOING INTO DOCK 19 AND ALSO DID NOT SOUND HORN WHEN ENTERING THE DOCK
- Operator removed fuel cradle without engine frame hoist attached or engine frame jack stand in place. Engine frame tipped over next to operators in workstation.
- security personel driving gator ran into a 4 × 6 wheeled cart with sub parts on it. moved parts on the cart and the cart itself multiple feet into a guard rail in work area. then left area

The idea behind such reports, it seems, is to sustain the practice of refraining from snitching on a coworker but calling for a training refresher on stop signs and a barricade-free zone for walking. When I talked to the safety specialists at John Deere, they told me a near-miss report takes anywhere from a few hours to a couple weeks to close, the time it takes to investigate the occurrence through conversations with employees and determine the actions needed to lower the risk.

The safety-related resources of big companies show in the bins of safety glasses and earplugs and gloves of different sizes that greet workers when they enter the shop floor; the workers grab what they need from the bins whenever they need replacements. At smaller shops, workers often bring their own safety glasses, earplugs, and gloves. Zach, for example, told me that he had bought a bag of ear plugs and that I was welcome to use them; I bought a canister of my own violet-colored ones and told Regen that she could take whatever she needed. That is, a culture of sharing has developed, especially for items that don't have a size. I've purchased several pairs of coveralls and welding gloves for my work at Howe's. How well fabrication shops equip workers for their jobs varies widely—from supplying nothing to supplying an expensive hood and respiration system.

Whatever shop you work in these days, your situation will almost certainly improve upon the work conditions for welders and other metal workers from the early twentieth century to the 1970s. As they examined the culture of "rough masculinity" that arose in part in response to adverse working conditions, scholarly histories of welding and other trades work described the production systems—Taylorist and Fordist—that took hold in manufacturing in the twentieth century.³ The first of these, Taylorism, gets its name from Frederick Taylor, a mechanical engineer who developed what became known as scientific management, which refers to analyzing a work procedure so that it can be accomplished more efficiently. Taylorism accounted for the ergonomics of tools and the alignment of a worker's capabilities to a given task. The second, Fordism, refers to dividing production and assigning each worker to one single step in a product's manufacture, as in Henry Ford's automobile assembly line. Scholars argue that these methods of streamlining production boosted economies but also, in isolating workers from the final product, made it more difficult for them to find meaning in their work. As a consequence, workers developed a masculine culture that countervailed their feelings of powerlessness.

Describing masculinity in early heavy industries like iron and steel works but focusing on Clydeside, Scotland, from the 1930s to the 1970s, historians Ronnie Johnston and Arthur McIvor wrote:

When safety helmets and protective goggles were first introduced in the 1950s and 1960s many workmen initially resisted wearing them.... In part this was because the early versions of protective clothing were uncomfortable and could interfere with productivity and hence earnings. However, wearing masks, helmets and goggles was seen by some workers as a sign of personal weakness and an affront to manliness.⁴

Drawing on work from other historians, Johnston and McIvor wrote:

Dangerous, dirty, dusty and physically exhausting work, with the constant stream of injuries and deaths in the pits, metal works and the shipyards hardened boys up, desensitizing them to

danger and socializing them into a competitive, macho environment. Any sign of weakness, emotion and vulnerability could lead to being pilloried: the butt of jokes, scathing banter, vicious nicknames and sometimes very public humiliation.⁵

Times have changed, of course, but I'm thinking here about my coworker Zach, who slashed open the palm of his hand on a piece of 18-gauge sheet metal and, at first, balked at the idea of going to urgent care for treatment. I wonder how much that rough masculinity exists in workplace communities of practice today and tamps down reporting of injuries.

I'm also thinking about safety guards on angle grinders. At Howe's, as in other smaller shops, we don't use safety guards. Don't get me wrong. We have established practices for safety at Howe's. We yell "Clear!" before we stomp the foot pedal to operate the shears. We grind metal so that the sparks aim toward the floor and cover the pipe threader so an errant spark doesn't catch its residual cutting fluid on fire. We leave the hoists where others won't hit their head on them. We use extension cords to avoid making trip hazards out of our tools' power cords.

Removing the safety guard from an angle grinder appears to be common practice—at least in the United States. In my first class in welding school, my fellow students told me that no one keeps the guard on because it gets in the way when you're trying to reach tight spots. All through welding school, bucking the practice of my fellow students, I kept the guard on my grinder. I did it because I had watched a YouTube video that shows how shards shoot out in all directions when a cutting disc explodes. Scary stuff. But when I got to Howe's, I saw that none of the grinders lying in a stack along with used grinding wheels and cutting discs had a guard. All my coworkers had taken off the guards on their grinders as well. Not wanting to stick out any more than I did as the only woman and figuring that Jim and the rest must know what they're doing, I took the guard off mine.

This no-guard practice holds even though OSHA mandates them. As one commenter wrote on a UK welding forum:

it seems to be a thing in america. i rarely if ever see a video with the guard on if it hails from the land of the "free."⁶

Is it possible that there's something in the American character that propagates this silly practice? I don't know. I'm not sure what else could explain this disregard for safety, particularly given the stories you hear. Online forums about metal work contain countless stories of people who learned their lesson after a grinder kicked back or after a cutting wheel exploded:

The last time I used my grinder was after someone else had taken off the guard. I was trying to slot concrete when the wheel caught in it. It immediately whipped around and cut a neat 1/8" slot in one of my calves. Bled like mad, I wrapped in several layers of paper towel and drove to the ER.⁷

OSHA citations sit online too. Here's an excerpt of one about a worker who was using a grinder wheel to shape a loader bucket:

Employee #1 began cutting at an approximately 45-degree angle. The wheel snagged the body of the grinder, causing the abrasive wheel to break apart and dislocated from the spindle.

Flying debris ejected from the grinder and struck Employee #1 in his face. Employee #1 was not wearing a face shield, but was wearing ANSI labeled safety glasses. The impact of the flying debris upon his face caused two facial lacerations and a broken nose.⁸

Besides wanting to fit in, to integrate into the workplace community, I think I also wanted to signal to Jim that I'm serious about my work; I didn't want to slow my work by adjusting a guard. In a way, taking the guard off my grinder also meant trusting that Jim knows best. And he does, almost always. But despite his expertises, Jim is also product of his prior membership in other no-guard work communities. Jim knows how to do pretty much everything related to metal, but when it comes to avoiding injuries, I think he's also been lucky.

Mitigating UV Radiation

I don't remember learning anything about the long-term health effects of welding during my welding education; when teachers focused on safety, they focused on immediate dangers, like arc eye. Arc eye, or welder's flash, happens when eyes are exposed to the welding arc without sufficient ultraviolet (UV) protection. It's basically a sunburn in your eye. If the injury is bad enough, it can get infected and cause real damage. Beside this risk—one mitigated by the UV-absorbing lens of a welding hood—we didn't spend much time on other health risks, especially long-term health risks. And workplaces differ in how much they address these risks.

Welding gives off UV radiation, which, given enough time, damages skin and eyes and causes other health problems. Even if workers wear face shields when they are themselves welding, they are exposed to UV if they stand near others who are welding. UV radiation increases as your weld amperage increases, so people using a super-hot, high-amp process like the pulsed-spray transfer used to weld combines and other big equipment at John Deere's Harvester plant would be really susceptible to radiation if they weren't wearing good PPE. Studying UV radiation from different types of mig welding, Hitoshi Nakashima, an occupational health researcher, along with his colleagues, concluded that people mig welding mild steel without proper protection "are exposed to hazardous quantities of UVR [ultraviolet radiation] for short periods of time."⁹ OSHA only specifies protection for welders' hands, neck, and ears, but no one I've seen in any of the ten shops I visited wore anything other than a long-sleeved shirt and work pants or coveralls. While some workplaces mandate such protections, they appear in others because the workplace community has recognized their importance. You've got to be totally covered or the radiation can get to your skin.

Indeed, you can sense the annoyance from commenters on the welding subreddit who responded to a post from a welder who had tig welded a broken joint on an artificial leg. The original poster's idea was to share the good work they had done by fixing the leg. One of the pictures they shared, however, showed them tig welding the

artificial leg bare-handed and in a short-sleeved t-shirt. The most upvoted response to the poster's images was this:

May I make a small suggestion or two?

Gloves and sleeves.¹⁰

Other responses similarly ignored the intent of the original post—to show off the tig weld—and focused instead on the welder's disregard for their own health. For the online communities of welders, whether on Reddit or on dedicated forums like Welding Design & Fabrication, covering your skin to ward off UV is sacrosanct, just as it is in the fabrication shops that I visited.

That said, apparently a lot of people around the world are welding without sufficient protection from UV. In a BBC article about Kabir Abu Bilal, a professor in Zaria, Nigeria, who has a second job as a welder, the accompanying photo showed him stick welding with no gloves and no face shield, only dark glasses, meaning that his face and hands were exposed to UV.¹¹ A study of 327 Ugandan welders working in small shops found that only 110 (34.7%) used face shields, as opposed to goggles. Far more respondents, 287 (90.5%), used goggles. Just 241 (76%) used gloves.¹² These results indicated that workers recognized the immediate threat of arc flash—eye inflammation from UV—and thus wore goggles, but also showed that most workers either didn't have access to gear that would protect them from UV radiation, namely, face shields and gloves, or couldn't afford it. Similar studies of occupational injuries in South India, Nigeria, Kenya, and Iran have produced the same and sometimes worse results.¹³ For example, a study of 280 welders in Nigeria found that 66.4% of them wore goggles, but just 24.3% wore gloves, and only 3.6% wore a face shield.¹⁴ In that study, welders reported that their main reason for not using PPE was lack of availability, although those who didn't wear gloves also cited lack of comfort as a reason. The authors concluded by calling for governments, employers, and other stakeholders to promote “ownership and consistent use of PPE.”¹⁵

In the shops around Iowa that I visited, the only open question about a full welding hood and welding gloves was whether the shop or the employee would pay for the PPE. But a long list of studies shows that same doesn't hold in many other countries, particularly countries in the Global South. Yet few of the studies discussed the apparent problem of affordability. One exception was Yetunde Tagurum's coauthored study of welders in Jos, Nigeria. Those authors recommended that “safety devices should be made readily available and accessible through sale at subsidized rates to welders by local and state governments.”¹⁶ While I have absolutely no idea what it's like to work in India, Nigeria, or elsewhere as a welder or anything else, subsidized gear is an idea worth implementing everywhere so that workers can protect themselves from UV.

Mitigating Fumes

Before occupational safety came to the fore in the 1960s and 1970s, factories rarely had adequate ventilation. Jussi Turtiainen and Ari Väänänen, occupational health researchers, related how workers at one car factory nicknamed a nickel-plating room the “intoxication space” because, by the end of the day, workers were delirious.¹⁷ They quoted one machinist who was asked to describe his first day on the job: “I was driven to the foundry where my job would be. At the door I nearly panicked when I was faced with hundreds of sooty men and an infernal noise. A fine smut-dust hovered all over. But you get used to everything.”¹⁸

In their historical analysis, Johnston and McIvor also described the Red Road Flats in Glasgow, where workers cutting asbestos boards refused to wear protective masks. Workers perceived that respirators impaired breathing and slowed output.¹⁹ The consequences seemed distant to them, and the need for productivity was immediate. That same problem of distant consequences exists today and manifests in workplace communities that weld without a respirator, a fume extractor, or at the very least, proper ventilation. In addition, until the 1960s, trade unions ignored unsafe practices in favor of focusing on raising wages. By the 1960s, Johnston and McIvor wrote, unions began to educate their members and push them to “abandon time-honoured machismo work practices.”²⁰

Nowadays in the United States, OSHA regulates ventilation in standard 1926.353, which covers workers’ right to breathable air (Fig. 7.1):

Local exhaust ventilation shall consist of freely movable hoods intended to be placed by the welder or burner as close as practicable to the work. This system shall be of sufficient capacity and so arranged as to remove fumes and smoke at the source and keep the concentration of them in the breathing zone within safe limits as defined in subpart D of this part.²¹

Despite such standards governing workplace air quality, you don’t have to read far in online forums devoted to trades to find stories of fabrication shops that fail to follow OSHA or other nationally mandated regulations governing workplace ventilation and

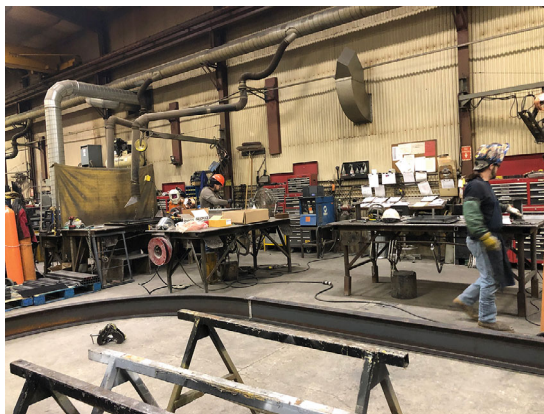


Fig. 7.1 The shop floor at Sargent Metal Fabricating. The fume extraction system appears at the top. A funnel attached to a fume extraction duct hangs over a weld table in the upper left

other safety matters, such as machine guards. And I'm thinking of posts like this one on the welding subreddit in response to a post about a shop's lack of ventilation for employees tig welding stainless steel:

Can't really speak too much on stainless but was in a shop that had crude oil burning off all the time- from what I was told radioactive shit. Fucking brown air. Wouldn't let us open doors. (North Dakota winter and power bill.) Ventilation didn't work worth a shit. They'll prob put two and two together that you called OSHA. Especially if you're only one wearing respirator. If I was you I would amp up your PPE- based off what more knowledgeable than myself people have to say.... Start looking for another job.²²

This post exemplifies an interesting (and I suppose not too surprising) theme in posts about welder safety: the reluctance of shop owners to lose shop heat in order to ventilate and the workers' tacit acceptance of that practice. At Howe's we try to mitigate welding fumes, but it's not always an easy task, especially in winter. We turn on the ventilation system, but the air improves even more when the garage doors are open and the cross wind moves fumes out of the shop.

Adam, who's been welding longer than all of us except Jim, bought a hood with a respirator, so the garbage in the fumes that he creates ends up in the filters that rest in the small of his back. This filtration system—hood, hoses, filter pack—sells for around \$2,000 new. Most welders, I think, would like to have the option of using one, but most workplaces do not provide them, and many welders cannot afford them. At Howe's, the rest of us do the best we can to keep our heads out of the plumes arising from our welds. Sometimes we roll Jim's big fume extractor near to where we're working so that it can suck up most of the fumes. But we don't always use it because it's bulky and difficult to move in the cluttered shop. Even so, ventilation and filtration systems are the very things that help welders avoid joining the ranks of those who have, over the long term, developed health problems that stem from or are exacerbated by exposure to fumes, which contain fine particles of metallic oxides, silicates, and fluorides and toxic gases such as carbon monoxide, ozone, and nitric oxide.²³ Although the composition of weld fumes depends on the flux, base metal, and electrode, none of the fumes is good for you.

In their meta-analysis of epidemiological studies of welders, Patti C. Zeidler-Erdely from the National Institute for Occupational Safety and Health, along with her colleagues, found "a reduced ability of workers exposed to metal fumes to ward off a pulmonary infection."²⁴ Multiple studies have shown excess cancer risk among welders.²⁵ One of them showed a 78% elevated risk for mesothelioma in welders.²⁶ Exposed to nickel and hexavalent chromium, welders working on stainless steel seem particularly susceptible to lung cancer.²⁷

Despite the terrible health problems related to welding fumes, many workers must advocate for themselves to get adequate ventilation and filtration systems. Doing so, however, means countering existing practice. Moreover, it's difficult to advocate for yourself when you fear you may lose your job outright or be "soft fired," assigned either too few shifts or the worst shifts.

Connecting with Scar Stories

As I mentioned above, warding off arc eye is one of the things I learned when I was a welding student. My teachers told us that we must have UV protection for our eyes (and everything else). More difficult, though, is avoiding cuts and burns. It seems to me, if you work in a metal shop, you can expect to get cut and burned. Minimizing the damage becomes the goal. Even so, I expect if you work in a shop long enough, you'll end up in urgent care at some point.

My urgent-care trip took place my first paid day at Howe's. Yes, the first day. I was bending flat bar on the press brake. The job was to make one hundred jersey barricades, the body of which consisted of a piece of flat bar with four bends and three punched holes. Jim had done all the set-up work on the press brake, namely, setting a stop. All I had to do was push the flat bar in the press brake until it touched the stop, press the foot pedal to make the first bend, flip the piece over, and press the foot pedal again to make the second bend. Simple. Especially because it was my first day getting paid, I tried to pay close attention to each iteration, but the task was repetitive, and daydreaming soon enough commenced.

It turns out that plenty of researchers have examined people's brains as they do repetitive tasks, finding that repetition suppresses the part of the brain that governs alertness and motivation, making it more difficult to sustain attention and on-task thoughts.²⁸ And then sure enough, when I started on the fortieth-or-so jersey barricade, I got the tip of my left middle finger between the flat bar being bent and the steel support attached to the front of the press brake, clipping it between the two as the press brake applied 600,000 pounds of pressure. I managed to pull my finger out before it was completely sandwiched in, but the metal crushed my skin and left a gash that spurted blood on the floor.

I got myself to the bathroom, where the medicine cabinet replete with a panoply of band-aids, gauze, and burn-relief sprays waited for me. With grime-covered hands, I tried to clean the wound, eventually wrapping several layers of bandage until it looked like a giant caterpillar had decided to make its cocoon on my middle finger. I went back to work, paying close attention to the position of my fingers as I slid the flat bar up against the stop. I waited until after work—about three hours later—to head to the urgent care for an x-ray. The nurse cleaned me up and told me that I didn't break the bone. But the gash took a long time to seal back up, and the tip of that finger still feels weird—a bit numb. I've got a little scar now to remind me of what can happen when you don't attend to the position of your body and all its parts.

These scars we acquire become catalysts for stories. Metal workers aren't the only ones, I'm sure, who enjoy a friendly exchange of scar show-and-tell. Remember the scene in *Jaws* where Hooper, Quint, and Brody briefly forgot their shark troubles with Quint's moonshine and stories of scar-producing experiences? The scars on their bodies anchored their accounts, tales that gave them a glimpse of each other's personhood, and culminated in Quint's horror story about the men from the USS *Indianapolis*. With scar stories, we relate what we've done, from the heroic to the stupid, and thus connect with others within the community. Besides the interpersonal

work they do, such stories can also teach, as more-expert people describe and explain their solutions to difficult problems.

I started racking up burns when, in weld school, I began to learn how to weld overhead. Overhead welding is a type of out-of-position welding, meaning any weld that's not done in the flat or horizontal positions. As I've mentioned, resource-rich companies like John Deere use sophisticated machines to flip and turn large assemblies so that workers can always weld flat or, at worst, horizontal. To their point, welders can learn flat and horizontal welding more quickly, and they can complete flat and horizontal welds faster because they don't have to spend time positioning themselves. In terms of quality, flat and horizontal welds are better because they get better penetration; gravity works to draw the filler metal into the joint.²⁹ Besides being more difficult than flat or horizontal welding, overhead welding tends to burn, as sparks and slag can easily fall on you. Experienced welders position themselves to avoid most of the fallout and will invest in leather sleeves that protect their arms and neck. But learning how to weld overhead pretty much means learning to deal with burns. As one commenter on the welding subreddit wrote: "Honestly, I feel like if you don't burn yourself a couple times learning to weld, you're doing it wrong."³⁰ In other words, participation in the community necessitates burns.

In online forums, welders trade burn stories. I easily found two in a thread about wearing leathers to mitigate burns. The first story captures a popular theme in burn-scar stories: the frequent impossibility of saving yourself from the pain:

Nothing beats standing on a 4 inch wide beam welding a overhead ... and having a big glob coming down and going right through your boot. All you can do is just stand there and let it burn. No way you can get that boot off in time let alone while standing on the 4 inch beam 40 some feet in the air.³¹

Another story on this same thread exemplifies a related theme—welding through the pain, usually in order to finish a weld pass without a restart, even though you're getting burned by the heated metal or the heat of the arc:

If your knuckles aren't blistered finishing that critical root pass to avoid another stop / start you aren't doing it right until you learn to work smart and not hard. Necessity is the mother of invention. When you're motivated by pain to find a better way, you will.³²

This commenter saw the burn pain as an incentive within deliberative practice. Following the commenter's thinking, the welder must analyze their body position, weld angle, and results to find a method that reduces the chance of burns.

While such online comments from welders indicate the broader societal expectation that men—still around 94% of welders in the United States³³—must harden themselves to pain, welders' scar stories indicate an additional understanding that being a member of a skilled trades community of practice means enduring pain.

Conclusion

In the United States, large fabrication facilities mandate health and safety training. In smaller shops, such training can occur sporadically or not at all. Everyone working in a shop environment would benefit from lessons on opening gas-regulator valves, moving gas canisters, using and storing acetylene and other flammable liquids, replacing frayed cords on power tools, installing (or reinstalling) a grinder's safety guard, avoiding eye injuries when using belt sanders, avoiding trip hazards, moving large objects with hoists, using fume extractors and filter masks when welding, and using ear plugs and better yet, earmuffs. Even small shops with limited resources could offer lessons from employees gifted with an ability to communicate clearly. And such lessons could take hold in tradespeople's minds if they were repeated and updated periodically and if they were treated with deserved seriousness instead of with eye-rolling acquiescence to big-brother government rules.

In addition to training, OSHA mandates that employers provide the PPE necessary to do a job. Similar rules hold in European Union countries and the United Kingdom, Australia, and New Zealand, among others. Some employers comply by providing employees with a stipend to maintain and replace welding hoods, jackets, gloves, and boots. Such programs should be expanded to help workers finance hood and filtration systems like the ones used at John Deere.

Besides thinking about health and safety practices as compliance with regulations, I've found that it's helpful to think of them too as signals of membership within a workplace community, as cultural activities that arise through newcomers' everyday participation in the environment of their workplace. Adherence to and rejection of health and safety practices constitute another way that workers signal their belonging in a community of practice.

Notes

1. Lave and Wenger, *Situated Learning*, 40.
2. Wenger, *Communities of Practice*, 47.
3. Turtiainen and Väänänen, "Men of Steel?" 452.
4. Johnston and McIvor, "Dangerous Work," 144.
5. Johnston and McIvor, "Dangerous Work," 139.
6. qwakers, "it seems to be a thing in america."
7. Dave L., "The last time I used my grinder."
8. Occupational Safety and Health Administration, "Accident Summary Nr: 201,182,656."
9. Nakashima et al., "Hazard of Ultraviolet Radiation," 456.
10. Standard_Zucchini_46, "May I make a small suggestion or two?"
11. Abubakar, "The Nigerian Professor."
12. Itiakorit, Zziwa, and Osuret, "Prevalence and Determinants."
13. Alexander et al., "Occupational Safety Measures"; Awosan et al., "Knowledge and Safety Practices"; Soltanpour, Rasoulzadeh, and Mohammadian, "Occupational Exposure"; Odhiambo, Peterson, and Isaac, "Knowledge about Physical Hazards."
14. Awosan et al., "Knowledge and Safety Practices," 5.

15. Awosan et al., “Knowledge and Safety Practices,” 9.
16. Tagurum et al., “Awareness of Occupational Hazards,” 2232.
17. Turtiainen and Väinänen, “Men of Steel?” 461.
18. Turtiainen and Väinänen, “Men of Steel?” note 48.
19. Johnston and McIvor, “Dangerous Work,” 145.
20. Johnston and McIvor, “Dangerous Work,” 146.
21. Occupational Safety and Health Administration, *Ventilation and Protection*.
22. 406f150, “Can’t really speak too much on stainless.”
23. Canadian Centre for Occupational Health and Safety, “Welding – Fumes and Gases.”
24. Zeidler-Erdely, Erdely, and Antonini, “Immunotoxicology of Arc Welding Fume,” 420.
25. MacLeod et al., “Cancer Risks”; Moulin, “A Meta-Analysis of Epidemiologic Studies”; Ambroise, Wild, and Moulin, “Update of a Meta-Analysis”; Zeidler-Erdely, Falcone, and Antonini, “Influence of Welding.”
26. MacLeod et al., “Cancer Risks.”
27. Ambroise, Wild, and Moulin, “Update of a Meta-Analysis”; Kendzia et al., “Welding and Lung Cancer”; Matrat et al., “Welding, a Risk Factor of Lung Cancer”; Sjögren et al., “Exposure to Stainless.”
28. Horn and Adamczyk, “Reticular Formation”; Loukidou, Loan-Clarke, and Daniels, “Boredom in the Workplace”; Warm, Parasuraman, and Matthews, “Vigilance Requires Hard Mental Work.”
29. Hobart Brothers, “Differences in Flat and Horizontal.”
30. Awesomecdudley, “Honest, I feel like if you don’t burn yourself.”
31. ironman715, “Nothing beats standing on a 4 inch wide beam.”
32. Comprehensive_Ad2433, “If your knuckles aren’t blistered.”
33. Data USA, “Welding, Soldering, & Brazing Workers.”

References

- 406f150. “Can’t really speak too much on stainless.” Reddit, November 21, 2023. <https://www.reddit.com/r/Welding/comments/1810d9j/comment/ka9d5yh/>.
- Abubakar, Mansur. “The Nigerian Professor Who Makes More Money Welding.” BBC, January 27, 2024. <https://www.bbc.com/news/world-africa-68079364>.
- Alexander, Vijay, Kulandaipalayam Natarajan C. Sindhu, Pradeep Zechariah, Abigail Veravolu Resu, Suryanarayan Rajendran Nair, Deepthi Kattula, Venkata Raghava Mohan, and Reginald George Alex. “Occupational Safety Measures and Morbidity among Welders in Vellore, Southern India.” *International Journal of Occupational and Environmental Health* 22, no. 4 (2016): 300–306.
- Ambroise, Denis, Pascal Wild, and Jean-Jacques Moulin. “Update of a Meta-Analysis on Lung Cancer and Welding.” *Scandinavian Journal of Work, Environment, & Health* 32 (2006): 22–31.
- Awosan, Kehinde Joseph, Muhammad Aliyu Makusidi, Mohammed Taofeek Olaekan Ibrahim, A. Suleiman, T. Magaji, and F. Mbatifuh. “Knowledge and Safety Practices Related to Exposure to Physical and Chemical Hazards among Welders in Sokoto, Nigeria.” *Asian Journal of Medicine and Health* 9, no. 1 (2017): 1–11.
- Awesomecdudley. “Honest, I feel like if you don’t burn yourself.” Reddit, November 25, 2021. https://www.reddit.com/r/Welding/comments/r2ad9z/learned_what_burnt_flesh_smells_like_today/.
- Canadian Centre for Occupational Health and Safety. “Welding – Fumes and Gases.” February 10, 2024. https://www.ccohs.ca/oshanswers/safety_haz/welding/fumes.html.
- Comprehensive_Ad2433. “If your knuckles aren’t blistered finishing that critical root pass.” Reddit, November 25, 2021. <https://www.reddit.com/r/Welding/comments/r2ad9z/comment/hm3rdx0/>.

- Data USA. "Welding, Soldering, & Brazing Workers." Accessed October 27, 2024. <https://datausa.io/profile/soc/welding-soldering-brazing-workers>.
- Dave L. "The last time I used my grinder was after someone else had taken off the guard." Comment on ToolGuyd blog, October 23, 2015, <https://toolguyd.com/angle-grinder-wheel-guards-safety-discussion/>.
- Hobart Brothers. "Differences in Flat and Horizontal Versus Out-of-Position Welding." Accessed May 13, 2024. <https://www.hobartbrothers.com/resources/technical-articles/differences-in-flat-and-horizontal-versus-out-of-position-welding/>.
- Horn, Anja K. E., and Christopher Adamczyk. "Reticular Formation: Eye Movements, Gaze and Blinks." In *The Human Nervous System*, edited by Jürgen K. Mai and George Paxinos, 328–366. Cambridge, MA: Academic Press, 2012.
- ironman715. "Nothing beats standing on a 4 inch wide beam welding a overhead moment." WeldingWeb.com, December 12, 2009, <https://weldingweb.com/vbb/threads/36550-Are-people-getting-burned-right-through-their-leathers>.
- Itiakorit, Brian, Esther Bayiga Zziwa, and Jimmy Osuret. "Prevalence and Determinants of Occupational Injuries among Welders in Small Scale Metal Workshops in Wakiso District, Uganda." *The East African Health Research Journal* 5, no. 1 (2021): 106–112.
- Johnston, Ronnie, and Arthur McLvor. "Dangerous Work, Hard Men and Broken Bodies: Masculinity in the Clydeside Heavy Industries, c.1930–1970s." *Labour History Review* 69, no. 2 (2004): 135–151.
- Kendzia, Benjamin, Thomas Behrens, Karl-Heinz Jöckel, Jack Siemiatycki, Hans Kromhout, Roel Vermeulen, Susan Peters et al. "Welding and Lung Cancer in a Pooled Analysis of Case-Control Studies." *American Journal of Epidemiology* 178, no. 10 (2013): 1513–1525.
- Lave, Jean, and Etienne Wenger. *Situated learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.
- Loukidou, Lia, John Loan-Clarke, and Kevin Daniels. "Boredom in the Workplace: More than Monotonous Tasks." *International Journal of Management Reviews* 11, no. 4 (2009): 381–405.
- MacLeod, Jill S., M. Anne Harris, Michael Tjepkema, Paul A. Peters, and Paul A. Demers. "Cancer Risks among Welders and Occasional Welders in a National Population-Based Cohort Study: Canadian Census Health and Environmental Cohort." *Safety and Health at Work* 8, no. 3 (2017): 258–266.
- Matrat, Mireille, Florence Guida, Francesca Mattei, Sylvie Cénée, Diane Cyr, Joëlle Févotte, Marie Sanchez et al. "Welding, a Risk Factor of Lung Cancer: The ICARE Study." *Occupational and Environmental Medicine* 73, no. 4 (2016): 254–261.
- Moulin, Jean Jacques. "A Meta-Analysis of Epidemiologic Studies of Lung Cancer in Welders." *Scandinavian Journal of Work, Environment, & Health* 23, no. 2 (1997): 104–113.
- Nakashima, Hitoshi, Akihiro Utsunomiya, Jyunya Takahashi, Nobuyuki Fujii, and Tsutomu Okuno. "Hazard of Ultraviolet Radiation Emitted in Gas Metal Arc Welding of Mild Steel." *Journal of Occupational Health* 58, no. 5 (2016): 452–459.
- Occupational Safety and Health Administration. "Accident Summary Nr: 201182656 – Employee's Face Is Injured by Flying Object." OSHA Accident Report Detail. August 4, 2005. https://www.osha.gov/ords/imis/accidentsearch.accident_detail?id=201182656.
- Occupational Safety and Health Administration. *Ventilation and Protection in Welding, Cutting, and Heating*. 1926.353. OSHA, June 30, 1993. <https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.353>.
- Odhiambo, Onguto Nicholas, Warutere Peterson, and Mwanzo Isaac. "Knowledge about Physical Hazards and Use of Personal Protective Equipment Based on Demographic Characteristics and among Small Scale Welders in Nairobi City, Kenya." *Journal of Scientific Research and Reports* 26, no. 6 (2020): 120–130.
- qwakers. "It seems to be a thing in america." Migwelding: The DIY Guide, November 6, 2023. <https://www.mig-welding.co.uk/forum/threads/angle-grinder-guards.133259/>.

- Sjögren, Bengt, Klaus Stågis Hansen, Helge Kjuus, and Per-Gunnar Persson. "Exposure to Stainless Steel Welding Fumes and Lung Cancer: A Meta-Analysis." *Occupational and Environmental Medicine* 51, no. 5 (1994): 335–336.
- Soltanpour, Zahra, Yahya Rasoulzadeh, and Yousef Mohammadian. "Occupational Exposure to Metal Fumes among Iranian Welders: Systematic Review and Simulation-Based Health Risk Assessment." *Biological Trace Element Research* 201, no. 3 (2023): 1090–1100.
- Standard_Zucchini_46. "May I make a small suggestion or two?" Reddit, February 10, 2024, <https://www.reddit.com/r/Welding/comments/1answf8/comment/kpuo0cd/>.
- Tagurum, Yetunde O., Martin D. Gwomson, Pankyes M. Yakubu, James A. Igbita, Moses P. Chingle, and Oluwabunmi O. Chirdan. "Awareness of Occupational Hazards and Utilization of PPE amongst Welders in Jos Metropolis, Nigeria," *International Journal of Research in Medical Sciences* 6, no. 7 (2018): 2227–2233.
- Turtiainen, Jussi, and Ari Väänänen. "Men of Steel? The Masculinity of Metal Industry Workers in Finland after World War II." *Journal of Social History* 46, no. 2 (2012): 449–472.
- Warm, Joel S., Raja Parasuraman, and Gerald Matthews. "Vigilance Requires Hard Mental Work and Is Stressful." *Human Factors* 50, no. 3 (2008): 433–441.
- Wenger, Etienne. *Communities of Practice: Learning, Meaning, and Identity*. Cambridge University Press, 1999.
- Zeidler-Erdely, Patti C., Aaron Erdely, and James M. Antonini. "Immunotoxicology of Arc Welding Fume: Worker and Experimental Animal Studies." *Journal of Immunotoxicology* 9, no. 4 (2012): 411–425.
- Zeidler-Erdely, Patti C., Lauryn M. Falcone, and James M. Antonini. "Influence of Welding Fume Metal Composition on Lung Toxicity and Tumor Formation in Experimental Animal Models." *Journal of Occupational and Environmental Hygiene* 16, no. 6 (2019): 372–377.

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Chapter 8

Learning Technical Drawings



Abstract At some point along their journey, most tradespeople encounter technical drawings. These drawings constitute an important communication between those who work in offices, such as engineers and project managers, and those who work on the shop floor, such as welders and machinists. Typically, technical drawings contain at least a front, a top, and a side view. More complex fabricated items often receive detailed treatment, including multiple views. In addition, technical drawings for welded products use welding symbols, a standardized code for specifying the type and size of a weld, along with information about its finish. In this chapter, I discuss research on how people learn to use technical drawings. In doing so, I draw from my conversations with employees at Vermeer, Power Brace, and other shops that I visited. I also draw from my experiences at Howe's, where we encounter technical drawings of all sorts, from sketches on notebook paper to computer-assisted drawings.

If you put in enough time in at a school, you'll eventually run into a truly terrible teacher. After seven years of graduate school to get a master's and then a doctoral degree, I'd experienced my share of unprepared and unmotivated individuals who have found themselves front and center in a classroom. In one sense, it's to be expected. Lots of people who become university professors have no training in the ways that people learn, the process of learning, or the best practices of scaffolding students' learning. A few professors I encountered had clearly tried to understand pedagogical methods, mixing lecture, solo and group activities, games, and videos. Many others did their best, diligently but without innovative techniques, to help their students along. A few were magnificently awful, as if they were striving for incompetence, like my sociolinguistics teacher who, each class, veered from the day's alleged topic to talk at length about his daughter or to virtue signal his progressivism with yarns of his activist days. This guy didn't just fail to plan his class periods; he failed to convey or co-construct any knowledge about the subject matter.

But no teacher I met during years of studying linguistics matched the unholy incompetence of the man who taught (I use that word loosely) the class in print reading and symbol interpretation during my first semester at welding school. Rather than starting us with simple drawings and moving progressively through more complex

ones, he simply grabbed old technical drawings that happened to be lying around the classroom and randomly pointed to specifications and welding symbols, mumbling their meaning. He failed to understand that teaching spatial representation required a range of approaches; students of different abilities and experiences would need a variety of pathways toward competence in envisioning a three-dimensional (3D) object from its two-dimensional (2D) representations. He failed to understand that students would need deliberative practice via sequenced activities designed to help students see 3D from 2D representations and draw 2D representations from 3D objects.

What grinds my gears about this class, even years later, is that if he had simply Googled “teaching technical drawing” he would have found articles and syllabi that provide ideas for moving students—even ones who struggle to understand spatial representations—out of novice-level knowledge and toward greater competence. He would have found even more ideas if he had dropped that phrase into Google Scholar’s search bar. There he’d have found research on developing the ability to interpret and create spatial representations. Instead, he walked into class without a plan, leaving us students uneducated and unexercised in this important knowledge domain. In addition, his coverage of welding symbols—those special codes that specify characteristics of a weld—lumbered ahead with the same lack of curiosity about how people learn to interpret a new communicative system.

In this chapter, I discuss my research on the process of and best practices for learning spatial representation. In doing so, I draw from my conversations with employees at Vermeer, Power Brace, and other shops that I visited. I also draw from my experiences at Howe’s, where we encounter technical drawings, albeit usually ones less complicated than those found at larger fabrication facilities. In the process, I also discuss the development and use of welding symbols and explore what’s known about how people learn a new communicative code like this standardized system.

Representing 3D in 2D

Most studies that examine learners’ abilities to understand 2D representations of 3D objects and to make 2D representations of 3D objects focus on engineering students. Engineering students usually take at least one course in what’s often called “visual representation,” learning how to use CAD, computer-aided design, to facilitate their work. Students in trades programs don’t typically learn how to produce technical drawings, but they must competently interpret them. At Power Brace, for example, a lead welder told me, “You get into the more technical areas where the mills are being run, where welders are doing their job, where they’re bending parts or forming them on the press brakes. Those guys have to be trained further, so that they’re able to interpret all of the details of this.” Tradespeople, like engineers, must understand the genre conventions of technical drawings used in their professions; for example, to do their jobs successfully, most welders must gain competence in reading welding

symbols, an additional layer of code in technical drawings used to specify the location, preparation, size, finish, and other characteristics of each weld. However, many people struggle to interpret technical drawings, especially in envisioning a 3D object from a 2D representation. A lead welder at Quality Manufacturing confirmed:

And I think that's probably the most challenging thing that we face as an employer is that most people, whether they went to school or not, really struggle with blueprint interpretation. ... Because we are finding that a lot of our new hires, and even existing team members for that matter, their minds struggle to be able to take a 2D image into a 3D.

The technical drawings, or mechanical drawings, or blueprints, or just prints, used in fabrication draw on at least two human abilities: (1) the ability to associate various arrows, lines, symbols, and so on, with referents, whether concepts or material objects and (2) the ability to envision and mentally manipulate a 3D object, particularly when represented in 2D.

In the shops that I visited and at Howe's, orthographic technical drawings were the primary means by which items for fabrication were represented. Such drawings employ descriptive geometry, namely, geometry that focuses on the procedures involved in representing 3D in 2D. Although geometric drawing traces back to Plato,¹ the French mathematician Gaspard Monge honed the practice of orthographic representation, capturing three dimensions in front, side, and top views.² While the technical drawings that arrive in shop settings can represent more than those views, these three views constitute the core of an orthographic representation. Figure 8.1 shows an example. To interpret these views, tradespeople learn the conventions used to represent the object, such as object, hidden, center, extension, leader, and section lines, indications of linear and angular dimensions, and symbols and notations for the various types, size, and placement of welds. A shared visual language allows everyone who knows it to employ their spatial ability to visualize a 3D object from the 2D representation.

Many professions have visual languages, each combining text and numbers with symbols (such as welding symbols) and employing graphical representations (such as solid and dotted lines). Various researchers have investigated how people create and interpret spatial representations and how those representations, such as architects' sketches, geographers' maps, and radiographers' capture sheets, develop conventions and become genres. In their interviews of 55 people in different professions, researchers Alessia Eletta Coppi, Alberto Cattaneo, and Jean-Luc Gurtner found that the visual representations of people in technical work, such as woodworkers, plumbers, and multimedia technicians, shared characteristics within and among professions. They postulated that this finding related to shared international standards, namely from the International Organization for Standardization, or ISO.³ For example, these professions had a shared meaning for $\emptyset$, the symbol indicating diameter.

If you've read Chapter 5 of this book, you won't be surprised to learn that the United States differs from a lot of the world in the realm of orthographic drawings. The United States uses what's called third-angle projection, while European countries and many Asian countries use first-angle projection. First angle shows the object as

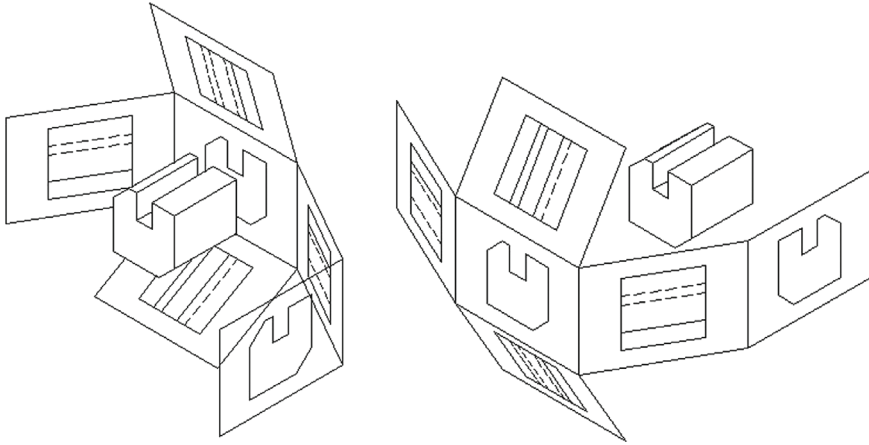


Fig. 8.2 First-angle representation (left) projects an object's side to the opposite interior wall. Third-angle representation (right) projects an object's side directly to the exterior wall. *Source* David W. Melton and Gary Stewardson, "The American Drafter: Why Use 1st Angle Projection in a 3rd Angle World?" Fall 2008, page 4. Permission to use from the authors and *Technology Interface Journal*

may turn to solid-model representations, digital representations that allow users to zoom in and out and to cut and rotate objects to understand their composition.

Tradespeople may also encounter technical drawings as a part of the dialogue generated during the process of collaborating with a client in the design of the item for fabrication. In Chapter 6, I talked about how technical drawings at Howe's sometimes serve as a starting point for a conversation with a customer about how the item would best be fabricated. In the case of the 10-foot shepherd's hooks that I discussed in Chapter 6, Jim looked over the customer's drawing on graph paper, considered it for a moment or two, and then determined that keeping upright the 10 feet of tubing above ground would require longer spikes under the ground than the customer's drawing indicated. Jim and the client modified the design based on Jim's assessment, and my fabrication followed the new design.

At other shops I visited, shop owners and weld technicians discussed transforming customers' ideas—their sketches—into technical drawings through iterations of drafts made with CAD software. In other words, spatial representations enable improvements in product design which are in turn reflected in subsequent drawings. Gabriela Goldschmidt, a professor of architecture and town planning, said that spatial representations, are "indispensable" to design development because they allow collaboration and a "shared mental model."⁷ For example, at Sargent Metal Fabricating, I saw a client's emailed sketch finalized through dialogue about the client's requirements (Fig. 8.3). The agreed-upon design, specified in the conventions of a technical drawing, would meet the client's needs and facilitate efficient production of multiples.

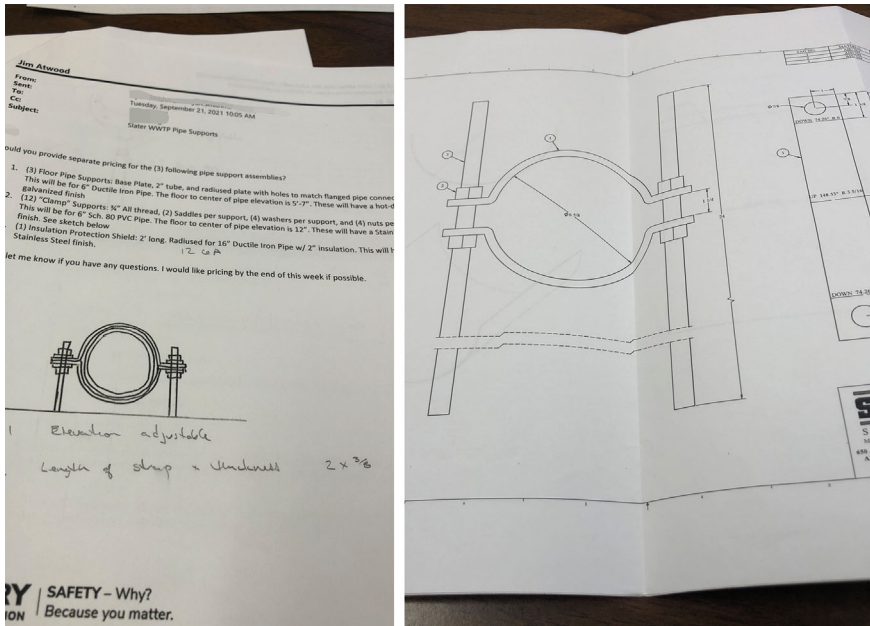


Fig. 8.3 An emailed sketch and specifications sent to Sargent Metal Fabricating (left) and an orthographic drawing for the sketch generated through collaboration with the client at Sargent Metal Fabricating (right)

At Power Brace, my guide through the shop recounted how the company, which has earned ISO certification for design, created technical drawings for an inventor of a splash guard:

He brought it in, but he had no working print. He had to create a print, which is not identical to this because we made a few changes that make it better for manufacturing, and then we sent it off to him and let him look it over and make sure that he signs it off. I don't know how well he understands the prints, but I think he's got a basic concept of what we're going to do. Then, we'll do what's called the first article. We'll make a part and then we'll take it to him and say, "Is this exactly what you want before we get into full production?" Yeah, there's steps. He brought this in. Our reverse engineer, I guess, made a print, sent it to him, said, "Is this what you want?" We needed his sign off before we could make first article. Then we make it. We'll ask him to look at that. There's a lot of back-and-forth clarification to make sure.

The iterative process described here is one that researchers, such as Claudia Eckert and her colleagues, have studied to understand how representations from pencil sketches to computer-aided drawings facilitate brainstorming and collaboration and generate a shared understanding, or intersubjectivity.⁸ Although Power Brace focuses on mass production of its list of products, the company retains the willingness of smaller shops like Sargent Metal Fabricating to create and revise technical drawings to fine-tune the client's idea so that it can be efficiently fabricated in quantity.

Learning to Interpret Technical Drawings

Interpreting a technical drawing for fabrication draws from conceptual knowledge of the code system—the graphical, numerical, and alphabetical symbols—used to represent the geometry of an object. More than that, interpreting a technical drawing draws on procedural knowledge, specifically, the procedure of interpreting those symbols to envision the 3D object that they represent. Novice-level readers of technical drawings often struggle, evidenced by posts like these to the welding subreddit:

mechanical drawings. can anyone help me understand how to read these? i'm in a welding class that requires me to learn how to read these drawings and i just can't grasp how to read them.⁹

Can someone rough sketch a pictorial view this object using given top view, front view, and "B" or "D" side view? I can't make sense of it.¹⁰

The second comment above came from someone struggling to figure out what a side view of an object would look like if the front view were a circle and the top view were a square. I empathize with folks like these. I've struggled with technical drawings too.

Developing Spatial Ability

Trying to help people learn how to interpret and create technical drawings, researchers have studied people's spatial intelligence, or spatial ability, which under the theory of multiple intelligences sits alongside linguistic, logical-mathematical, bodily-kinesthetic, and other intelligences. Spatial ability includes spatial visualization, defined as "the ability to mentally manipulate, rotate, twist, or invert pictorially represented stimulus objects."¹¹ For example, a person with high spatial-visualization ability can imagine in both 2D and 3D what an object would look like if it were rotated 90 degrees.

Indeed, studies of spatial ability began with investigations of mental rotation. A germinal study by psychology researchers Roger N. Shepard and Jacqueline Metzler examined people's ability to mentally rotate isometric images (i.e., drawings that give the illusion of depth) of block configurations and match them to another image. They found that the time people took to rotate the images directly related to the degree of rotation required to align one block configuration to the other.¹² Since that study, other researchers have followed up, studying whether people mentally rotate images holistically or in parts. Researchers Mark D. Folk and R. Duncan Luce found that people will take the path of least resistance, rotating just a part of an object, if doing so will allow them to make a same/different comparison. They also found that when people have to mentally rotate the complete object to make a same/different comparison, the complexity of the object determines how long the task will take.¹³ Later researchers determined that such tasks call on three processes: (1) perception, creating a mental representation from sensory data, (2) spatial transformation, the

ability to manipulate the mental representation, and (3) comparison, comparing the mental representation against other representations. Researchers Andrew Lovett and Holger Schultheis noted a fourth process not named in earlier studies: spatial adaptation, a person's ability to hone a mental representation for the task at hand by attending to relevant details and ignoring the rest.¹⁴ Here I think of Jim mentally rotating—easily, it seemed to me—the C-channel sides of the truck ramp that I discussed in Chapter 4 to determine how I'd oxyacetylene cut angles out of them.

Besides investigating how people perceive 3D objects from 2D representations and how they then mentally manipulate those objects to perform tasks, research has also investigated apparent differences in the ways males and females perform tasks that call on their spatial abilities. Marcia C. Linn and Anne C. Petersen conducted a meta-analysis of such research, finding large differences in mental rotation abilities and medium differences in spatial perception, defined as the ability to perceive spatial relations among distractors. Interestingly, Linn and Petersen found no significant differences between males and females in their ability to carry out multiple-stage tasks, for example, paper-folding tasks, that required manipulating spatial information.¹⁵ Further meta-analytic research suggested that females fair worse in mental rotation of complex shapes because they are more likely to take a piecemeal approach: "The piecemeal strategy might cause difficulty on complex shapes because it involves encoding, rotating, and comparing more individual features."¹⁶ That said, other research suggests that even males rotate objects in a piecemeal fashion.¹⁷ In addition, some studies have not found an object-complexity effect at all.¹⁸

In fact, some research suggests that it's not mental rotation that generates the differences between males and females but rather the creation of the 3D image in the first place—the perception: "Thus, it is possible that sex differences on mental rotation tasks may not actually be attributable to a sex difference in mental rotation, but rather to the surrounding processes involved in this task, such as encoding the stimulus to be rotated."¹⁹ Further research on the topic has explored possible natural (e.g., hormonal) and contextual (e.g., socioeconomic status) factors in differences, but conclusions for now remain tenuous.

Educational research has occasionally explored ways to teach 3D visualization from 2D technical drawings, recognizing that students need procedural as well as conceptual knowledge to carry out such tasks.²⁰ To teach orthographic drawing, instructors commonly use the glass box method, where students draw on the exterior of a glass box an object that sits inside the box. This activity affords them practice in visualizing a 3D object as a 2D view. In his master's thesis, CAD instructor Brian Kurszewski explained another visualization method that he developed for his high-school course. Instead of the glass box method, he developed what he called the bowl visual aid, where students place the object in a glass bowl and then slide the object from the bottom to the rim to get different views. Kurszewski found that students found the bowl method helpful. Out of 51 participants, 26 recommended using both glass box and bowl methods to teach orthographic drawing.²¹

Teachers have also used blocks of different shapes to teach visualization. Students construct a form from blocks and then draw orthographic projections of it.²² Maizam

Alias, Thomas R. Black, and David E. Gray described how they used a variety of activities to develop spatial ability, such as using building blocks, sketching objects from observation and memory, and manipulating objects. The gains they found pointed to “the role of concrete spatial activities.”²³ Education researcher Sinan Olkun helpfully delineated a progression of increasingly complex learning activities that involve blocks, pointing out that novice drafters can move from working with to working without models.²⁴ In addition to blocks, researchers have tested and advocated for activities using on-screen solid-model representations to develop spatial abilities. Such research indicates that the use of solid models boosts spatial ability.²⁵

As mentioned above, much research on how people strengthen their competence with technical drawings has focused on engineering students, who learn not only to read drawings but also to create them, usually with CAD software. Some of this research has examined the use of advanced technologies, particularly virtual reality and augmented reality to scaffold engineering students’ spatial ability.²⁶ Studies comparing 3D to 2D representations have shown that students prefer 3D representations, which allow them to rotate, cut, and enlarge. In a study focused on inspecting welded joints, Luis Miguel Arroyave Espinosa and his colleagues compared 3D virtual and augmented reality, 3D print, and PDF3D. They found that PDF3D required less training than the others, was easiest to disseminate, and was most accessible to students.²⁷ For smaller shops with fewer resources, PDF3D or something akin to it would likely be a more feasible option than virtual or augmented reality for training employees in interpreting technical drawings.

We didn’t use any of these high-tech methods in my class on technical drawings, not that I expected virtual reality or even 3D PDF files. How hard would it have been, though, to progress from interpreting orthographic drawings of simple objects to drawings of more complex ones, making each lesson contingent on what we’d learned before? How hard would it have been to start us off with drawing stacks of blocks and progressing to more challenging forms? Even a cursory glance online from researchers such as Sinan Olkun reveals that teachers and researchers have for decades been thinking about ways to help people with less developed spatial ability learn how to visualize 3D from 2D.²⁸

Learning the Syntax of Welding Symbols

Interpreting a technical drawing requires learning symbol systems used to generate a shared understanding. Researchers David H. Uttal and Lei Yuan defined a symbol as “something that someone intends to stand for something else.”²⁹ How people associate the symbol with its referent in part depends on its resemblance to its referent. Charles Sanders Peirce, one of the most renowned semiotics scholars, used the term “symbol” solely for depictions that have an arbitrary relation to their referent. The word “pipe,” for example, does not resemble a pipe, but through the conventions of English, we understand its referent. Peirce used the word “index” to refer to a depiction that in some manner points to its referent. The arrow in Fig. 8.4 would, in

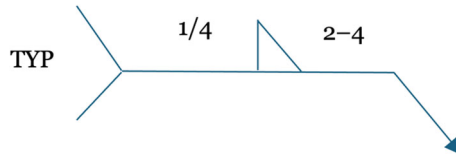


Fig. 8.4 All welding symbols contain a reference line, an arrow, and a weld symbol. The welding symbol here specifies a fillet weld on the other side of the joint that the arrow indicates. The fillet weld should have 1/4-inch legs. Each weld should be 2 inches long. The welds should be spaced 4 inches apart, center to center

Peirce’s analysis, be an index, as it points to a depiction of the joint on a technical drawing. The depiction of the fillet weld in Fig. 8.4—the triangle—is itself what Peirce called an “icon,” a depiction that resembles its referent.³⁰ Here, like researchers David H. Uttal and Lei Yuan, I use the word “symbol” to cover everything in Peirce’s three categories.

In the United States, technical drawings for fabrication tend to follow the standards of the American Welding Society, or AWS, as laid out in its *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.³¹ Essentially, the same AWS system of welding symbols has been in place since 1947, and this is the system that welders in the United States learn—at least a little—in welding school or in a workplace training program. Around the world, tradespeople use similar symbols, often the ISO’s standards,³² although slight differences appear among countries.

Welders and other fabricators must learn to interpret the meanings conveyed in welding symbols in order to carry out a weld procedure. Thus, welding symbols fall into the category of performative symbols. Performative symbols, Richard Sproat said in his comprehensive examination of symbol systems, “indicate a sequence of actions to be taken to perform a particular task.” Other examples in this category include musical notation, Ikea assembly instructions, and knitting patterns.³³ Like some of its performative category members, welding symbols incorporate broader and more common symbol systems. First, they incorporate alphabetical elements, or written language. For example, the welding symbol in Fig. 8.4 contains the abbreviation TYP, which stands for “typical” and means that the parameters in that welding symbol will apply across similar joints in the item being assembled. Many other abbreviations are possible, from references to a detail (e.g., “DET A”) to a cutting or welding process (e.g., “SMAW” for stick welding) to an indication of finish (e.g., “G” for grinding). Second, welding symbols critically contain numerical elements, such as the size of the weld and, if an intermittent weld, its pitch. Depending on the type of weld indicated, a welding symbol may contain the depth of the bevel, the size of the root opening, the size of the weld’s effective throat, the angle of its groove, or the number of slot or plug welds. The welding symbol in Fig. 8.4 indicates that each leg of the fillet weld should be ¼ inch. It also indicates the welder should perform intermittent welds instead of one single weld, each 2 inches long and 4 inches from each other when measured center to center.

Welding symbols contain graphical elements as well, such as its straight reference line and its arrow, but also its weld symbols. In the AWS system (and, actually, in the other systems too), a welding symbol always contains a reference line, an arrow, and a weld symbol. In other words, each *welding* symbol contains a *weld* symbol, such as the triangle indicating a fillet weld in Fig. 8.4. Welding symbols can contain other graphical elements, such as $\cup$ to indicate a concave contour, $\bigcirc$ to indicate “weld all around” or spot weld (depending on placement in the welding symbol), and $\blacktriangleright$ to indicate “weld in the field.” Welders’ comprehension of welding symbols stems in part from their understanding of alphabetical and numerical symbol systems, but they need to learn how elements of those broader systems operate within a welding symbol. They must also learn new symbols, particularly weld symbols.

Weld symbols are, in Peirce’s categorization, icons because they resemble their referents. Like the triangle of the fillet weld looks like a cross section of a fillet weld, the weld symbol for a V-groove weld looks like a V. This “semantic closeness” facilitates recognition.³⁴ Symbol researchers Brady R. T. Roberts, Colin M. MacLeod, and Myra A. Fernandes wrote in their study of the memorability of symbols and words:

Symbols are only effective communicators of information when a person already knows, or can figure out, what they are intended to convey. For practical reasons, then, it is preferable for symbols to be highly standardized and better yet for them to have intuitive interpretations.³⁵

Weld symbols are standardized and resemble their referents, supporting their memorability.

Then welders must learn the ways that elements from these systems combine in the welding symbol’s syntax to generate a specific meaning. Like writing systems that follow the syntactic properties of the languages that they encode, nonlinguistic symbol systems can have syntax too. As researcher Karen A. Cerulo wrote in her analysis of aural and visual symbols, “The combination of a symbol’s elements conveys a meaning that may differ from that of any single element of the symbol. Meaning, then, is largely contingent on the syntactic structure of the symbol ... the way in which words, sounds, colors, or image are put together.”³⁶ In addition, as Richard Sproat pointed out, syntax has dimension.³⁷ To interpret a welding symbol, you have to consider 2D space—what’s above and what’s below the reference line—to understand the procedure being specified. Welding symbols, in other words, are not strictly linear.

While the syntax of some welding symbols equates to “see Jane run” simple sentences, welding symbols, when laden with complexity brought about with more specifications from the variables listed above, can become difficult to parse and intimidating for novice-level readers. The welding symbol in Fig. 8.5 calls for five $2 \times 1/2$ -inch slot welds filled $1/8$ inch and spaced 3 inches apart, center to center. Complex welding symbols like this one easily intimidate, especially in the context of an orthographic representation. The learner not only has to use spatial visualization to mentally represent the object, but also must decode the procedures specified in the drawing’s welding symbols. It’s no wonder that people lament the difficulty of reading technical drawings for fabrication: The task requires multiple competences.

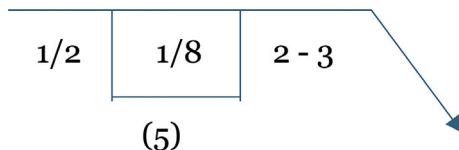


Fig. 8.5 This complex welding symbol specifies five $2 \times \frac{1}{2}$ -inch slot welds that are to be filled $\frac{1}{8}$ inch and spaced 3 inches apart, center to center

Using Technical Drawings on the Job

All fabrication shops that I visited relied on their workers to interpret orthographic drawings, so I asked a welder at Vermeer to pretend as if he had just received the drawing that lay in front of us:

Jo: Okay. So when you encounter something like this, what do you do first? What's your first thing to look at? The steps to understanding it?

Welder: I would say first thing I would look at is just the whole thing altogether, and how it's put together. And each part, what parts go where. This goes this way, not flipped round, make sure everything's the right way. Then I would say I look at the welds, because some of the welds are different. Like you got 0.3 here, 0.3 here, but 0.2 everywhere else. And you've got fillet welds here and then got a different weld there. You also have to look at your notes, make sure you, any notes you have, right here it says grind smooth. So after you weld that, you have to grind that smooth when you're done.

Jo: Okay. And what about any of the other components of the drawing?

Welder: Down here, this is just your parts list. So it tells you, every item has a number right here. So number one right here, and then item number is right here. And then over here has a quantity of how many each machine that that part gets. And here's just what the part's called.

This welder, who had worked at Vermeer for over three years, had built the subassembly represented in the technical drawing in front of us hundreds of times, but his response indicates his perception of his approach to interpreting a drawing for the first time. Using his spatial ability, he reads to understand the orientation of the components to one another. Then, using his fluency in the code of welding symbols, he determines the placement, size, and finish of the welds.

To achieve this level of proficiency in their employees, big manufacturers in particular have put into place various supports to scaffold newcomers' learning. Workers at Vermeer, John Deere, Quality Manufacturing, and Power Brace receive formal training in orthographic drawings and welding symbols, alongside their other welding and safety training. At Vermeer, I had a chance to talk to a few people going through the training program. I asked one about the process of learning how to read technical drawings. They confirmed that I'm not alone in struggling to read welding symbols and to perceive 3D from 2D: "Yeah. It was the welding symbols and turning something 2D into 3D. So I have a pretty difficult time doing that."

Even if they don't have formal training programs in place, companies with sufficient resources augment orthographic drawings with other documentation to help

welders better understand the arrangement of parts and the size and length of the welds they must perform. These process descriptions, also called job cards or weld guides, usually provide isometric views—views that convey perspective—to supplement the orthographic drawing's views. At John Deere, these process descriptions also include a text description of the entire task. Combined with the orthographic prints, process descriptions help welders visualize the final product. In addition, at big facilities like Quality Manufacturing, Vermeer, and John Deere, welders can see screen-displayed CAD drawings to verify the steps they need to carry out.

When I visited Vermeer, the company had implemented even more informative and helpful instructions in its newest plant: solid modeling that offered the ability, in the words of the employee who took me through the new facility, “to be able to zoom in, zoom out, explode the part, put it back together, rotate it.” Solid modeling in CAD involves representing the object from the inside and the outside, allowing cutaway and exploded views. In other words, solid modeling software can reduce the spatial ability required to complete a task.

Yet another supplement to technical drawings are jigs and fixtures. Differentiating one from the other, engineering researchers Charles Chikwendu Okpala and Ezeanyim C. Okechukwu wrote that a jig “is the device which guides the tool” (Fig. 8.6) and a fixture “is a device that securely holds the job in position during machining operations” (Figs. 8.7 and 8.8).³⁸ Fabrication shops that produce thousands of the same item—production welding—commonly use fixtures to hold components in place so that employees can assemble and weld them quickly. With fixtures and jigs, welders don't need to measure to determine where one piece should be welded to another. They don't need to check alignment. Jigs and fixtures make the fabrication process far more efficient, increasing accuracy and reducing production and quality-control costs.³⁹ Because Howe's is a job shop with few long fabrication runs, we don't use fixtures and jigs every day. But if we will make multiples of some item—especially if there's a chance that we'll do yet another production run of the item in the future—we'll develop a fixture. Fixtures and jigs take time to develop, so the payoff in efficiency must counterbalance the time spent in constructing them. For example, at Howe's, Zach created fixtures and jigs to aid in the process of building goat cages, an ongoing project for a local farmer. After building one cage and learning that the client wanted at least 10 more, Zach built fixtures for welding the cage's rather complex doors. Zach's fixtures and jigs, along with a process description that he developed, hold and convey his proficiency in the tasks involved in building a cage and help the next person achieve accuracy and maintain consistency.

Enveloping an object, fixtures, like technical drawings, represent an item's space. And building fixtures requires precision. A weld technician at Quality Manufacturing explained the process:

We got shims and all different denominations and sizes and angles and everything. And you would, you would constrain your part. And then we inspect it ourselves, our lead guy inspects it, and then it goes to a free weld inspection in the lab. And then they will give it back to us. We'll weld it. And, our lead guy will inspect it, and then it goes to the lab again. And then we're free to go ahead and start producing it. But it's a special thing. Some guys

Fig. 8.6 The jig that Zach created to guide the oxyacetylene torch when cutting C-channel at the base of a goat cage

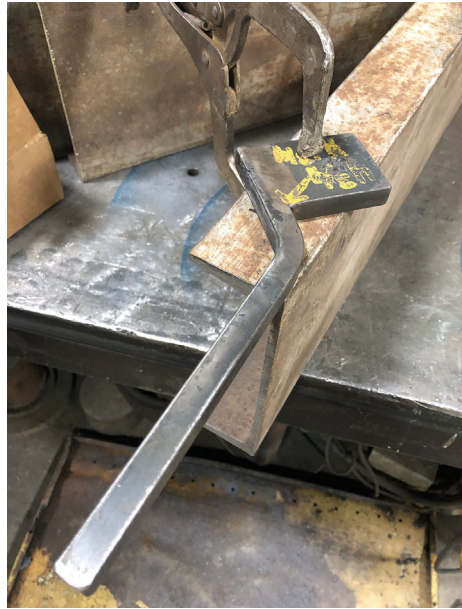
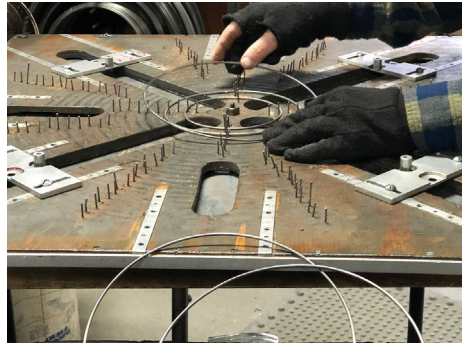


Fig. 8.7 The fixture that Jim designed for my lampshade skeleton project. On the left, the fixture holds a steel lampshade skeleton. I made it as a prototype for the client before switching to stainless steel. On the right, the fixture holds an incomplete stainless-steel lampshade skeleton

Fig. 8.8 A fixture for making a fan cover at Sorem Manufacturing



here can really plan together a modular fixture in a hurry with really creative things involved. You know, some guys are better than others. We all get it done, but some dudes are amazing.

Like the spatial ability required to understand and visualize orthographic representations, some people are stronger than others at developing fixtures. But this weld technician's comment also makes clear what research on the development of spatial ability says: While some people seem to have greater natural spatial ability, everyone can improve with scaffolded learning and practice.

As with their building of fixtures, tradespeople create templates to ensure that the dimensions of their fabricated products, including its bends and curves, meet the specifications directed in the technical drawing. Figure 8.9 shows a wall of templates used at Custom Steel Service to make cylinders. When I visited Custom, I talked with a shop manager while watching an employee roll sheets of steel into cylinders:

Jo: And so does he have any drawings or specifications that he's going off of? How does he know the diameter of the tubing?

Manager: He has a print.

Jo: Okay.

Manager: He's rolled tens of thousands of these. So he's got-

Jo: [Spotting a wall of templates] Oh, template. Okay.

Manager: I don't think he even has the print pulled out.

Jo: Okay.

Manager: He has notes on everything he ever rolls.

Jo: Oh, cool. Oh. Okay.

Manager: Press brake die numbers, so he knows which dies to use. The settings on the press.

Like Zach's development of fixtures and jigs for the goat cages, the master roller at Custom had created templates that combined spatial guidance with the textual guidance of his notes. His templates aided his own recall and helped to scaffold the learning of anyone else who did the job later.

Nearby, I spotted an angled cylinder with paper pieces taped to it. When I asked whether those pieces were also for a template, the manager explained that rather than

Fig. 8.9 A wall of templates at Custom Steel Service



having the fabricators at Custom work from a technical drawing, the client brought in the part that he wanted duplicated. Representing the angles and slight bends would be easier with a template:

Owner: There's one piece that we're struggling getting.... We'll model something off of the actual part. Then, once we get one good one, we'll make this so that we now have a pattern, a match.

Jo: You're putting each one on the template?

Owner: Yes. Sometimes it's better to keep it simple.

They'd be making multiples of this challenging part, and the template would help ensure that each iteration adhered to the dimensions of the original.

At Howe's, Jim frequently makes templates to supplement a technical drawing or, because we deal most often with one-off fabrication or repair work, in place of a technical drawing (Fig. 8.10). For example, each time Jim takes a handrail fabrication job, he makes a template of the stairs, including where they reach the building and where they touch the ground. The template helps in placing the posts and the rails during fabrication. Also, when we create curves in metal, either with the press brake, the Hossfeld bender, or the Di-Acro bender, we might create a template to ensure that the radiuses match what we need.

Even with the support of process descriptions, fixtures, jigs, and templates, in all the shops I visited, newcomers learned to interpret technical drawings with the help of more-expert people. As one welder told me about learning to read technical drawings, "I had a lead worker who would show me what's important to know and how to scan over something and absorb it all at once." Indeed, the biggest operations had

Fig. 8.10 Matching the bends in flat bar to a template at Howe's



formalized these relationships with lead welders or weld technicians who help less knowledgeable employees interpret the orthographic drawings, the welding symbols they contain, and other documentation aimed at facilitating their work. At Quality Manufacturing, welders receive formal training, but they also get support from a lead welder:

Our basic process is you have a welder, and they have a lead person who's an experienced welder who is also kind of managing them. So the, the lead person's responsible for setting them up on the job, making sure that their settings are correct. ... They work with the welder to get the settings right. To get the part right. If there's a process that I should be going over with them- They do all of those things.

Essentially, this lead welder does what Jim has done for me when I've had to work from a technical drawing: They explain the technical drawing, along with demonstrating and explaining any unfamiliar steps in preparing for and carrying out the task. At Quality, the lead welder scaffolds the less experienced person's conceptual knowledge, including conventions of orthographic drawings and welding symbols, and procedural knowledge, including the setup of the welding machine and the order of tasks.

Conclusion

My visits to fabrication shops suggested that production welders find support in interpreting technical drawings, support that comes via supplements to their orthographic views and welding symbols, including process descriptions, isometric drawings, solid-model representations, jigs, fixtures, and templates. Nevertheless, welders must develop competence in reading technical drawings for fabrication. This holds especially true for welders working in smaller shops that often lack resources to generate, compile, and update process descriptions and other aids to fabrication.

It's no wonder that technical drawings overwhelm fabricators when they first encounter them; they require people to flex spatial ability and to decode the syntax of an unfamiliar symbol system. And like repair and fabrication projects, each new technical drawing can bring unfamiliar inscription elements, such as an unfamiliar weld symbol or abbreviation. Moreover, fabricators encounter poorly drafted technical drawings and illogical welding symbols with some frequency. On the welding subreddit, users post images of technical drawings they've been tasked with interpreting, asking for others' input on what the engineer could have meant. For example, in response to one redditor's question, "What do these symbols mean?" a senior contributor and moderator responded:

Means your engineer is randomly clicking options in cad. It's a fillet on top of a 30° [30 degree] bevel. Grind the root side flat. All around. But from this view I don't see how the fillet is possible (unless one member is taller than the other) and the all-around seems unnecessary. And it's upside down, symbol above the reference line means weld from other side, which doesn't match the dwg [drawing].⁴⁰

The difficulties inherent in technical drawings multiply when they contain drafting errors.

People at the novice-level stage need rules to follow, so people just starting to learn how to interpret technical drawings need teachers who can scaffold their learning with materials that pose sequential challenges, one building on the next, culminating in interventions targeting learners' ability to break down complicated drawings into their components and thus to interpret them in a stepwise process that avoids overwhelm. To strengthen the ability to envision 3D objects, learners greatly benefit from scaffolded interactions with a more expert teacher, someone who can identify, for example, where students have missed hidden lines and how to indicate a countersunk hole. They also benefit from extensive deliberative practice, moving from simple to complex drawings and between interpretation and production with a teacher checking on their work.

While fabricators are most often concerned with interpreting technical drawings, as opposed to producing them, learning to interpret hinges on strengthening the ability to see 3D in 2D representations. Generating 2D representations from 3D objects helps strengthen that ability because it forces learners to translate 3D into 2D. Methods like the glass box and Kurszewski's bowl work in that they help eliminate distracting details and thus help students focus on one view at a time.⁴¹

While research suggests that some people may have more natural ability to visualize 3D objects, it has also shown that all people progress through scaffolded learning and deliberative practice, even in the realm of envisioning different perspectives by mentally rotating objects. Welders' concern for interpretation of technical drawings means that they would all benefit from interventions that target their spatial abilities.

In addition, welders new to technical drawings must learn an unfamiliar symbol system—welding symbols. Welders need to connect weld symbols to their referents, noting the semantic closeness of the symbol to the referent. They also need to learn the required and optional slots in a welding symbol's syntax—where the pitch appears and where the leg size appears, for example. They should understand which syntactic elements frequently occur, such as the weld's length. Similarly, they should understand common abbreviations, such as "CJP" for complete joint penetration. Having learned how to parse a welding symbol, learners would benefit from scaffolded and learning and deliberative practice that moves from simple syntax to complex syntax. Besides analyzing orthographic and isometric drawings to understand the referents of welding symbols, students would benefit from 3D models that show the outcome of a welding symbol's procedure. I saw such models used at Power Brace and other fabrication training facilities to illustrate simple welding symbols; more complex models would help learners parse complex and intimidating welding symbols too. Analyzing already fabricated subassemblies and products against their technical drawings would facilitate such development.

In short, although my technical drawing instructor didn't seem interested in taking on the challenge, it's possible to create a useful course that focuses on interpreting technical drawings and the welding symbols they contain, provided the teacher gathers appropriate materials and plans activities that will progressively challenge students to strengthen their spatial abilities.

Notes

1. Bento da Silva and Agostinho, "A Strategy for Teaching," 1940.
2. Melton and Stewardson, "The American Drafter," 2.
3. Coppi, Cattaneo, and Gurtner, "Exploring Visual Languages," 91.
4. Melton and Stewardson, "The American Drafter," 5.
5. Melton and Stewardson, "The American Drafter," 7.
6. Melton and Stewardson, "The American Drafter," 9.
7. Goldschmidt, "To See Eye to Eye," 44.
8. Eckert et al., "Sketching across Design Domains."
9. Current-Spare-6429, "mechanical drawings. can anyone help me understand."
10. Such_Pie_3781, "Can someone rough sketch a pictorial view."
11. McGee, "Human Spatial Abilities," 893.
12. Shepard and Metzler, "Mental Rotation of Three-Dimensional Objects."
13. Folk and Luce, "Effects of Stimulus Complexity."
14. Lovett and Schultheis, "Spatial Adaptation."
15. Linn and Petersen, "Emergence and Characterization."
16. Levine et al., "Sex Differences in Spatial Cognition," 129.
17. Xu and Franconeri, "Capacity for Visual Features," 129.

18. Farah and Kosslyn, "Structure and Strategy."
19. Xu and Franconeri, "Capacity for Visual Features," 129.
20. Uria et al., "Methodology for Part Visualization."
21. Kurszewski, "A Study of an Alternative," 49.
22. Sroka-Bizoń and Terczyńska, "Perception of View."
23. Alias, Black, and Gray, "Effect of Instructions," 11.
24. Olkun, "Making Connections."
25. Marwa, Choji and Dalumo, "Improving Spatial Ability Skills"; Torner, Alpiste, and Brigos, "Spatial Ability."
26. Alias, Black, and Gray, "Effect of Instructions."
27. Arroyave Espinosa et al., "Solving Spatial Vision Difficulties," 2.
28. Olkun, "Making Connections."
29. Uttal and Yuan, "Using Symbols," 296.
30. Peirce, *Collected Papers*.
31. American Welding Society/American National Standards Institute, *Standard Symbols*.
32. International Standards Organization, *Symbolic Representation on Drawings*.
33. Sproat, *Symbols*, 28.
34. Liu et al., "Investigation of the Contributory Factors," 3.
35. Roberts, MacLeod, and Fernandes, "Symbol Superiority," 11.
36. Cerulo, "Putting It Together," 113–114.
37. Sproat, *Symbols*, 27.
38. Okpala and Okechukwu, "The Design and Need," 214.
39. Okpala and Okechukwu, "The Design and Need."
40. BadderBanana, "Means your engineer is randomly clicking options in cad."
41. Kurszewski, "A Study of an Alternative."

References

- Alias, Maizam, Thomas R. Black, and David E. Gray. "Effect of Instructions on Spatial Visualisation Ability in Civil Engineering Students." *International Education Journal* 3, no. 1 (2002): 1–12.
- American Welding Society/American National Standards Institute. *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. A2.4. Miami, FL: AWS, 2012.
- Arroyave Espinosa, Luis Miguel, Álvaro Antón-Sancho, Edwan Anderson Ariza-Echeverri, and Diego Vergara. "Solving Spatial Vision Difficulties Related to the Instruction of Welded Joints by Using PDF-3D." *Education Sciences* 13, no. 1 (2022): 28. <https://doi.org/10.3390/educsci13010028>.
- BadderBanana. "Means your engineer is randomly clicking options in cad." Reddit, February 13, 2022, <https://www.reddit.com/r/Welding/comments/srnzgi/comment/hwsupf5/>.
- Bento da Silva, Iris, and Oswaldo Luiz Agostinho. "A Strategy for Teaching and Learning Technical Drawing." *International Journal of Engineering Education* 34, no. 6 (2018): 1939–1950.
- Cerulo, Karen A. "Putting It Together: Measuring the Syntax of Aural and Visual Symbols." In *Vocabularies of Public Life*, edited by Robert Wuthnow, 111–129. London: Routledge, 2002.
- Coppi, Alessia Eletta, Alberto Cattaneo, and Jean-Luc Gurtner. "Exploring Visual Languages across Vocational Professions." *International Journal for Research in Vocational Education and Training* 6, no. 1 (2019): 68–96.
- Current-Spare-6429. "mechanical drawings. can anyone help me understand." Reddit, November 8, 2022, https://www.reddit.com/r/Welding/comments/yq3eud/mechanical_drawings_can_anyone_help_me_understand/.
- Eckert, Claudia, Alan Blackwell, Martin Stacey, Christopher Earl, and Luke Church. "Sketching across Design Domains: Roles and Formalities." *AI EDAM* 26, no. 3 (2012): 245–266.

- Farah, Martha J., and Stephen M. Kosslyn. "Structure and Strategy in Image Generation." *Cognitive Science* 5, no. 4 (1981): 371–383.
- Folk, Mark D., and R. Duncan Luce. "Effects of Stimulus Complexity on Mental Rotation Rate of Polygons." *Journal of Experimental Psychology* 13, no. 3 (1987): 395–404.
- Goldschmidt, Gabriela. "To See Eye to Eye: The Role of Visual Representations in Building Shared Mental Models in Design Teams." *CoDesign* 3, no. 1 (2007): 43–50.
- International Standards Organization. *Symbolic Representation on Drawings: Welded Joints*. 2553:2019. ISO, approved March 2019, corrected September 2021.
- Kurszewski, Brian. "A Study of an Alternative Visual Aid Used to Teach Orthographic Drawing in an Introductory Drafting Course." Master's thesis, University of Wisconsin-Stout, 2007.
- Levine, Susan C., Alana Foley, Stella Lourenco, Stacy Ehrlich, and Kristin Ratliff. "Sex Differences in Spatial Cognition: Advancing the Conversation." *WIREs Cognitive Science* 7, no. 2 (2016): 127–155.
- Linn, Marcia C., and Anne C. Petersen. "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis." *Child Development* 56, no. 6 (1985): 1479–1498.
- Liu, Jing, Huiying Wen, Dianchen Zhu, and Wesley Kumfer. "Investigation of the Contributory Factors to the Guessability of Traffic Signs." *International Journal of Environmental Research and Public Health* 16, no. 1 (2019): 162. <https://doi.org/10.3390/ijerph16010162>.
- Lovett, Andrew, and Holger Schultheis. "Spatial Adaptation: Modeling a Key Spatial Ability." *Spatial Cognition & Computation* 21, no. 2 (2021): 89–113.
- Marwa, Nuili, J. Choji and B. D. Dalumo. "Improving Spatial Ability Skills of First-Year Students in Basic Engineering Drawing Using a Solid Pair Model." *Open Journal of Educational Development* 1, no. 2 (2020): 1–12.
- McGee, Mark G. "Human Spatial Abilities: Psychometric Studies and Environmental, Genetic, Hormonal, and Neurological Influences." *Psychological Bulletin* 86, no. 5 (1979): 889–918.
- Melton, David W., and Gary Stewardson. "The American Drafter: Why Use 1st Angle Projection in a 3rd Angle World." *Technology Interface Journal* 9, no. 1 (2008). https://tiij.org/issues/iss ues/fall2008/10_Melto/10_Melto.pdf.
- Okpala, Charles Chikwendu, and Ezeanyim Okechukwu. "The Design and Need for Jigs and Fixtures in Manufacturing." *Science Research* 3, no. 4 (2015): 213–219.
- Olkun, Sinan. "Making Connections: Improving Spatial Abilities with Engineering Drawing Activities." *International Journal of Mathematics Teaching and Learning* 3, no. 1 (2003): 1–10.
- Peirce, Charles Sanders. *Collected Papers of Charles Sanders Peirce, Volumes I and II: Principles of Philosophy and Elements of Logic*, edited by Charles Hartshorne and Paul Weiss. Cambridge, MA: Harvard University Press, 1932.
- Roberts, Brady R. T., Colin M. MacLeod, and Myra A. Fernandes. "Symbol Superiority: Why \$ Is Better Remembered Than 'Dollar.'" *Cognition* 238 (2023): 105435, 11. <https://doi.org/10.1016/j.cognition.2023.105435>.
- Sproat, Richard. *Symbols: An Evolutionary History from the Stone Age to the Future*. Cham, Switzerland: Springer Nature, 2023.
- Shepard, Roger N., and Jacqueline Metzler. "Mental Rotation of Three-Dimensional Objects." *Science* 171, no. 3972 (1971): 701–703.
- Sroka-Bizoń, Monika, and Ewa Terczyńska. "Perception of View—How to Develop Spatial Imagination." *Journal Bulletin of Polish Society for Geometry and Engineering Graphics* 25 (2013): 19–26.
- Such_Pie_3781. "Can someone rough sketch a pictorial view." Reddit, July 6, 2023, https://www.reddit.com/r/Welding/comments/14sbnq8/can_someone_rough_sketch_a_pictorial_view_this/.
- Torner, Jordi, Francesc Alpiste, and Miguel Brigos. "Spatial Ability in Computer-Aided Design Courses." *Computer-Aided Design and Applications* 12, no. 1 (2015): 36–44.
- Uria, Sierra, Egoitz, Mikel Garmendia, Javier Muniozguren, and Isabel Larrakoetxea. "Methodology for Part Visualization Problem Solving (Reading, Interpretation and Creation of Multiview Technical Drawings)." In *Proceedings of ICED 09, the 17th International Conference on Engineering Design*, vol. 10, edited by M. Norell Bergendahl, M. Grimheden, L. Leifer,

- P. Skogstand, and U. Lindemann. Palo Alto, CA, 2009. <https://www.designsociety.org/publication/28864/Methodology+for+Part+Visualization+Problem+Solving+%28Reading%2C+Interpretation+and+Creation+of+Multiview+Technical+Drawings%29>.
- Uttal, David H., and Lei Yuan. "Using Symbols: Developmental Perspectives." *WIREs: Cognitive Science* 5, no. 3 (2014): 295–304.
- Xu, Yangqing, and Steven L. Franconeri. "Capacity for Visual Features in Mental Rotation." *Psychological Science* 26, no. 8 (2015): 1241–1251.

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Chapter 9

Learning Shop Genres



Abstract This chapter examines three written genres in fabrication shops: invoices, near-miss reports, and nonconforming-part tags. Such genres are complex. For example, invoices manifest multiple contingencies, such as the price of steel at the time of purchase and the time of sale, the price of competing, cheaply manufactured alternatives, and the efficiency of the employees. The chapter ends by considering how writing instructors might use these genres and other writing common to skilled trades in the writing courses skilled-trades students take as a part of their degree programs and how skilled-trade instructors might employ them to facilitate trade students' building of conceptual and procedural knowledge.

Introduction

I think it's not common to associate a shop floor with written documents, but written language pervades fabrication shops—both job shops like Howe's and production shops like John Deere. Fabricators of all types use a variety of texts, such as technical manuals and process descriptions, and produce a variety of texts as well. I only guessed at this truth when I started welding school and began collecting videorecordings of welding instructors in scaffolded interactions with their students. After I'd completed that study, which culminated in my book *Welding Technical Communication: Teaching and Learning Embodied Knowledge*, I wanted to employ the expertise I'd developed during 20 plus years in writing studies to a new domain: the fabrication shop floor. So I began my visits to fabrication shops around Iowa, looking to investigate the written genres used and produced by welders and others working in fabrication. This chapter discusses three genres of writing that I found during my visits. Invoices, near-miss reports, and nonconforming-part tags are genres that shop-floor workers learn to produce.

Such genres have largely been overlooked in technical communication research, partly for pragmatic reasons and partly for reasons of bias. Pragmatically, writing scholars have difficulty accessing these genres because doing so means gaining access to company documents, and companies are reluctant to share for fear of

weakening their position in the market or releasing proprietary information. To some extent, these genres constitute what writing researchers have called occluded texts, “formal documents which remain on file” but are not accessible to others outside their limited audience.¹ Thus, people charged with writing these texts “have no adequate knowledge of the context.”²

The field of writing studies has also avoided these genres because of a sort of bias; these genres tend to be brief and to use templates that constrain what and how much authors can write. They don’t necessarily look like “real writing.” For example, a nonconforming-part tag constrains the writer via its small size and via the lines allotted to explain the nonconformity. Even students and teachers in career and technical education (CTE) can underestimate the literacies needed in their work, as Richard Edwards, Sarah Minty, and Kate Miller found in their study of a hospitality curriculum.³ So, in other words, such genres seem less substantial and less influential than genres that scholars have examined in depth, such as academic research articles and corporate communications.

They’ve also thus far been overlooked in a relatively new field related to technical communication: English for vocational purposes. This branch of English for specific purposes attends to the language used in skilled trades and analyzes its contexts of use and its influences on the workplace. Researchers such as Averil Coxhead have, for example, analyzed corpora—large groups of texts—to determine the technical vocabulary that people entering the plumbing industry will need on the job.⁴ With other researchers, Coxhead examined not only the lexical features of vocational texts, but also grammatical and multimodal features. Their book, *English for Vocational Purposes*, covers a range of written and spoken discourse, from tutoring in automotive technology classes to visual elements in textbooks, to the role of reading in trades education. But as Coxhead and her colleagues pointed out, their studies—like those of most others researching skilled-trade literacies—have focused on “the educational context and [do] not extend to language use in vocational workplaces.”⁵

In addition to examining invoices, near-miss reports, and nonconforming-part tags, I consider how writing instructors might use these genres and other writing common to skilled trades in the writing courses that skilled-trade students take as a part of their degree programs and how skilled-trade instructors might employ such genres to facilitate students’ building of conceptual and procedural knowledge. In sum, in this chapter, I examine three skilled-trade genres to begin the process of illuminating occluded skilled-trade genres. Then, I discuss how these and other genres used and produced in skilled-trade settings might be used in writing courses and in disciplinary courses to advance students’ learning.

Invoices

At a small shop like Howe’s, everyone who repairs and fabricates produces invoices. In other fabrication shops, shop-floor workers might not participate in developing an invoice for their projects. In larger shops like Power Brace, managers create invoices

from project data the employees' input into the online management system. Also, fabrication companies use prior jobs to estimate the employee hours a project will take and then bid on the project and finish the work for the bid price. At still other fabrication facilities like John Deere and Vermeer, welders and other shop-floor workers fabricate the company's own products, as opposed to products for a client. But in small shops like Howe's, creating invoices becomes part of an employee's daily tasks. At Howe's, we write up an invoice for each customer, even ones who purchase steel rather than having us do a repair or fabrication project. Every purchase requires an invoice.

Invoices are some of the oldest, if not the oldest, documents in human history. Priests living in Sumer—now south-central Iraq—invented cuneiform to track crops and products produced from them, such as wine. This writing system, consisting of wedge shapes, was logosyllabic, meaning it used characters to represent a word or a morpheme, which is a smaller language unit that is not a word but nevertheless has meaning, such as the “s” marking plurality in English. As far back as 2900 BCE, the Sumerian priests wet clay slabs and then inscribed them.⁶ And even in antiquity, these accountants used invoice templates. The Pylos Tablet, circa 1450 BCE, features Linear B—the script of Mycenaean Greek—on ready-to-fill lines. Even back then, people standardized how they tracked sales of items such as jugs and lamps.⁷

At Howe's, these lists of materials and services at first appear rather straightforward; if you worked four hours on a project, you bill for four hours of labor. If the project used 10 feet of $2 \times \frac{1}{4}$ -inch flat bar, you bill for that quantity of flat bar. But with more consideration, these supposedly uncomplicated invoice line items reveal their complexity. Part of becoming a member of the work community is learning to navigate these complexities.

Working in a repair and fabrication shop like Howe's forces you to consider the shifting costs of materials, mainly steel, aluminum, and stainless steel. The cost of these materials changes according to their markets, which are in turn dependent upon national and international policies and events. After Jim buys steel from his suppliers for use in projects or for resale, the price may rise or drop substantially, complicating how we determine material costs on invoices. When I started working at Howe's in spring of 2022, the pandemic had wreaked havoc on commodities like steel. When production slowed in 2020, surpluses caused steel prices to drop.⁸ Then, when production surged in 2021, material shortfalls, shipping delays, and inflation pushed prices to all-time highs.⁹ Then, prices fell again when supply caught up with demand, but wars in Ukraine and Gaza destabilized the market again.¹⁰

Volatility has continued, so at Howe's we check suppliers' prices frequently to determine the price per foot or price per square foot that we should charge to customers. We use an online spreadsheet to keep track of our prices. When we've called to check a particular size and thickness, such as 2-inch $\times$ 3/16-inch flat bar, we type in the price and note the date that we checked it. Each time I write up an invoice, then, I have to decide whether to call the supplier for an updated price or to use the price in the spreadsheet, asking myself, for example, is a price six months old too old to use?

More complicated than settling on a steel price is determining the price to charge a customer for labor. The first question that arises is this: Which activities count toward billable hours? I've described in other chapters how Howe's overflows with materials, machines, and tools. Do I charge customers for the time I spend moving a welding machine to my worktable or the time I spend clearing amassed detritus from a table to make a spot to work? Do I charge for the time I spend cleaning up after I've finished a project and for the time I spend writing up and calculating the invoice line items? Sometimes it's difficult to delineate the boundary between billable and nonbillable hours.

Another labor question involves the quantity of billable hours devoted to a project. Employees with competent-level knowledge or lower will take longer to complete the tasks involved in a project because each step of the way, they'll deliberate longer than someone with greater expertise. Jim regularly bills for fewer hours than I've actually spent on a project. In late 2022, I wrote:

I made up an invoice for the wheelchair ramp I did yesterday. We charged for just a half hours of work. Today, after all that grinding and welding, we charged for just one hour of work. Jim charges for what he thinks the work should take—even though he's got me doing it, and I take twice as long.

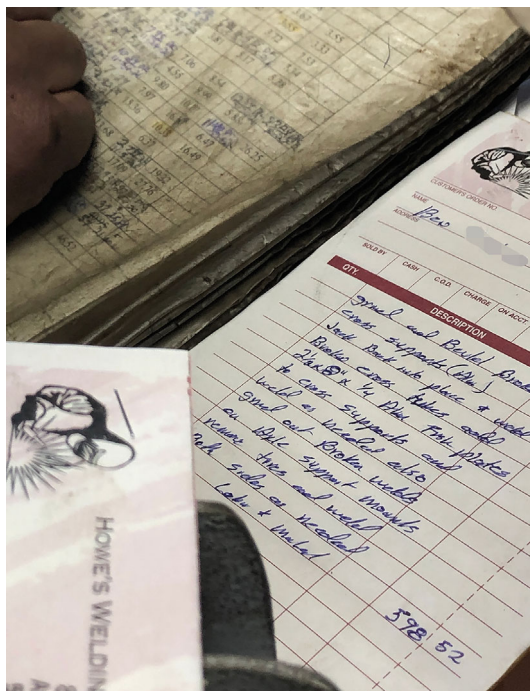
Jim calls me a “fledgling,” excusing my slowness, and asks whether I could do the project faster if I had to do it again. Almost always, the answer is yes. I could set up the lathe faster if I had to do it again because now I understand how to change the angle on the bit. I could stick weld around round-stock spikes more quickly because I've practiced it. That said, after a few years in the shop, I've told him a couple times that I did indeed finish the project as quickly as anyone could. Each time, Jim looked at me skeptically and subtracted 30 minutes from the labor time I listed on the invoice. I wrote in August 2023 on one of these occasions:

Jim told me to say that the labor on the birdfeeders had been just 2.5 hours. He's worried that people will say he charges too much. The guy didn't bat an eyelash at the price, though, when I called to tell him that he could pick them up.

Jim calculates billable hours based on the work of proficient- and expert-level workers—not fledglings like me (Fig. 9.1). He runs the risk, then, of losing money every time I take on a project. This is the risk of investing time into training someone; the investment only pays off if the person stays and begins to finish projects efficiently enough to turn a profit.

Finally, another complication relates to repairs of cheaply made house or lawn items, such as watering cans and shepherd's hooks. Cheap stuff takes more time to repair. It's often thin and poorly constructed, so you have to be extra careful when welding it, and you usually have to weld joints that the original manufacturer overlooked. Jim hates to say no when people ask him to repair cheap stuff. So it's possible to spend hours fixing something that the customer bought on Amazon for \$30. For example, one summer, a customer brought in a tree-shaped metal sculpture (Fig. 9.2). Thin tubes of LED lights intertwined around the metal rings of the “tree” and the star that was supposed to sit on top. The star had snapped off, and the customer

Fig. 9.1 An invoice that Jim wrote. It describes the labor on a trailer, including grinding and beveling and adding new supports



wanted us to weld it back on. Doing so, however, would mean unwrapping the LED tubing so that it wouldn't melt from the heat of the tig welding. On this rare occasion, Jim let me tell the customer that doing the work wouldn't be cost-effective for the shop. I think it was the threat of the tangle of LED lights that convinced him we were better off letting this project go.

Invoices force writers to research current prices for materials and to calculate the customer's cost in relation to the supplier's prices. More important, they require writers to communicate with customers, specifically, to describe and perhaps explain the steps of the invoiced project to justify the price of labor.

Near-Miss Reports

As mentioned in Chapter 7, near-miss reports are internal documents intended to improve safety practices. This genre’s aim, according to OSHA, is to describe “a potential hazard or incident in which no property was damaged and no personal injury was sustained, but where, given a slight shift in time or position, damage or injury easily could have occurred.”¹¹ Near-miss reports gather information on incidents, also called precursors, because these incidents “are not self-revealing,” except to the people who experience them.¹² Organizations lose potentially helpful information

Fig. 9.2 This holiday lawn sculpture with LED tubing was an item not worth the cost of repair



about the health and safety of employees if they fail to gather and analyze near-miss data.

Near-miss reporting started in the early 1930s, with the publication of Herbert William Heinrich's *Industrial Accident Prevention: A Scientific Approach*.¹³ Heinrich conceived the safety pyramid, also called the accident triangle, after analyzing 75,000 injury records from an insurance company's archives. His pyramid organizes safety incidents into levels, from hazardous acts and conditions at the bottom, to near misses, to minor accidents, to serious accidents, to fatality at the top of the pyramid. Heinrich argued that analyzing near misses and minor accidents and improving training and conditions to lower their frequency would lower serious accidents and fatalities as well. Following this research, aviation companies began implementing near-miss reporting. The practice spread to other industries in the 1970s, particularly after disasters like the 1976 Seveso chemical spill that exposed thousands of human and nonhuman beings to six tons of aerially released harmful chemicals.¹⁴

Scholars who study occupational safety have examined reporting policies that organizations can use to incentivize workers to report their near misses. Such incentives overcome employees' reluctance stemming from potential blame from other employees, interference with teamwork, shame from making a mistake, and fear of disciplinary actions.¹⁵ Research on near-miss reporting has also examined the systems employers can use to analyze reports to improve health and safety. To facilitate analysis, companies often use templates to organize employees' near-miss experiences. These templates typically request:

- The date, time, and place of the incident.

- The type of concern (e.g., an unsafe act, condition of an area, condition of equipment, or use of equipment).
- A description of the concern.
- An assessment of whether any safety procedures had been violated.
- Recommendations for fixing the concern.

Interestingly, even though companies rely on workers to describe their near-miss incidents, research on near-miss reporting and systems barely mentions the quality (i.e., the helpfulness) of workers' reports. For example, Maria Grazia Gnoni and her colleagues conducted a meta-analysis of 40 articles about near misses, finding that only 10 focused on identifying and reporting near misses and even these primarily focused on automatic detection of incidents rather than on employees' reports.¹⁶

The lack of interest in report quality likely stems from their placement in the back-and-forth of organizational communication about safety. At big production facilities, employees' reports, usually submitted through an online form, initiate further communication about the event. If the employee puts their name on the report, a manager will follow up with a conversation aimed at elaborating what happened. Thus, the employee's near-miss report need not rigorously detail the event or hazard because a conversation will fill in the story's gaps. That said, for the reasons mentioned above, employees don't always want to attach their names to near-miss reports; the option to remain anonymous keeps a near-miss reporting system robust. Quality of reporting in such cases would make a difference in understanding how and why the event occurred. For example, near-miss reports like these, gathered during my shop visits, would benefit from additional detail if the writers were unknown:

- Mainframe tipped over during transport. Top plate of front mainframe dolly separated base of dolly.
- Retainer pin slipped out of fixture and allowed valve to swing loose, almost falling to the floor.
- Hose was left unconnected. Upon starting unit, if one happened to be in line of fire of this hose, hydraulic oil injection possible.

What happened to make the mainframe tip over? How did the retainer pin slip out? Where did the incidents occur? How many people were involved or nearby? Analysis and subsequent actions benefit from reports with relevant detail.

Nonconforming-Part Tags

Like near-miss reports, nonconforming-part tags are occluded in that they are internal documents, rarely seen outside a fabrication shop. Designed to help organize production and maintain quality control, nonconforming-part tags have their roots in craft guilds of medieval Europe. Guilds maintained product quality, inspecting for defects and marking those products that passed inspection. But the craftspeople also marked their own products, and those marks allowed faulty items to be traced back to the

people who made them. During the Industrial Revolution, Taylorism took over, increasing production without increasing the number of workers. When quality problems arose, manufacturers developed inspection systems to keep defective products from customers. In the 1920s, Walter Shewhart, known as the father of statistical quality control, developed mathematical models to monitor the quality of a manufacturer's output.¹⁷

Today, to gain ISO 9001 certification—the certification for management of quality—a manufacturer must show that it has a robust process to ensure that nonconforming products are identified and sequestered to prevent their unintended use.¹⁸ ISO standards don't dictate how a company should identify and isolate nonconforming parts, but companies use these methods frequently:

- A tag, sign, sticker affixed to the part.
- A labeled bin or box the part is placed in.
- A note or painted code on the part.
- Tape or ribbon wrapped around the part.
- A barcode affixed to the part.

Whether a manufacturer seeks or sustains ISO 9001 certification, it needs some way to signal nonconformance. Thus, shop-floor employees in smaller production shops and big plants fill out nonconforming-part tags. These tags, typically ordered from printers, contain a template that guides the employee's communication. Namely, the tag requests the part number and the reason the part fails to conform to standards. The writer might also state the action to be taken. For example, on one nonconforming-part tag that I saw during a shop visit, not only did the writer state how the part failed to conform (i.e., holes in the wrong location), but also stated what's to be done with it, or the disposition—that it was to be sent to the tool room. The writer also noted other important details: the size of the holes (0.75 inch), the threads per inch (10), and the course-thread tolerance (UNC-2B).

Similarly, Fig. 9.3 shows a nonconforming-part tag from Power Brace. There, the writer supplied (1) the reason for the nonconformity (i.e., lack of gas), (2) the nonconformity (i.e., porosity in the weld), and (3) the actions to be taken.

Writing about the importance of having a system to identify and correct nonconformities, Craig Cochran, a quality management expert, argued that the recording

Fig. 9.3 A nonconforming-part tag at Power Brace

REJECTED

JOB NO. _____ P. O. NO. _____

PART NO. 57Q350BPC SERIAL NO. _____

PART NAME _____

NO. OF PIECES REJECTED 2

REASON Robot ran out of gas
Porosity throughout - Grind out
& Re-weld

INSPECTOR NC DATE 9/30/02

U LINE
1-800-855-5510

process must be “simple and concise.”¹⁹ The example in Fig. 9.3 follows Cochran’s guideline; it is indeed simple and concise. However, as with near-miss reporting, it’s difficult to find any guidelines that shop-floor employees could use as they, as newcomers to the genre, begin to describe and explain nonconformities and to direct others in solving the problem.

Skilled-Trade Knowledge in the Writing Classroom

My work at Howe’s and my visits to other shops around Iowa revealed that fabrication work requires writing. While trades writing generally doesn’t involve long and elaborated genres like recommendation reports or business proposals, it does nevertheless require tradespeople to consider their purpose and audience and the setting of their communication. Occluded documents like invoices, near-miss reports, and nonconforming-part tags offer opportunities for both writing and skilled-trade teachers to develop students’ conceptual and procedural knowledge.

I’m certainly not the first person to think about ways that shop-floor genres and other writing related to trades might be employed in trades students’ disciplinary courses and in the writing course that many skilled-trade students take as part of their educational programs. Other researchers have investigated the outcomes of contextualized writing classes, writing classes that incorporate elements of students’ disciplines. These contextualized writing courses constitute one approach to a broader movement in writing: writing across the curriculum, or WAC. A WAC program is “any organized, recognized, and sustained effort—no matter how modest in people, resources, and funding—to help faculty in any and every course use writing more deliberately and more often.”²⁰ At the start of the twentieth century, university administrators and faculty generated WAC-inspired specialized writing courses, such as technical or business communication, sometimes as the second half of a sequence beginning with a first-year composition (FYC) course.²¹ They intended these courses to target more specific needs and interests. Although more honed than their FYC counterparts, these courses nevertheless target broad audiences as they try to meet the communication needs of large groups of students, such as all engineering majors or all business majors.

In contrast to writing courses like technical communication, contextualized writing courses home in on their audiences with even greater precision. In what would become a widely accepted definition of contextualization, Christopher Mazzeo, Sara Y. Rab, and Julian L. Alssid wrote in their study of basic skills programs in community colleges that contextualized courses “more seamlessly link the learning of foundational skills and academic or occupational context by focusing teaching and learning squarely on concrete application in a specific context that is of interest to the student.”²² Also writing about CTE, researchers Travis Park, Donna Pearson, and George B. Richardson wrote that a contextualized course “remains authentic to workplace problems and solutions.”²³ But such contextualization does not always manifest in the writing course that trades students take as part of their program of

study—even when that course focuses on technical communication. These classes tend to follow a curriculum that covers rhetorical concepts through students’ analysis and production of technical genres, such as instructions and technical descriptions, and career documents, namely cover letters and résumés. Developing career documents of course helps students obtain work within their field of study. And genres like instructions and technical descriptions provide relevant practice in audience analysis and in developing writing that manifests features such as specificity and quantification, conciseness and clarity, parallel structure, and usable and accessible document design. However, these genres don’t represent the genres that welding, automotive, and other trades students will write on the job.

Moreover, some schools housing skilled-trade programs do not require a course in technical or professional communication. Students have the option to enroll in a FYC course, even though most FYC curricula do not meet the literacy needs of skilled-trade students. In most FYC courses, students analyze fiction and nonfiction texts and respond to those texts in informative and persuasive essays. As Dustin Ledford wrote in his master’s thesis about a contextualized writing course, “Essays and research papers can be great tools for helping students understand writing. I have taught with these types of assignments for many semesters, but the more I have used them, the more I have questioned whether they were the *best* method to teach writing in the technical college setting” (emphasis in original).²⁴ Ledford’s doubts about typical FYC content led to his implementing a writing course contextualized for healthcare students at a two-year technical college. Ledford developed both low- and high-stakes assignments. His low-stakes assignments included text analysis, text evaluation, prewriting and drafting, analysis of medical jargon, and evaluation of online sources. His high-stakes assignments included a letter of response to a request, a comparison of documents on the same topic but written for different audiences, and instructions for insulin injections. Ledford developed these assignments with the idea that students’ investment in their writing would grow in relation to the direct relevance of their assignments to their profession.²⁵

Similarly, for her preparatory English course, Jennifer Holden visited CAT dealerships, interviewing 23 service managers, supervisors, warranty administrators, and technicians to understand their reading and writing practices. She wrote, “I had no idea what English skills apprentices utilized in their CAT courses or on the job. Knowledge of the CTE content and students’ future occupations seemed essential for the enrichment of my own curriculum.”²⁶ Through her interview research, she developed technician-relevant lessons and assignments, including those on the service report, a genre that “requires technicians to state the customer’s complaint, the machine’s cause of failure, any resultant damage, and—most importantly—the explanation of repair.”²⁷ Her goal, she wrote, was to build through collaboration with CAT professionals an understanding of which communicative activities would help students most in their careers.

Also working toward the learning outcomes of FYC, Sarah A. Parlier developed contextualized writing courses for four occupational programs: culinary arts, diesel-power equipment technology, Caterpillar Think BIG, and a General Motors

automotive-service program.²⁸ Parlier developed assignments that asked students to produce genres common in their fields, such work orders and accident reports. Parlier's study examined students' writing, pre- and post-course surveys, and pre- and post-course interviews. At the end of the semester, over half of the students met all the FYC goals, and most students met five out of six of them, including defining a context, making informed style choices, and adhering to the conventions of written discourse. She also found that, at the end of the courses, students saw themselves as "strong" writers, rather than the "average" writers they had assessed themselves to be at the beginning of the semester.²⁹

Like Parlier, Tanya Sorenson revised a writing course for trades students, specifically, students in welding, automotive repair, and construction. Like many professional, business, and technical writing classes, the professional writing class that Sorenson developed included job search documents, namely cover letters and résumés.³⁰ But like the other contextualized courses described above, it included genres relevant to students' trades, such as a response to a customer-complaint letter, an incident report, and a bid proposal. Sorenson found that "the immediate relevancy of the career documents seemed to catch the students' interest early in the quarter."³¹ And afterwards, as they tackled the trade genres, the students, Sorenson wrote, "found relevance and value in 'school writing' for the first time as they came to realize that 'school writing' was actually job writing and life writing."³²

Such contextualized writing classes developed for trades students strive to incorporate genres relevant to students' future employment. They attempt to move beyond genres that students will read on the job but are unlikely to compose, such as technical descriptions, to use genres that tradespeople compose—even if not very often, as is the case with incident reports. Invoices, near-miss reports, and nonconforming-part tags constitute three occluded and overlooked genres like those that Parlier, Sorenson, and others identified and incorporated into their writing courses. Focusing lessons on relevant genres like work orders and service reports allows teachers to help students analyze audience, purpose, and setting in relation to writing they'll develop in their work.

More specifically, the invoice genre can give students practice in describing materials and labor. Regarding labor, students can practice breaking down a project into its tasks, such as shearing plate, deburring pieces, punching, drilling, and chamfering holes, machining parts on the lathe or mill, fixturing the pieces, and welding the pieces together. Invoices can sometimes offer opportunities for briefly explaining choices in fabrication as well, such as why holes were drilled instead of punched and why tig rather than mig welding was chosen. Stylistically, invoices offer particularly good opportunities for practice in parallel structure.

Similarly, nonconforming-part tags join practice in analyzing part defects with practice in conveying those analyses concisely and clearly. Given that some nonconformities are not readily identifiable, students can also practice describing the defects they find, using specificity and quantification. And while not all nonconforming-part tags ask the writer to identify the action to take, students can practice writing verb-first instructions that direct the next steps. Indeed, lessons attached to this genre easily connect to lessons on the genre of instructions, where students differentiate between

declarative and procedural language and focus on word choice, sentence mood, and verb tense and number.

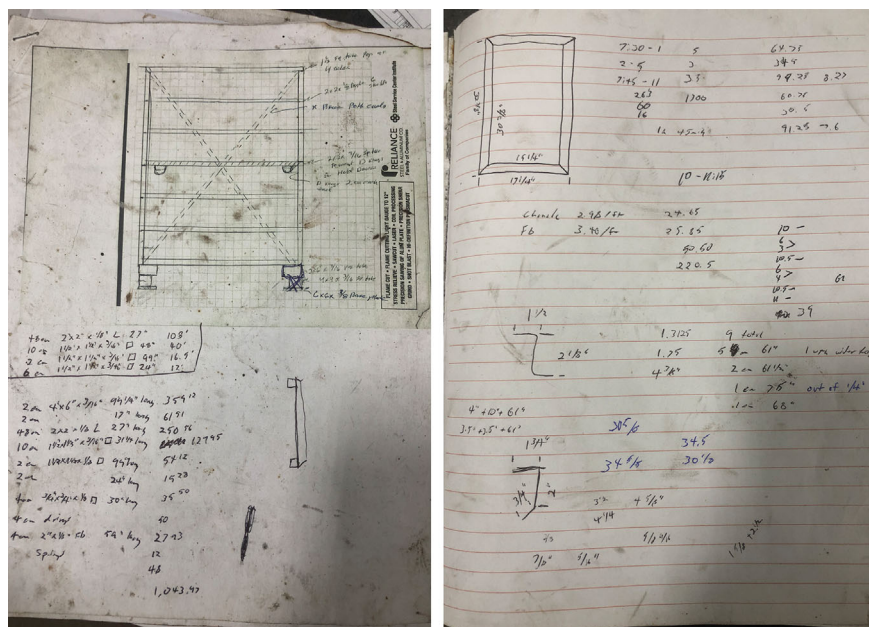
Near-miss reports, like the incident/accident reports that Parlier incorporated into her contextualized FYC course, provide opportunities for greater elaboration. Students can describe an event that they've experienced or use a teacher-provided scenario, practicing providing clear and relevant detail. They can explain why the event happened or why the hazard exists. They can explain how they avoided injury or how others might yet be injured if the hazard is not rectified. In short, near-miss reports, too, provide opportunities for analysis, detailed description, and coherent explanation. And like invoices, nonconforming-part tags and other shop-floor genres that tradespeople compose as opposed to read, near-miss reports make clear that tradespeople, too, are writers.

Writing in Skilled-Trade Classes

The WAC philosophy incorporates two complementary ways of using writing: writing to communicate and writing to learn. The writing classes described above focused on writing to communicate, where students' projects targeted the conventions, including the genres, common to communication in their chosen fields of study, such as welding. Although writing classes tend to focus on this part of WAC, disciplinary courses as well can incorporate activities aimed at developing students' disciplinary communication competences. Describing an initiative to embed English into CTE courses, specifically, welding and construction courses, Angela M. Kohnen detailed her work with two skilled-trade instructors: Doug, a construction teacher, and Harold, a welding teacher.³³ From these instructors, Kohnen learned more about the genres that they had produced on the job. Both instructors, for example, asked students to develop genres common in their fields. Kohnen described the welder's "daily journal" as a genre:

The daily journal of a welder, for example, is a jargon-heavy document that must be kept meticulously. It is multimodal (Harold mentioned including pictures to document problems) and for various audiences (once Harold's journal was used as evidence in a lawsuit).³⁴

I didn't see daily journals in the shops I visited, but at that point in my welding journey—when I was visiting fabrication sites—I didn't know to ask the tradespeople that I met whether they kept a journal tucked away somewhere in their workspace. That said, my colleague Adam, who has worked for several manufacturers in Iowa as well as for Jim, shared his journal with me (Fig. 9.4). In it, I found cuts lists and prices, notes on clients' drawings, Adam's own drawings, and lists of time spent on various tasks. Some of Adam's notes helped him remember dimensions and processes during fabrication; other notes—the cut lists and material prices and the time on tasks—would find their way into an invoice. By introducing journals and other genres, trades courses can help students understand the literacies of their professions and participate fully within them. Thus, the writing to communicate part of WAC corresponds to Lave



summarize” to relevant content. He also asked them for daily journal entries that explored what they worked on, what problems they encountered, what solutions to those problems they tried.⁴⁰ Such writing typifies writing to learn.

Indeed, when I visited Lake Superior College in Duluth, Minnesota, as part of an earlier research project, I met an instructor there who had incorporated the writing-to-learn philosophy into his welding courses. At one point in my interviews with him, he discussed having students write out assessments of their welds:

Instructor: So especially early on in the program, one thing I have them do is try and create welds of specific sizes, which is a skill in and of itself. And the first couple times they try it, it's really hard. And so I have them do an exercise where there's no specific requirement to the weld- But what they do is every time they run a weld, they measure it. And then they start looking, "Is the weld positioned correctly? Is it even? Is it flat?" Those sorts of things. And then if it's not, what are you going to do to fix it? So if they start building the habit of this constant sort of quality control and critical thinking applying to their welds, and it's one of those things where for a lot of my students, they've never done anything like that before.... They actually evaluate it and write it down.... But what I tell them is, "You should be doing this in your brain all the time."

Jo: Yeah. What are they writing down?

Instructor: So the one I had them do was a fillet weld. And so they were measuring the legs of the fillet weld as they went and then as it was getting bigger and bigger, were the legs even? Was one leg getting bigger than another? And then if they saw issues with the weld, so if they had discontinuities or other things like that, they were documenting those as well. And then they were writing down how they were going to fix it.

Jo: Had they encountered that sort of exercise where they were writing while welding before?

Instructor: No.

Jo: How'd you come up with that?

Instructor: So one of the things that hit me, I think it was- it really hit me last year, um, was there were a lot of times where I would just sort of talk about the thought process I had- As a welder while welding. And I was starting to realize that the thought process that just sort of innately showed up for me, a lot of the students didn't have. And so what I want to do is kind of show them: This is the reason why I think this way and just basically said, "Give it a shot." And it was one of the ways for me to kind of document what they were doing, so that I could track it, and then just to really force them to actually think through it that way.

This welding instructor had incorporated, without the benefit of a WAC program, writing activities aimed at reinforcing critical thinking about achieving quality and correct welds. About such activities, Kohnen paraphrased Harold, the welding teacher in her WAC efforts:

According to Harold, the "neck up" aspects of the work, knowing when and why to engage in certain processes, was what would allow graduates of his program to be better employees, capable of making their own decisions and advancing in the field. Writing was a key part of acquiring this knowledge.⁴¹

Challenges to Contextualized Writing Courses and WAC Programs

Neither contextualized writing courses nor writing-enhanced disciplinary courses lack challenges to their start-up and maintenance. Contextualized writing courses require writing instructors, often not subject-matter experts in their students' trades, to rework their courses around unfamiliar topics and genres. Doing so requires numerous conversations with trade experts and trade instructors, conversations that eat into writing instructors' schedules, already packed with classes and grading. As John Wachen and colleagues pointed out in their discussion of I-BEST, instructors embedded in content courses need time to get experience in the technical area; it's difficult "to provide instruction on certain topics until they become more comfortable with and knowledgeable about the technical content."⁴² And writing instructors shouldn't have to do this course enrichment on their own time; they need resources in the form of release time and professional development funds to make their contextualized classes relevant and efficacious.

Thus, we need more studies to supply evidence for what we hypothesize to be true: that skilled-trade students better develop as writers in writing courses that clearly manifest relevance to their trades. With data from such studies, writing specialists who are willing to revamp a course around the disciplinary needs of their students will have evidence to back their proposed curricular changes and to motivate administrative investment. Such data are particularly necessary, as Sorenson pointed out, when teachers argue for dual-teaching, where an English instructor embeds in a disciplinary course to help develop both writing-to-learn and writing-to communicate activities.⁴³

Another practical challenge to contextualized writing courses is scheduling. To what extent is it possible to offer courses aimed at specific fields—welding, automotive repair, machining—at days and times that students are available? Writing about the challenges of scheduling her contextualized courses, Parlier wrote, "A faculty member who is interested in working with these occupational programs would have to accept an eight-week teaching assignment. What's more, course delivery time may also be established without input from the composition instructor."⁴⁴ In light of such scheduling restrictions, administrators and teachers who first develop contextualized courses may find it difficult to find other instructors to sustain them. In addition, contextualized courses silo students into smaller groups, increasing the possibility that a class—for reasons related to program enrollment—won't register enough students to proceed. Students and their advisors are left to find a writing course—any writing course—that will meet the program requirements.

Finally, there's the challenge of encouraging and helping trade instructors to incorporate writing into their courses. As Kohnen wrote, "content teachers may see these [writing] strategies as an extra burden, separate from the teaching of their subject matter."⁴⁵ Disciplinary teachers, who might at first equate writing with grammar, might feel unprepared to use and evaluate writing and may not think of themselves as writers. Commitment to WAC means freeing up a writing specialist's time, time that

they can spend collaborating with trade instructors on activities like the weld-analysis writing activity implemented at Lake Superior College.

Conclusion

In this chapter, I tried to demonstrate how written communication pervades trades work. I discussed the variables that I've learned to consider as I develop an invoice at Howe's. I also examined two other shop-floor genres that manifested during my visits to shops around Iowa. Finally, drawing on my background in writing studies, I considered the process and challenges of creating writing courses contextualized to different trades and of creating writing-enhanced trade courses. In future research, I plan to continue work started by Sarah H. Parlier and others. Even now such work continues in the contextualized courses of teacher/scholars like Maria-Lucia Di Placito. Di Placito was one of the first people I contacted when I began to examine writing in skilled trades. At Humber College in Toronto, Ontario, she led the development of Writing 108: English 1 for Skilled Trade Professionals, a course contextualized for trades such as HVAC and welding. While investigating and developing common trade genres, students practice broader skills, such as summarizing and analyzing documents and evaluating evidence. Such courses honor the idea that all students, including CTE students, are writers—whether they believe it or not.

Notes

1. Swales, "Occluded Genres," 46.
2. Ding, "Genre Analysis of Personal Statements," 387.
3. Edwards, Minty, and Miller, "The Literacy Practices."
4. Coxhead and Demecheleer, "Investigating the Technical Vocabulary of Plumbing."
5. Coxhead et al., *English for Vocational Purposes*, 2.
6. Encyclopedia Britannica, "Cuneiform Writing."
7. Sacks, "Linear B."
8. Commodity [Inside], "The Steel Industry."
9. FRC Global, "The Hidden Costs of Covid"; Gordian, "What the Data Says."
10. Cowden, "2024 Steel Prices."
11. Occupational Safety and Health Administration, "Near-Miss Incident Report Form," para. 1.
12. International Atomic Energy Agency, "Low Level Event," 10.
13. Heinrich, *Industrial Accident Prevention*.
14. Thoroman, Goode, and Salmon, "System Thinking Applied to Near Misses."
15. Vepsäläinen and Lappalainen, "Utilization of Incident Reporting"; Storgård, Erdogan, and Tapaninen, "Incident Reporting in Shipping"; Lappalainen et al., "Incident Reporting in Finnish Shipping Companies."
16. Gnoni et al., "Near Miss Management Systems."
17. American Society for Quality, "The History of Quality."
18. Cochran, "Putting the Wraps."
19. Cochran, "Putting the Wraps."
20. WAC Clearinghouse, "What Is a WAC Program?"

21. Bazerman et al., *Reference Guide to Writing across the Curriculum*, 17.
22. Mazzeo, Rab, and Alssid, "Building Bridges to College and Careers," 3–4.
23. Park, Pearson, and Richardson, "Curriculum Integration," 204.
24. Ledford, "Thinking Outside the Toolbox."
25. Ledford, "Thinking Outside the Toolbox."
26. Holden, "Building a Better Technician," 27.
27. Holden, "Building a Better Technician," 28.
28. Parlier, *The Impact of Contextualizing*.
29. Parlier, *The Impact of Contextualizing*.
30. Sorenson, *Contextualizing College-Level English*.
31. Sorenson, *Contextualizing College-Level English*, 154.
32. Sorenson, *Contextualizing College-Level English*, 153.
33. Kohnen, "'They're Not Keeping.'"
34. Kohnen, "'They're Not Keeping,'" 667–668.
35. Lave and Wenger, *Situated Learning*.
36. McLeod and Maimon, "Clearing the Air," 579.
37. Zeidenberg, Cho, and Jenkins, "Washington State's Integrated Basic Education."
38. Martinson et al., "Washington State's Integrated Basic Education and Skills Training."
39. Kohnen, "'They're Not Keeping,'" 665.
40. Kohnen, "'They're Not Keeping,'" 665.
41. Kohnen, "'They're Not Keeping,'" 667.
42. Wachen, Jenkins, and Van Noy, "How I-BEST Works," 20.
43. Sorenson, *Contextualizing College-Level English*, 61.
44. Parlier, *The Impact of Contextualizing*, 199.
45. Kohnen, "'They're Not Keeping,'" 661.

References

- American Society for Quality. "The History of Quality." Accessed May 14, 2024. <https://asq.org/quality-resources/history-of-quality>.
- Bazerman, Charles, Joseph Little, Lisa Bethel, Teri Chavkin, Danielle Fouquette, and Janet Garufis. *Reference Guide to Writing across the Curriculum*. Anderson, SC: Parlor Press, 2005.
- Cochran, Craig. "Putting the Wraps on Nonconforming Products." *Quality Digest*, March 2002. <https://www.qualitydigest.com/static/magazine/mar02/html/nonconform.html>.
- Commodity [Inside]. "The Steel Industry Faces Serious Challenges after Covid-19." April 6, 2023. <https://commodityinside.com/the-steel-industry-faces-serious-challenges-after-covid-19/>.
- Cowden, Michael. "2024 Steel Prices: Will Volatility Continue?" *The Fabricator*, December 13, 2023. <https://www.thefabricator.com/thefabricator/blog/metalsmaterials/2024-steel-prices-will-volatility-continue>.
- Coxhead, Averil, and Murielle Demecheleer. "Investigating the Technical Vocabulary of Plumbing." *English for Specific Purposes* 51 (2018): 84–97.
- Coxhead, Averil, Jean Parkinson, James Mackay, and Emma McLaughlin. *English for Vocational Purposes: Language Use in Trades Education*. New York: Routledge, 2019.
- Ding, Huiling. "Genre Analysis of Personal Statements: Analysis of Moves in Application Essays to Medical and Dental Schools." *English for Specific Purposes* 26, no. 3 (2007): 368–392.
- Edwards, Richard, Sarah Minty, and Kate Miller. "The Literacy Practices for Assessment in the Vocational Curriculum—The Case of Hospitality." *Journal of Vocational Education & Training* 65, no. 2 (2013): 220–235.
- Encyclopedia Britannica. "Cuneiform Writing." *Britannica Concise Encyclopedia*. Britannica Digital Learning, 2017.

- FRC Global. "The Hidden Costs of Covid to the Steel Industry." Blog entry. January 13, 2022. <https://www.frcglobal.com/blog/the-hidden-costs-of-covid-to-the-steel-industry>.
- Gnoni, Maria Grazia, Fabiana Tornese, A. Guglielmi, M. Pellicci, G. Campo, and D. De Merich. "Near Miss Management Systems in the Industrial Sector: A Literature Review." *Safety Science* 150 (2022): 105704.
- Gordian. "What the Data Says: Steel Price Updates." Blog entry. April 25, 2024, <https://www.gordian.com/resources/steel-price-updates/>.
- Heinrich, Herbert William. *Industrial Accident Prevention: A Scientific Approach*. New York: McGraw Hill, 1931.
- Holden, Jennifer. "Building a Better Technician: One Teachers Account." *Techniques (ACTE)* 84 (2009): 27–29.
- International Atomic Energy Agency. "Low Level Event and Near Miss Process for Nuclear Power Plants: Best Practices." Vienna, Austria, IAEA, 2012.
- Kohnen, Angela M. "'They're Not Keeping a Journal of Feelings': Literacy Initiatives and Career and Technical Education." *Journal of Adolescent & Adult Literacy* 58, no. 8 (2015): 660–669.
- Lappalainen, Jouni, Anne Vepsäläinen, Kim Salmi, and Ulla Tapaninen. "Incident reporting in Finnish Shipping Companies." *WMU Journal of Maritime Affairs*, 10 (2011), 167–181.
- Lave, Jean, and Etienne Wenger. *Situated learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.
- Ledford, Dustin. "Thinking Outside the Toolbox: A Teaching Resource for Vocational Writing." Master's thesis, Kennesaw State University, 2019.
- Martinson, Karin, Sung-Woo Cho, Karen Gardiner, and Asaph Glosser. "Washington State's Integrated Basic Education and Skills Training (I-BEST) Program in Three Colleges: Implementation and Early Impact Report." October 17, 2018. <https://www.acf.hhs.gov/opre/report/washington-states-integrated-basic-education-and-skills-training-i-best-program-three>.
- Mazzeo, Christopher, Sara Y. Rab, and Julian L. Alssid. "Building Bridges to College and Careers: Contextualized Basic Skills Programs at Community Colleges." ED473875. January 2003. <https://eric.ed.gov/?id=ED473875>.
- McLeod, Susan, and Elaine Maimon. "Clearing the Air: WAC Myths and Realities." *College English* 62, no. 5 (2000): 573–583.
- Occupational Safety and Health Administration. "Near-Miss Incident Report Form." 2021. <https://www.osha.gov/sites/default/files/2021-07/Template%20for%20Near%20Miss%20Report%20Form.pdf>.
- Parlier, Sarah A. "The Impact of Contextualizing First Year Composition for Occupational Program Students at the Community College: A Study of Student Learning and Student Perceptions." PhD diss., Illinois State University, 2013.
- Park, Travis, Donna Pearson, and George B. Richardson. "Curriculum Integration: Helping Career and Technical Education Students Truly Develop College and Career Readiness." *Peabody Journal of Education* 92, no. 2 (2017): 192–208.
- Sacks, David. "Linear B." In *Encyclopedia of the Ancient Greek World*, 3rd ed., edited by David Sacks. Facts On File, 2015. <https://search.credoreference.com/articles/Qm9va0FydGljbGU6NDg0MzU2NA==?aid=100725>.
- Sorenson, Tanya. "Contextualizing College-Level English Composition Courses: A Study of Students' Perceptions." PhD diss., Northeastern University, 2019.
- Storgård, Jenni, Ilknur Erdogan, and Ulla Tapaninen. "Incident Reporting in Shipping: Experiences and Best Practices for the Baltic Sea." Turku, Finland: Centre for Maritime Studies University of Turku, 2012. https://www.utu.fi/sites/default/files/media/MKK/A59_incident%20reporting.pdf.
- Swales, John. "Occluded Genres in the Academy." In *Academic Writing: Intercultural and Textual Issues*, edited by Eija Ventola and Anna Mauranen, 45–58. Amsterdam: John Benjamins, 1996.
- Thoroman, Brian, Natassia Goode, and Paul Salmon. "System Thinking Applied to Near Misses: A Review of Industry-Wide Near Miss Reporting Systems." *Theoretical Issues in Ergonomics Science* 19, no. 6 (2018): 712–737.

- Vepsäläinen, Anne, and Jouni Lappalainen. "Utilization of Incident Reporting in the Finnish Maritime Industry." Turku, Finland: Centre for Maritime Studies, University of Turku, 2010. <https://www.utupub.fi/handle/10024/63604>.
- WAC Clearinghouse. "What Is a WAC Program?" Accessed May 14, 2024, <https://wac.colostate.edu/repository/teaching/intro/programs/>.
- Wachen, John, Davis Jenkins, and Michelle Van Noy. "How I-BEST Works: Findings from a Field Study of Washington State's Integrated Basic Education and Skills Training Program." Community College Research Center, 2010. <https://ccrc.tc.columbia.edu/media/k2/attachments/how-i-best-works-findings.pdf>.
- Zeidenberg, Matthew, Sung-Woo Cho, and Davis Jenkins. "Washington State's Integrated Basic Education and Skills Training Program (I-BEST): New Evidence of Effectiveness." Community College Research Center, 2010. <https://files.eric.ed.gov/fulltext/ED512261.pdf>.

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Chapter 10

Women Learning



Abstract Although severely underrepresented in the trades in the United States and elsewhere, women learn to navigate the interactions, activities, and spaces that comprise their community of practice. Even at Howe's, where my coworkers are convivial and helpful, I've encountered obstacles to learning and to getting my work done. After exploring the reasons women choose to work in trades, I discuss how tradeswomen learn to develop workarounds—strategies that help them surmount social, physical, and psychological obstacles put in their path: outsider status, scrutiny, stereotypes, sexual and gender harassment, and condescension.

Introduction

For a long time, I was the only woman working at Howe's. Then, for a short while, there were two of us. Just entering her twenties, Regen is the daughter of a local farmer, businessperson, and longtime client of Howe's. She encountered welding repair when she was growing up on the farm. Through her dad, she met Jim and began working at Howe's when she started welding school after high school graduation. Her path to Howe's accords with research on women in skilled trades, which shows that "informal networks remain the most traditional pathway into the trades."¹ Women who have these informal networks, often fathers and brothers, seem to more readily perceive a trade as possible and desirable.

Unlike Regen, many other women arrive at trades later, after years in a different career. They choose a trade in part because they enjoy the pride that comes from building something tangible. In a study of skilled construction workers, researchers found that the tradespeople most frequently cited pride in creating something in the physical world as a positive attribute of their work. In fact, 53% of the respondents mentioned this pride.² Similarly, in *Shop Class as Soulcraft*, Matthew Crawford pointed to this type of pride, although he seemed to ascribe it solely to men:

The satisfactions of manifesting oneself concretely in the world through manual competence have been known to make a man quiet and easy. They seem to relieve him of the felt need to offer chattering interpretations of himself to vindicate his worth. He can simply point: the building stands, the car now runs, the lights are on.³

This pride in work that changes the world resides in everyone—all genders—and is what brought me to welding school and to Howe's. It's that pride I wanted to feel but didn't when I looked at that stack of printed pages gathered to support my promotion at the university. And now, even after these years of working at Howe's, I love the days when I finish a project that I've been working on for a few days or a week. On those days, I look upon the completed work and feel a sense of pride in having repaired or built something solid and purposeful.

Of course, the trades also attract women who want a sufficient and steady paycheck. During one of my shop visits, I talked to Maria and Laila, both of whom had worked as welders and as salaried employees. Maria came to welding after finishing her bachelor's and master's degrees. After years of work in a field outside trades, she had lost her job:

Maria: I just applied for different jobs. I had got divorced, and I was underemployed. Any job that I applied for it was like \$12 to \$15 an hour, and then I was paying for my own insurance, so really that kind of- I mean, really I was only bringing in probably around \$10 an hour. I mean, it's hard with two kids to try to make that work, and once my kids were older . . . then I was able to- I was like, "You know what? I'm sick of not making any money."

Maria had originally applied to work as an assembler, but welders were needed. Her story mirrors that of a welding student, Sophia, whom I spoke to years ago for another book project. She came to the industrial maintenance program at Northwoods College after years spent in nursing:

Sophia: I honestly was just so tired of being so emotionally attached and that it was just draining me so. I would take everything home with me. . . . I came here, and like they allow people to shadow classes. And I was just like oh, that sounds interesting. Because on my outside time I like to refurbish furniture, and like- I've always like wanted to learn about like electricity and all that stuff. . . . And I came and shadowed it, and they were building conveyor belts. I was just like, wow, this is really cool. And so I was like, you know what? I'm going to do it. It pays well.

Trades offer people a clearer path to financial stability that many jobs, especially those traditionally filled by women, can't provide. It also offers that opportunity for pride in making something tangible that so many tradespeople mention when asked about why they chose their job.

Underrepresented in trades, women learn to navigate the interactions, activities, and spaces that comprise their community of practice. Even at Howe's, where my boss and coworkers are kind and helpful, I've encountered obstacles to learning and to getting my work done. In this chapter, I sketch the problems that tradeswomen encounter and the ways they learn to develop workarounds—strategies that help them surmount social, physical, and psychological obstacles put in their path.

Outsider Status

I love that, in my job at Howe's, I'm using the opportunities that tenacious tradeswomen made possible. Such women include all those who developed skilled-trade expertise during World War II and then in peacetime were pushed aside—made outsiders again—in massive postwar layoffs. Labor historian Evan K. Rose concluded from his study of US Employment Service data:

Although women's wartime employment experience was exceptional in its breadth, rewards, and novelty, this short-lived exception to prevailing norms was only made possible by the extreme circumstances of war and was abruptly ended by the arrival of peace.⁴

Although these women worked in a range manufacturing trades, one day at Howe's I felt myself particularly connected to Rosie the Riveter, the character made famous in a US government campaign to encourage women to work in jobs with higher pay that were previously unavailable to them. That day, Jim demonstrated and explained how to use a rivet gun to insert pop rivets into predrilled holes. Jim wanted to use rivets to attach an aluminum sheet to a wheelchair ramp instead of welding it on so that the owner could remove it later if they wanted (Fig. 10.1). By the end the day, I'd practiced riveting enough that I felt confident in my ability to do the task again, and I felt a bit more connected to Rosie.

As it turns out, women took on many trades during the war, not just riveting. For example, women manufactured rubber products, telecommunications equipment, and ordnance; they built ships, trains, and planes; they worked in construction,

Fig. 10.1 Rivets in a wheelchair ramp



forestry, and farming. And although Winnie the Welder got far less attention than Rosie, thousands of women worked as welders as well.⁵

Unfortunately, since women were ejected from trade jobs after World War II, they have remained largely excluded. They remain overwhelmingly outnumbered by men across trades. In 2023, women made up 5.8% of welders and 6.3% of machinists in the United States.⁶ In other countries, women fair about the same or worse. In Australia, for example, they're 1% of welders and 2% of machinists.⁷ Thus, in the United States and elsewhere, small shops like Sargent Metal Fabricating, Custom Steel Service, and Howe's could go years without employing a woman. Indeed, one day, a customer said to me, "You don't see a girl in an environment like this very often." I replied, "No, I suppose not." Thinking for a moment, he continued, "You must love what you do." Without hesitation, I returned a forceful, "I do!"

I love working at Howe's not only because I'm developing competences across knowledge domains but also because I feel valued. I haven't had to work around sexism from my boss or coworkers. On the contrary, the men at Howe's have been respectful and congenial colleagues, as well as willing teachers when I've had questions about tools and machines, welding processes, and next steps in my projects. They've also been willing learners when I've had some relevant knowledge to contribute. Similarly, some of the women in Jean Reith Schroedel's *Alone in a Crowd* described their positive experiences with coworkers. Lydia Vasquez, a machine operator, related that the men at her first trades job helped her when she needed it:

The men did not seem to have anything against seeing a woman running a machine there. They were so willing to help me do things, make a set-up, bring parts, or whatever, that I had no fears at all. If somebody was willing to teach me, I was willing to learn.⁸

Another tradeswoman featured in the book, Nora Quealey, worked on an assembly line for trucks and noted similarly kind colleagues:

But in general the guys were really good.... [T]he guys never gave me the feeling that I was taking the job from a man or food from his family's mouth. If I needed help, I didn't even have to ask, if they saw me struggling, they'd come right over to help.⁹

Some of us get lucky and land in safe spots.

But for other women in trades, work life has been and continues to be much more difficult than it has been for me. For example, writing about women pilots and women automotive mechanics, Meraiah Foley and her colleagues found that the women were made to feel that they were "unwelcome interlopers."¹⁰ In a study examining women's experiences in trades, one group of researchers wrote that group identity is as much about exclusion as it is about inclusion. New members alter and redefine a group, and existing members—men—often perceive the changes as detracting from the strength and competence that they ascribe to themselves.¹¹ Women's exclusion manifests as discouragement or outright gatekeeping that keeps women from vocational programs, apprenticeships, promotions, and union memberships.

Thus, to gain even marginal acceptance, particularly as part of an organization that "favors traditional normative masculine practices,"¹² tradeswomen often strive to reduce gender's salience.¹³ A story that Laila told me reflected this strategy:

What I have noted is over time I feel like women stay, I feel like the ones that stay, they are here to earn a paycheck, and I've also had heard comments here about... there was a young woman who was not a very big girl, she was cute, she wore really baggy clothes, she wore really baggy pants, and the comment was made, "Why does she dress that way? She's a really cute girl. Why does she dress that way?" I said, "Because she's here to work." I said, "I worry a lot more about the girl who shows up in a tank top and tight jeans than that girl."

In Schroedel's book, machinist Amy Kelley spoke of choosing to live sex- and gender-neutrally at work:

As soon as I walk in the door at work it's like I'm not any sex at all. It's no sex at all. It doesn't matter if I'm a man or a woman. I'm a machinist. I can do the work. The guys look at me, not because I'm a woman, but because I'm a machinist. And that feels real good.¹⁴

Commenters to the bluecollarwomen subreddit, discussing the possibility of wearing makeup to work, made similar points:

I find it distracts from my abilities and my work. It's dumb, but I prefer to be seen as they [sic] worker, rather than that girl. I don't wear makeup day to day either.¹⁵

In general, attempting to deemphasize gender by avoiding shows of traditional femininity helps women mitigate their outsider status and get through the workday unscathed.

Scrutiny

Tradeswomen must prove themselves worthy of their positions. Multiple studies focusing on women in trades have described the concern that men coworkers scrutinized their performance.¹⁶ Maria told me a story about starting out as a welder and undergoing men's assessments:

So they put us with these two seasoned guys and we were doing that two-week onboarding training, and then I think part of it too is they just wanted to see what they were getting. . . . And I remember them tacking together a couple of pieces of metal for me and saying, "Okay, I want you to weld a six millimeter weld here and an eight millimeter weld here," and I was so nervous because these are the guys that I'm going to work with, and I just was so nervous and I laid down the welds and put my hood up and the guy goes, "Well, goddamn, bitch can weld," and I was like, "Oh my god, thank god."

I know how Maria felt. Sometimes customers travel past the front desk and into the shop to talk to Jim, and every so often, if they're near me, I can feel them watching and assessing my work. These silent evaluations particularly frustrate me when I'm judged during learning situations, that is, as I'm practicing something new or difficult. I worry that I could make a mistake and give them evidence to support what I imagine they've thought all along: that women don't belong in a fabrication shop. Once two customers talked to Jim while I used the ironworker to punch ovals in a piece of cut-in-half rectangular tubing. Because the punch shape was oblong, I had to use a combination square to make sure that the oblong's sides were square to the tubing's

edge. But this was the first time that I had added this step to the already difficult procedure. Now I had to step on the pedal to lower the punch, find the indentation of the spot to punch, hold a combination square against the metal, step on the pedal, and pull the stripper towards me. All with Jim and his pals standing nearby.

I could feel my legs getting wobbly, which is a symptom called “jelly legs,” I found out later. It arises from the fight-or-flight response activated by a stressor, in my case, a procedure that required eye-hand-foot coordination and that had an audience. With jelly legs, blood rushes from the legs to where the body thinks it’s needed most, namely, the heart and the brain. In this case, I feared Jim’s buddies would mistake my at-best competent-level knowledge for the best that women can do, adding support to the idea that a woman in the shop is a cute novelty or a quota maker, not a valuable worker. Yet even when I’m observed as I carry out less challenging tasks, I encounter this same stress and symptom, all arising from the possibility of embarrassing myself and, even worse, embarrassing womankind.

Writing about women in construction, researcher Heidi E. Wagner wrote, “Tradeswomen have to be good at their jobs because one woman’s failure (or even just fatigue or making a mistake) is often not seen as an individual failure, but as a failure of all women’s capabilities as construction workers.”¹⁷ Other scholars have found much the same: “Women reported that when they made a mistake in their work, severe consequences could flow for themselves and for women working in their occupation more broadly.... A mistake made by one woman would be discussed by male colleagues as ‘proof’ that women were ill-suited to their role.”¹⁸ That day on the iron-worker, I managed to somewhat counteract the anxiety and the jelly legs by slowly breathing in through my nose and out through my mouth, a technique I’d learned via my interest in meditation and had used before when I felt my competence being surveilled. But I resented having to work around additional stress generated by being under review as I tried to learn a complicated procedure and as I tried to keep all my fingers.

Stereotypes

For the benefits of work in skilled trades—a bigger paycheck and pride in making something—there are, of course, downsides. Women in trades like welding must navigate workplaces that, although much improved from the conditions of earlier decades, continue to adhere to outdated thinking about what a tradesperson looks like. Maria continued:

And they don’t understand what the modern workplace in manufacturing is. You don’t have to be a big strong, burly guy to do this stuff. It’s all set into our standards that you’re supposed to lift stuff a certain way.

She continued with a story about what a coworker had told her as he reflected on the first day he had met her in training. He had doubted her ability to do the job:

[He said,] “Well, you look like somebody’s mom,” and I’m like, “Well, I am somebody’s mom.” So people can look different and be able to do the work, and we really need to get away from this visual of what we perceive a welder should look like.

Later in our conversation, Maria and her coworker Laila pointed out that anyone—no matter their size—should be able to handle the physical labor of any task in their workplace. They described a conversation with two men colleagues in which they discussed choosing a post for a new employee, who happened to be a petite woman. The two men each mentioned a department where she could be placed: One was a department that earns incentives for extra productivity, and the other wasn’t:

Laila: And I think [Man 1] made a comment like, “Oh, do you think she’ll... well, she’ll probably do better and succeed in [the non-incentive department],” and I said, “Whoa, whoa. Well, wait.”

Maria: Already right off the gate because she’s small and she’s female, you’re limiting what she’s going to make—

Laila: I said, “What’s it matter? She should be able to do any job anywhere in here, no matter her size,” and then [Man 1] brought up that point, more females do get placed in trucking jobs or lower paying jobs, and I said, “Yeah, we need to stop that.”

Maria: We need to give people opportunities.

Technically, the same OSHA rules apply in a small metal shop as apply in a big manufacturing facility, such as rules about lifting heavy objects. As in all other shops, we use hoists at Howe’s, but because we keep a large inventory of steel—20- and 24-foot sticks of flat bar and angle iron and 4 × 8-foot sheets and plates of steel—we end up muscling steel into place, whether from the steel truck to the racks or from the racks to the band saw, ironworker, or shear. Even with the help of a hoist, moving these heavy materials around takes effort and strength. I wrote in my journal on a spring day:

I pulled and cut a 96 × 48 sheet by myself too. When I asked Adam and Zach whether there was a trick to getting a sheet out of the stack, they said “muscle.” Ha! So I muscled my way in there and used the hoist to pull it out.

The tradeswomen whose work stories Schroedel compiled in *Alone in a Crowd* related similar thoughts, pointing out that no matter what, work in trades requires a measure of physical strength. For example, Laura Pfandler, a pipefitter, discussed the physical challenge of laying new pipe from the city’s main to a residence:

In Seattle you have blacktop and concrete, so you have to use a ninety-pound breaker. That’s a kind of jackhammer. Pretty much I would say the most demanding thing for a woman to do on the job is to use the breaker because it usually takes, depending on the concrete and blacktop, from a half-hour up to three or four hours. Fortunately, they don’t run away from you. It’s just heavy physical labor. What does run away is the tamper, which tamps down the earth.... It’s run by air and pounds down the dirt. But it’ll run away on you and is hard on the lower back. You gotta be fairly strong to even be able to lift it.¹⁹

Rules for lifting account for how often workers lift items, whether they bend when lifting, how high they lift an item, and other important details, but they don’t necessarily account for the physicality of work beyond weight limitations on lifting.

Fig. 10.2 Some of the S hooks that I made to hold Jim's 18 auction-acquired come-alongs



On the day Jim told me to bend 20 pieces of ½-inch round stock, I had to use all my weight to pull the Hossfeld bender's arm to make the S shapes. The 20 S hooks would hang on a bar and hold the 18 come-alongs that Jim had bought at an auction the previous weekend (Fig. 10.2). In making the S hooks, I imitated Jim's demonstration, making one side into a tighter loop so that it would hold the bar securely and the other side into a U to hold the come-alongs. Tired after I'd finished all the bending, Jim told me to hang all the come-alongs from the mobile rack he had waiting just for this purpose. So I had to squat to pick each one up and use my legs and then arms to lift each of them to an awaiting hook. But I didn't complain. I already knew that my coworkers didn't think of me as strong; they'd seen me struggle with heavy items too many times to fool them in that regard. Nevertheless, I wanted them to think of me as tough. In her study of women in building trades, Amy M. Denisson pointed out that constructing a tough and—if possible—strong persona is a strategy that tradeswomen hone to get men to take them seriously.²⁰ I think of this self-presentation as a workaround as well in that it helps tradeswomen disarm potential teasing, harassment, and accusations of a lighter workload.

The persona of toughness becomes a variable in a formula tradeswomen use to calculate when it's okay to ask for or to accept help. At Howe's my math takes into account how pushed I am for time. If I have time to use the hoist to maneuver heavy angle iron to the rollers by myself, I do it. I do it because I want to show to myself and my coworkers that I'm capable of doing all that working at Howe's entails. But my math also considers the other shop tasks I'm supposed to finish. Usually I have an ongoing project to work on, and sometimes I've got a list of metal to cut. In these cases, I'll accept help moving the angle iron because that task takes just a few seconds when two people do it. Talking about how she determines whether to accept help, one of tradeswomen in Denissen's study put it this way: "So if somebody is going to offer to help me, I'm going to have them help instead of hurting my back trying to do it by myself. But I won't let them take it away from me."²¹ This tradeswomen's formula variables included the potential to get hurt doing the task alone and the necessity of remaining a participant in the task, as opposed to letting a man do the work.

Women may find, too, that the layout and organization of workspaces hamper their work, pushing them to develop workarounds as well as personas. At Howe's, for example, many items I need, such as hooks for hoses and cords and boxes of filler metal stacked on shelves, sit high and out of reach. When I need an item I can't reach, I have to locate something to climb on, such as a big piece of square tubing or, if I can find it, the stepstool. Similarly, because the driver's seat on the portable truck doesn't move, I have to scoot to the edge of the seat to reach the pedals and place a kneeling pillow behind me. In addition, some switches and connections on machines move only when the operator applies great force. Such is the case for the power switch of the old Westinghouse welder that we use for carbon-arc gouging. Because it's mounted high above a big Miller welder, I climb on top the Miller to get better leverage to flip the Westinghouse's recalcitrant power switch (Fig. 10.3). And I regularly use a piece of round tubing to get leverage when I'm using a wrench. Small impediments like these require workarounds.

And as my years in a metal shop add up, I've learned workarounds that function for me, for my body, even though they wouldn't likely be a man's preferred methods. Like the women in Denisson's study, I've been told numerous times to "hit it like a man," when striking a punch so as to make the dimple left in the metal sufficiently salient or when banging some stuck component into or out of place. Because I can't make my hammer blows as strong as Jim's, I've figured out my own methods of getting such tasks done. I strike the punch to mark a spot for punching or drilling with as much force as I can muster, and then I deepen the mark with a second blow. My method is less efficient, but it works. Ironically, these "hit it like a man"

Fig. 10.3 The (green) Westinghouse welder with the obstinate power switch above a Miller welder



imperatives have at times come when I've purposefully held back on how forcefully I swung the hammer for fear of breaking something. To get a chuck out of the drill press, you insert a wedge-shaped tool called a drift above the chuck and hit the drift with a hammer. The chuck falls out. But as someone with advanced-beginner drill knowledge, I've worried that if I hit the drift too hard, I might break it or the drill press itself. In such cases, my knowledge level communicated what Jim and others interpreted as the manifestations of womanhood. I want to yell, "It's not because I'm a woman dammit; it's because I'm still learning!"

Sexual and Gender Harassment

Women who work in "male-dominated occupations," those occupations with fewer than 25% women,²² experience more sexual and gender harassment than women in other jobs, especially women in jobs where physical strength does not play a substantial role, as it does in trades.²³ These terms, "sexual harassment" and "gender harassment," resist easy definition. Indeed, the Equal Employment Opportunity Commission (EEOC) of the United States defined the terms somewhat circularly. Sexual harassment, according to the organization, is "verbal or physical harassment of a sexual nature."²⁴ Such harassment becomes illegal when it creates a hostile environment or when it brings an adverse effect in employment. Women cited in *Alone in a Crowd* described both varieties. Amy Kelley, one of two machinists that Schroedel interviewed, stated that her coworkers weren't a problem; her supervisors were:

I have complained to the EEO commission. The company has an EEO office. I had one supervisor that used to come up behind me and pat me on the butt, and I didn't even know he was back there. And I had another supervisor that would come around, when I didn't know it, and snap my bra strap!²⁵

Others, such as Anna Brinkley, an electrician, discussed how a lead electrician had tried to get her fired after she rejected his advances:

At the same time the lead man started this sexual harassment trip, he began playing a real anti-union role in the shop. He began being a snitch and aiding the supervisor in writing people up. Then he started helping the supervisor in trying to get rid of me.²⁶

These comments exemplify both the casualness and the seriousness of sexual harassment.

Kimbely Riddle and Karen Heaton's meta-analysis of 25 studies of occupations dominated by men found that organizational culture and gender composition preceded sexual harassment. Organizational culture refers to characteristics of the job, including its physicality, the relationship between the woman and her harasser, and the efficacy of harassment remedies.²⁷ Gender composition refers to the ratio of men to women; when women are heavily outnumbered and have more contact with men, sexual harassment is, not surprisingly, more likely.²⁸ Given that men outnumber women in most fabrication shops, women must rely on a supportive organizational culture to make their workplace safe.

Of course, as Schultz concluded, “making a woman the object of sexual attention can also work to undermine her image and self-confidence as a capable worker. Yet, much of the time, harassment assumes a form that has little or nothing to do with sexuality but everything to do with gender.”²⁹ The EEOC noted too that harassment “does not have to be of a sexual nature.”³⁰ The University of Chicago put it this way: “Gender-based harassment is not generally motivated by sexual interest or intent. It is more often based on hostility and is often an attempt to make the target feel unwelcome in their environment.”³¹ Most research on women in trades refers to gender-based insults as gender harassment. Such comments are sometimes couched as humor, allowing the offender to mask unacceptable behavior as harmless.³² But research has shown the opposite; gender-disparaging humor is far from anodyne in that it normalizes prejudice and fosters a culture that tolerates discrimination.³³

Although I work with men who respect women—and tradeswomen—Howe’s customers can be a different matter. Observing their responses to my presence in the shop has been something of a long-term sociology experiment in low-to-midgrade gender harassment. Trying to determine my reason for being at Howe’s, one customer asked me, “Are you the new secretary?” perceiving my most likely role to be that of a receptionist or bookkeeper. Another man commented on my presence in the shop by comparing my appearance to my coworker: “You’re better looking than the guy I talked to before.” Much has been written about men’s entitlement to casually evaluate women’s appearance both positively, like my customer did, and negatively.³⁴ Such evaluations constitute what scholars call an “objectification experience.” Such experiences remain common for women³⁵ and range from mild, like a compliment on appearance, to violent, like assault,³⁶ to unsettling, as when one man, paying his bill at the front desk, creepily whispered to me, “Your hands are dirty.”

Women in trades have reported encounters with customers who doubted their competence and who refused to deal with them, seeking a man instead.³⁷ Some customers at Howe’s fit this pattern. I’ve noticed that if I’m at the front desk with another (man) coworker, men will often look past me and address them, even though I’m older and, as far as they know, more experienced.

Other customers, usually older men, tell me how to do my job, such as cutting metal on the bandsaw, which is one of the most basic tasks in the shop. One man, watching me while I cut eight-foot lengths of tubing for him, told me that I didn’t need to place the end of my tape measure against the saw blade to get an accurate measurement; I could simply hook my tape measure over the saw blade and subtract 1/8-inch to find the correct length. I told him that his method—fine for getting a rough idea of length—wouldn’t work for a precise measurement. For one thing, the saw blade is 1/16-inch wide and, more important, his method doesn’t account for the difference between the intended length of metal and the hypotenuse created by hooking the tape measure above the item being cut. Unchastened and more determined to push me to acknowledge his superior knowledge, he asked me whether I knew the purpose of the black diamonds on my tape measure. Unfortunately, I’d forgotten that bit of knowledge, something that Jim had told me once over a year earlier. (The diamonds, 19 3/16-inches apart on a US customary tape measure, provide the correct spacing

between joists, or timbers. I'll never forget this now, even though it's not relevant to my job.)

The worst encounter I've had with a customer happened when a man—white, probably in his mid-60s, and wearing a baseball cap—came in the door and said brusquely, "I want two feet more of this." He had a piece of what looked like about two feet of 1-inch square tubing in his hand. I said, "Okay, let's look if that's 12 gauge or 11 gauge," thinking he'd hand it to me so I could inspect it more closely. Rather than acknowledge my outstretched hand, he growled, "Just more of this!" shaking the piece of tubing at me. Trying to remain polite, I invited him around the corner to look at the wall of tubing. There, I learned he wanted two pieces of roughly 24 inches. I found one piece of 11-gauge that measured 26-inches, but I didn't see any more short pieces, so I told him I'd have to cut two feet from a long stick. Since I had to make a cut anyway, I asked him if he wanted his original piece or the two new pieces cut into smaller pieces, and he curtly replied, "No."

When it was time to pay, I reminded him that the first piece I'd found was 26 inches, so he would need to pay for 50 inches of tubing. That's when he said something that, for the first time in the tense encounter, scared me. Using the royal "we," he snarled, "We're only paying for four feet. This was a drop. I shouldn't have to pay for more of it." I didn't know what to say; his strange use of "we" and his seething countenance shook me. Flustered at baseball-cap guy's aggression, which had started from the moment he walked in but had escalated throughout, I finally decided that I wasn't going to let his behavior go unmentioned. So, looking him squarely in the eyes, I said, "Ok. I don't appreciate the way you're talking to me." He hesitated. Then, he let out a petulant, "Well, I'm sorry." After the to-my-mind half-hearted apology, I didn't say anything else to him, like "thank you" or "have a good one" or any of the other polite gestures I usually pay to customers. But I'm ashamed to admit I gave him those two inches of tubing for free, just to get him out of the shop. If I could do it over, I'd tell him that he would have to pay for every inch or leave all of it, but my brain didn't get itself composed in time. Instead, the interaction has become one of those warehoused moments that I play back on the VHS tape in my head, wishing I could do it all over.

What caused baseball guy's aggression in the first place? I'd bet money that he's never the most congenial of fellows. But I'm guessing he was annoyed from the outset about having to interact with a woman to get the tubing he wanted. Now, it could be that I'm reading into the situation. Maybe he would have been as rude to Jim, Zach, or Adam. Maybe. But I think not. In any case, my worst-customer-ever story reveals yet another strategy that tradeswomen can employ: delimiting language. I explicitly told him that his language wasn't acceptable. But even in my privileged situation as a tradeswoman who works at a shop to learn, not to earn a living, pointing out the customer's inappropriate language was a last resort. I had ignored baseball-cap guy's rudeness and aggression until the end, when I decided my pride was worth potentially upsetting Jim (who, as I had suspected, was upset only that I'd had to deal with this person). Other women in trades aren't so lucky.

Condescension

Like Jim, my coworkers grew up as tinkerers, repairing cars and motorcycles. And I, like many other women, never got much preparation for shop work beyond a lesson in changing a tire. As sociologist Margarita Torre pointed out, “Gender-typical expectations acquired throughout childhood and early adulthood are carried over into the labor market, pushing men and women to self-sort into sex-typical jobs.”³⁸ My lack of mechanical experience is common in women. While a few women grow up in environments that promote interest in trades and in families that encourage exploration of those interests, many others like me come to trades needing remedial education. Sophia, the Northwoods College student, laughed when I asked her whether she had prior experience working with power tools and other shop equipment:

Sophia: No. I’m always like, “That thing over there,” you know. And I mean I have my own tools and things but it’s just like I don’t know their correct names. So I’m just there finding what works, and I know what does what.

Perhaps because many women come to trades with less background knowledge of tools and mechanical repair, it’s common in welding shops and programs for sympathetic men to express their belief that women are, in fact, better welders than men. One of my welding-school teachers had espoused this idea, likely to encourage me and the other one or two women in the class. Making conversation with me, a few customers—men—at Howe’s have advanced this idea too. Usually, these supporters back their claim with an anecdote about a talented woman welder they once knew.

If they’ve seen online marketing materials for welding programs or read articles about women welders in trade magazines, people embracing this idea may be thinking of claims—presumably based in research—that indicate women’s hand stability surpasses that of men. Yet, if promotional materials or articles cite any sources for this claim at all, they tend to cite a 2011 study by ergonomics researchers Hiroshi Endo and Koichi Kawahara, which examined the hand stability of 30 males and 30 females between the ages of 23 and 30 as they performed three pinching actions. That study found a significant difference between the two groups “at low force levels,” a phrase that refers to precise movements with the hands. Although the researchers noted that manual dexterity does not arise solely from hand stability, they indicated that their results could inform “occupational aptitude,” given that “females indicate a superior ability to perform precise operations, such as assembly of small parts in industry or in life science experiments.”³⁹ While I’m unsure what the authors had in mind when they mentioned the probable aptitude of females in life-science experiments, their claim about female hand stability granting a special advantage in trades took hold.

Although I’m open to the idea that young-adult females surpass males in hand stability, I’m surprised by the widespread use of this one study’s finding in recruitment materials aimed at drawing women to welding programs. After all, even in tig welding, where precise movements dominate, competence arises not just from hand stability but also the ability to control the torso and arms and to coordinate the eyes

and the hands. I can, however, understand the impetus of well-meaning program coordinators who hope to encourage reluctant women to take the scary step toward a new and man-dominated field.

Similarly overblown are claims that women's lower center of gravity gives them an advantage in welding over men. The argument goes like this: Women have greater balance and thus are less prone to toppling over when welding in high places. However well-intentioned the sentiment, the idea sets women apart yet again, this time assigning them special powers to excel. In an article for *The Welder* magazine, welder Gina Cutts wrote:

For most of my career, I was the sole woman on the job site. Repeatedly, and still to this day, men say that they knew/know a girl who welds and then announce that girls make some of the best welders. I always cringe when I hear this, but I have never spoken up or tried to correct this misinformed and outdated stereotype. Why would I? It was always said when I was the only woman. Women (not girls) are neither more nor less skilled at welding than anyone else. People become great welders through practice and opportunities to expand and increase their knowledge and skills.⁴⁰

To be even more specific, opportunities for scaffolded learning make a good welder, as does deliberative practice.

This idea also does damage. As if it's not hard enough to work in a trade dominated by men, under this thinking, women welders now have to live up to the expectation that their work—bolstered by their low center of gravity and their natural hand stability—will consistently surpass that of their men colleagues. After my teacher told me that women are naturally better welders, I worried even more about what was wrong with me. Why wasn't I the best student in the class? The quality of my welds usually rested in the mid-range of the class, rarely at the top. In tig welding class, for example, my beads weren't as consistent as those of some of the men. I couldn't seem to manifest my supposed innate excellence.

Like Gina Cutts, when I hear the "women are better welders" truism, I gently push back, pointing out that different body types—no matter sex or gender—have certain advantages and drawbacks when it comes to welding or any other trade. Sometimes hand stability is important. Sometimes strength is important. And so on. What I've learned on my trades journey is this: Women don't need to be coddled with condescension, however well-intentioned it is.

Conclusion

In this chapter, I've covered some of the challenges women commonly encounter in the trades: being perceived as outsiders, being scrutinized, being stereotyped, being harassed, and being condescended to. I've also discussed some ways that I've learned to work around such challenges, such as customers' gender-focused comments, when I've encountered them at Howe's. In the trades, women adapt so that they can do their work and grow their competences with minimal emotional outlay.

Trades workplaces that want to welcome tradeswomen should create and openly discuss resources available to tradeswomen and their allies, such as mentorship programs and EEO (equal employment opportunity) officers and representatives. And while tradeswomen will more likely find formalized mentorship programs and dedicated EEO offices in large fabrication facilities, tradeswomen in medium to small shops can ask for the resources needed to create on-site mentorship programs.

Mentoring outside of the workplace helps too. Lean In connects women and helps them advocate for equal pay and counter sexual and gender harassment. LeadHERtrades focuses on women in construction. Women in HVACR focuses on women in heating, ventilation, air conditioning, and refrigeration. Other groups are state specific. For example, Tradeswomen, Inc., targets its support to tradeswomen in California. And such groups grow all over the world.

In addition, informal mentoring will become more common as women enter trades work. Opportunities for newcomer tradeswomen to learn from their more experienced women colleagues will increase, and challenges like outsider status will (slowly) wane. As Maria said, “I feel like we shepherd people more, and maybe that’s just my perception but especially with young women, we try to go out and check on them. We try to make sure they feel included.” Indeed, numerous studies have shown the efficacy of role-models, mentors, and social networks for supporting women’s resilience in workplace cultures that might otherwise isolate or harass them.⁴¹ Tradeswomen like Maria—and their allies as well—advocate for safe and supportive work cultures rather than leaving women to fend for themselves as they strive to become full members of their community of practice.

Notes

1. Wulff et al., “Women Who ‘Talk the Tools,’” 34.
2. Welfare, Sherratt, and Hallowell, “Perceptions of Construction Work,” 5.
3. Crawford, *Shop Class as Soulcraft*, 15.
4. Rose, “The Rise and Fall,” 710.
5. Thomas, *Don’t Call Me Rosie*.
6. United States Department of Labor Statistics, “Labor Force Statistics.”
7. Jobs and Skills Australia, “Welders (First Class).”
8. Schroedel, *Alone in a Crowd*, 104.
9. Schroedel, *Alone in a Crowd*, 92.
10. Foley et al., “‘I’ll Never Be One of the Boys,’” 1686.
11. Bridges et al., “‘A Trade of One’s Own,’” 374.
12. Bridges et al., “‘A Trade of One’s Own,’” 374.
13. Denissen, “The Right Tools for the Job,” 1065.
14. Schroedel, *Alone in a Crowd*, 130.
15. Squirrelseer, “I find it distracts from my abilities and my work.”
16. Foley et al., “‘I’ll Never Be One of the Boys’”; Wulff et al., “Women Who ‘Talk the Tools.’”
17. Wagner, “Breaking Through the Concrete Ceiling,” 75.
18. Foley et al., “‘I’ll Never Be One of the Boys,’” 1684.
19. Schroedel, *Alone in a Crowd*, 21.
20. Denissen, “The Right Tools for the Job,” 1063.

21. Denissen, "The Right Tools for the Job," 1063.
22. 29 U.S. Code § 2508, "Definitions."
23. Gruber, "Sexual Harassment in the Public Sector"; Wasti et al., "Test of the Cross-Cultural Generalizability."
24. U. S. Equal Employment Opportunity Commission, "Sexual Harassment."
25. Schroedel, *Alone in a Crowd*, 126–127.
26. Schroedel, *Alone in a Crowd*, 200.
27. Riddle and Heaton, "Antecedents to Sexual Harassment," 360.
28. Riddle and Heaton, "Antecedents to Sexual Harassment," 361.
29. Schultz, "Reconceptualizing Sexual Harassment," 1687.
30. United States Equal Employment Opportunity Commission, "Sexual Harassment."
31. University of Illinois Chicago, "Gender-Based Harassment."
32. Powell and Sang, "Everyday Experiences of Sexism," 926.
33. Lawless et al., "Is It Really Just a Joke?"
34. Gapinski, Brownell, and LaFrance, "Body Objectification and 'Fat Talk'"; Kozee et al., "Development and Psychometric Evaluation"; Calogero, Herbozo, and Thompson, "Complimentary Weightism."
35. Swim et al., "Everyday Sexism."
36. Gervais, Vescio, and Allen, "When What You See Is What You Get."
37. Foley et al., "'I'll Never Be One of the Boys.'"
38. Torre, "Women in Blue," 414.
39. Endo and Kawahara, "Gender Differences," 280.
40. Cutts, "What Do You Call a Woman Who Welds?" para. 3–4.
41. Germain, Herzog, and Hamilton, "Women Employed"; Rosa et al., "Challenges, Success Factors."

References

- Bridges, Donna, Larissa Bamberry, Elizabeth Wulff, and Branka Krivokapic-Skoko. "'A Trade of One's Own': The Role of Social and Cultural Capital in the Success of Women in Male-Dominated Occupations." *Gender, Work & Organization* 29, no. 2 (2022): 371–387.
- Calogero, Rachel M., Sylvia Herbozo, and J. Kevin Thompson. "Complimentary Weightism: The Potential Costs of Appearance-Related Commentary for Women's Self-Objectification." *Psychology of Women Quarterly* 33, no. 1 (2009): 120–132.
- Crawford, Matthew. *Shop Class as Soulcraft: An Inquiry into the Value of Work*. New York: Penguin, 2010.
- Cutts, Gina. "What Do You Call a Woman Who Welds? A Welder," *The Welder*, April 19, 2023. <https://www.thefabricator.com/thewelder/article/aluminumwelding/aluminum-etc-what-do-you-call-a-woman-who-welds-a-welder>.
- Denissen, Amy M. "The Right Tools for the Job: Constructing Gender Meanings and Identities in the Male-Dominated Building Trades." *Human Relations* 63, no. 7 (2010): 1051–1069.
- Endo, Hiroshi, and Koichi Kawahara. "Gender Differences in Hand Stability of Normal Young People Assessed at Low Force Levels." *Ergonomics* 54, no. 3 (2011): 273–281.
- Foley, Meraiah, Sarah Oxenbridge, Rae Cooper, and Marian Baird. "'I'll Never Be One of the Boys': Gender Harassment of Women Working as Pilots and Automotive Tradespeople." *Gender, Work & Organization* 29, no. 5 (2022): 1676–1691.
- Gapinski, Kathrine D., Kelly D. Brownell, and Marianne LaFrance. "Body Objectification and 'Fat Talk': Effects on Emotion, Motivation, and Cognitive Performance." *Sex Roles* 48 (2003): 377–388.

- Germain, Marie-Line, Mary Jean Ronan Herzog, and Penny Rafferty Hamilton. "Women Employed in Male-Dominated Industries: Lessons Learned from Female Aircraft Pilots, Pilots-in-Training and Mixed-Gender Flight Instructors." *Human Resource Development International* 15, no. 4 (2012): 435–453.
- Gervais, Sarah J., Theresa K. Vescio, and Jill Allen. "When What You See Is What You Get: The Consequences of the Objectifying Gaze for Women and Men." *Psychology of Women Quarterly* 35, no. 1 (2011): 5–17.
- Gruber, James. "Sexual Harassment in the Public Sector." In *Academic and Workplace Sexual Harassment: A Handbook of Cultural, Social Science, Management, and Legal Perspectives*, edited by Michele A. Paludi and Carmen A. Paludi, 49–75. Westport, CT: Praeger Publishers, 2003.
- Jobs and Skills Australia. "Welders (First Class)." Accessed May 15, 2024. <https://www.jobsandskills.gov.au/data/labour-market-insights/occupations/322313-welders-first-class>.
- Kozee, Holly B., Tracy L. Tylka, Casey L. Augustus-Horvath, and Angela Denchik. "Development and Psychometric Evaluation of the Interpersonal Sexual Objectification Scale." *Psychology of Women Quarterly* 31, no. 2 (2007): 176–189.
- Lawless, Tiffany J., Conor J. O'Dea, Stuart S. Miller, and Donald A. Saucier. "Is It Really Just a Joke? Gender Differences in Perceptions of Sexist Humor." *Humor* 33, no. 2 (2020): 291–315.
- Powell, Abigail, and Katherine J. C. Sang. "Everyday Experiences of Sexism in Male-Dominated Professions: A Bourdieusian Perspective." *Sociology* 49, no. 5 (2015): 919–936.
- Riddle, Kimbely, and Karen Heaton. "Antecedents to Sexual Harassment of Women in Selected Male-Dominated Occupations: A Systematic Review." *Workplace Health & Safety* 71, no. 8 (2023): 356–365.
- Rosa, Jasmin E., Carol K. H. Hon, Bo Xia, and Fiona Lamari. "Challenges, Success Factors and Strategies for Women's Career Development in the Australian Construction Industry." *Construction Economics and Building* 17, no. 3 (2017): 27–46.
- Rose, Evan K. "The Rise and Fall of Female Labor Force Participation during World War II in the United States." *The Journal of Economic History* 78, no. 3 (2018): 673–711.
- Schroedel, Jean Reith. *Alone in a Crowd: Women in the Trades Tell Their Stories*. Philadelphia: Temple University Press, 1985.
- Schultz, Vicki. "Reconceptualizing Sexual Harassment." *Yale Law Journal* 107 (1997): 1683–1805.
- Squirrelseer. "I find it distracts from my abilities and my work." Reddit, October 11, 2023, <https://www.reddit.com/r/BlueCollarWomen/comments/1754hqj/comment/k4g206z/>.
- Swim, Janet K., Lauri L. Hyers, Laurie L. Cohen, and Melissa J. Ferguson. "Everyday Sexism: Evidence for Its Incidence, Nature, and Psychological Impact from Three Daily Diary Studies." *Journal of Social Issues* 57, no. 1 (2001): 31–53.
- Thomas, Kathleen. *Don't Call Me Rosie: The Women who Welded the LSTs and the Men who Sailed on Them*. London: RSM Press, 2004.
- Torre, Margarita. "Women in Blue: Structural and Individual Determinants of Sex Segregation in Blue-Collar Occupations." *Gender & Society* 33, no. 3 (2019): 410–438.
- University of Illinois Chicago. "Gender-Based Harassment." Accessed May 15, 2024. <https://sexualmisconduct.uic.edu/policy/definitions/gender-based-harassment/>.
- U.S. Code § 2508. "Definitions." <https://www.law.cornell.edu/uscode/text/29/2508>.
- U. S. Department of Labor Statistics. "Labor Force Statistics from the Current Population Survey 2023." January 26, 2024. <https://www.bls.gov/cps/cpsaat1.htm>.
- U. S. Equal Employment Opportunity Commission. "Sexual Harassment." Accessed May 15, 2024. <https://www.eeoc.gov/sexual-harassment>.
- Wagner, Heidi. "Breaking Through the Concrete Ceiling: Tradeswomen in the United States Tell Their Stories of Struggle and Success." *Journal of Working-Class Studies* 3, no. 1 (2018): 68–80.
- Wasti, S. Arzu, Bergman, Mindy E., Glomb, Theresa M., & Drasgow, Fritz. "Test of the Cross-Cultural Generalizability of a Model of Sexual Harassment." *Journal of Applied Psychology* 85, no. 5 (2000): 766–778.

- Welfare, Katherine, Fred Sherratt, and Matthew Hallowell. "Perceptions of Construction Work: Views to Consider to Improve Employee Recruitment and Retention." *Journal of Construction Engineering and Management* 147, no. 7 (2021): 04021053, 5. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0002057](https://doi.org/10.1061/(ASCE)CO.1943-7862.0002057).
- Wulff, Elizabeth, Donna Bridges, Larissa Bamberry, and Branka Krivokapic-Skoko. "Women Who 'Talk the Tools' and 'Walk the Work': Using Capital to Do Gender Differently and Re-gender the Skilled Trades." *Journal of Sociology* 58, no. 1 (2022): 26–44.

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Chapter 11

Developing Competences



Abstract After over two years of work at Howe's, I've developed competences in some knowledge domains, and with them, I've completed projects on my own, with little to no input from Jim or my coworkers. That is, I've developed sufficient competence in some domains to analyze a project, to plan its steps, and to carry out those steps. But as Dreyfus and Dreyfus wrote, "The competent performer judges by means of conscious deliberation." In this chapter, I first discuss the sometimes-agonized conscious deliberation I go through as I move through a project's steps. Discussing examples along the way, I discuss how, as I've developed competences, I've improved the quality of my projects while more often completing projects independently—or nearly independently. While I still make mistakes, I'm able to make decisions based on context, as effectively demonstrated in the realm of portables—those projects in different sites around Ames. Indeed, the chapter ends by discussing the progression of my learning in unpredictable worksites outside the walls of the shop.

Differentiating among the stages of expertise, Dreyfus and Dreyfus wrote:

Thus according to our description of skill acquisition the novice and advanced beginner exercise no judgment, the competent performer judges by means of conscious deliberation, and those who are proficient or expert make judgments based upon their prior concrete experiences in a manner that defies explanation.¹

After over two years of work at Howe's, I've developed competences in some of the knowledge domains required for consistently self-sufficient work in the shop. With this learning development, I've completed projects mainly on my own, with little to no input from Jim or my coworkers. I've developed sufficient competence in some domains, such as drilling or tig welding steel, to consciously analyze a project, to deliberate on and plan its steps, and to carry out all those steps largely unassisted.

But as Dreyfus and Dreyfus pointed out, a person of competent-level knowledge like me is continuously consciously problem-solving. Someone like Jim, someone with great experience and expert-level knowledge across domains, is capable of processing problems more intuitively, with less conscious deliberation.² So too is someone with proficient-level knowledge across domains, someone like Adam. The

main difference between proficiency and expertise, Dreyfus and Dreyfus said, is this: People with proficient-level knowledge understand a problem intuitively, but unlike those with expert-level knowledge, will still consciously consider how to go about solving the problem.

This chapter examines the conscious deliberation, successful analysis, and near-independent work of someone—in this case me—with job-shop competences. It also demonstrates that development of those competences within a more limited arena, that is, within the realm of portables—those unpredictable repair jobs found outside the shop.

Consciously Deliberating

Slowly, I've developed some ability to judge tasks for myself, always with (great) deliberation in identifying the challenges they'll pose and the ways I might overcome those challenges, for example, by prepping an item for repair, fixturing an item so that I can tack it, and determining the process and amperage to use for welding. My knowledge in some domains has approached the competent level, but my deliberations have been prolonged. At these moments, I feel like the living, breathing embodiment of the "Hamlet model of decision-making,"³ where the mind agonizes over choices and, like Hamlet, freezes in inaction. My ponderousness clearly reveals itself when I'm tasked with repairing oddly shaped, unwieldy items. For example, one spring day, Jim gave me an unusual—even for Howe's—project to work on. It was the top piece of a large tent, the kind used for wedding receptions (Fig. 11.1). I was supposed to drill and tap two holes on the top of the multiarmed part to secure a rounded cap that would sit on top. Before I started, I stood staring at the peculiarly shaped item, trying to determine what problems it would bring. After a minute, I realized that I'd have to take extra care with drilling and tapping the holes, as they would sit along a curved ridge. Then, I debated how I was going to clamp this unwieldy item for drilling and tapping. I spent 15 minutes finding pieces of steel to grip the tent top in the vise of the drill press, trying to keep each hole perpendicular to its location along the curve. Thus, both the planning and the execution of this task took much longer than either Jim or Adam would have required.

A few months later, Jim gave me a giant steel umbrella to fix (Fig. 11.2). It was part of an art project, and one arm of the umbrella had broken off. My job was to tig weld it back on. But like the tent top, the umbrella wouldn't sit flat. I spent a half hour arranging leftover pieces of square tubing to hold the umbrella and its broken leg in place while I got them tacked together. In addition, this was the first project that I had to tig weld while standing. Because the umbrella arms were so long, I couldn't otherwise reach the inside of the V that the arms created where they met the central tube. I pushed into my tig welding ZPD, balancing on one leg and using my right foot to control the welder's pedal as I carefully laid filler metal around the broken-off arm. My welds weren't pretty, but they'd work.

Fig. 11.1 A tent skeleton with two newly tapped holes



Fig. 11.2 The leg of an umbrella tig welded back on



These types of projects underscore the uniqueness of each project at Howe's. While Jim and Adam have built up the knowledge necessary to intuitively assess each project, unconsciously mapping a project's features onto similar features of prior projects, I consciously analyze each project, especially when their physical forms defy typical processes. In addition, with his expert-level knowledge, Jim would have intuited solutions for drilling the tent top and fixturing the umbrella, but my conscious deliberations added to the project durations. On the other hand and the bright side, I managed to identify the projects' challenges and carry out the repairs myself, both of which indicate competence.

As the examples above attest, attaining competence in some knowledge domain means moving away from the rule following of novice and advanced-beginner levels

toward consideration and planning. But that's not to say that competence won't experience setbacks, something research on the development of expertise doesn't always mention explicitly. Wanting to deliberately practice tig welding aluminum, I asked Jim if I could repair two aluminum lawn chairs that had been sitting in the pile for weeks (Fig. 11.3). I saw that several slats of each seat had broken, and all the slats needed reinforcement. I thought about cutting 16 aluminum pieces—two for each side of each slat—to attach each slat to each chair seat's frame. When I told Jim my idea, he told me that I was on the right track in thinking about what the chairs needed to work as they should, that is, without dumping their users on the ground. But he noted that I could make the job easier by cutting four larger pieces of aluminum support—one for each side of each seat—rather than making a bunch of pieces.

With that expert advice in mind, I cut four strips of aluminum flat bar, sanded them, and then set about to bending them so that they'd reinforce the ends of the slats and run along the sides of the chairs. When I tried to bend the first piece of flat bar on the small press brake, it snapped in two, sounding off like a firecracker. That's when I recalled relevant cognitive knowledge: Aluminum, like all other metals, comes in different alloys. Those alloys depend on the elements used in their creation, such as the silicon in 6061 aluminum. The 6061-aluminum flat bar I'd used has low ductility; it doesn't bend. So, I needed to cut strips of 5052 aluminum from drops stored at the back of the shop. In contrast, 5052 is alloyed with magnesium and chromium, making it more bendable, less brittle. Then I proceeded to redo the sanding I'd already done

Fig. 11.3 Tig welds on an aluminum lawn chair



on the four previous pieces. Once sanded, they bent beautifully and, once welded, would transfer the stress from weight on the slats to the frame.

Then I started tig welding the bent supports to the lawn chairs. Needing some time to situate my body—the angle of the torch in my right hand, my introduction of the filler metal with my left, and my right foot controlling the amperage with the pedal, my first weld looked, as I wrote in my journal that day, “really crappy.” I stuck the tungsten into the weld, producing contamination that looks as if someone had sprinkled black pepper into the liquid metal. But with more practice, coordinating my torch angle and travel speed and amperage all the while, the other welds progressively got better. I realized too as I progressed from slat to slat, that I didn’t need to worry so much about burning a hole through the slats or the frame. My constant fear of ruining a customer’s item started to abate.

The lawn chair project showed me that competent-level performance may include errors. Even though I stumbled, first with the cognitive knowledge of aluminum type and later with the procedural knowledge of aluminum tig welding, I wasn’t following rules, thinking consciously about a 45-degree travel angle or a travel speed of so many inches per minute like a person of novice- or advanced-beginner-level knowledge.

Being Right

As I develop competences, I’ve found that I can sometimes—not always—conjure a viable idea when Jim asks me how I’d solve some problem. This wasn’t always the case. About four months after I started at Howe’s, I wrote this in my journal:

Jim asked me for my opinion on two jobs that we (he) has to do. One was off a snowplow. The driver actually twisted 1 1/2 inch metal and snapped the pin (like 2 inches in diameter). The other was from an excavator. Jim is thinking about either making a new piece from the water jet or saving the piece but building up the components again (welding up layers like I did with the hitch months back). The main point here is that he keeps asking me what I think—perhaps hoping that I’ll show myself capable of having some insight. I’m not sure that I’ve shown that yet.

Especially early on in my time at Howe’s but even now, when Jim asks how I’d go about fabricating or repairing something, I’m limited by the scope of my cognitive and procedural knowledge, a limitation made worse from my lack of a background in mechanics, as I’ve lamented before. When I was working on a trailer for a tiny-house builder, I found that the trailer’s arm, made of square tubing, had welded into the receiver tubing under the trailer. The arm had dragged along the road, causing the two pieces to weld together. When I showed Jim the problem, he asked me, “How are you going to get it out?” I thought perhaps I could use a Dremel to grind the stuck tubing from the insides of the receiver tubing. Jim scoffed at that idea and asked, “Why not use a slide hammer?” Why not? Because I’d never heard of a slide hammer.

Jim navigated to his table, piled high with clamps, sanding belts, grinding wheels, and all else, and found underneath what I later learned was a small slide hammer.

Once Jim demonstrated how to use it—welding a small steel tag to the piece to be removed, attaching it to the slide hammer, and moving the handle back and forth—I understood how this tool was perfect for my purpose: The force of the blow transferred to the attached tubing, popping it out of the receiver. Indeed, the next day, I worked on salvaging the trailer tongue by carbon arcing the welds holding the old tubing inside of it. After I'd removed the old welds, Jim appeared, wanting to know what we'd use to extract the old tubing from the tongue. "Slide hammer!" I exclaimed. We've had the same conversations about pipe wrenches, Ford wrenches, reamers, knock-out punches, lock nuts, and myriad other items I'd never heard of before they became the preferred response to one of Jim's questions.

Jim's questions don't all hinge on knowledge of tools and their capabilities. Sometimes his questions demand design creativity, as when Jim asks how I'd construct a fixture or a jig to speed the process of building multiples of some item. When we had to weld 50 fence poles, Jim asked me how I'd construct a fixture that would hold the 10-foot-long tube against the square base while allowing someone to weld around the tube. But creativity, too, requires knowledge. It's easier to think of fixturing possibilities for tall fence poles if you have a rich set of experiences from which to pull ideas to transfer to the new situation. When I described my idea, which involved rolling the tube on two sets of two wheels, Jim had questions. Mainly he wanted to know how I'd clamp the 10-foot pole, resting horizontally on two sets of wheels, to the base that we'd be welding on. I didn't have a good answer for that. As Robert Sternberg wrote about creative expertise, "To be truly creative, one needs also to be analytically strong, because creativity involves, in part, analyzing one's own and others' ideas to determine what can be done better."⁴ My analytical capability was slouching toward competence, but still it stumbled on the way. We ended up using a fixture of Jim's design together with a weld placer, as mentioned in Chapter 6.

But now, years after the fence-pole project, I sometimes generate plausible answers. When two farmers came in with a bent shaft for a John Deere corn seeder, I told them that Jim would likely straighten it on the press brake. One of the farmers, not so much disagreeing with me as expressing a worry, said that he thought maybe we would have to cut out the bent shaft and fabricate a replacement. I went to the back of the shop, found Jim, and asked him to come to the front to assess the project. He told the customers the exact same thing that I did: We'd straighten it on the press brake. It felt good to know what needed to be done, even though I couldn't yet straighten the corn-seeder shaft myself.

Even better, over two years into my work at the shop, Jim asked me how I would make the bend and curve on a replacement fender for on an old Corvette. Remaking this car part would be tricky. It had a $\frac{3}{4}$ -inch lip, a 90-degree bend, along its length, but it was also curved to cover a wheel. Thinking about how Jim had demonstrated for me, Zach, and Adam how to use the Hossfeld bender to curve angle iron, I thought we might do the same for this project, treating the lip like one half of the angle iron, tucking it under the Hossfeld die that made the curve.

When I was done explaining my idea, Jim murmured, "Huh." Then he went to his shelves of Hossfeld dies to see whether he had one that fit the radius of the curve in the Corvette fender. As he looked through the dies, I asked him how he had been

Fig. 11.4 Comparing the new fender piece against the original



planning to solve the problem. He said that we could use one of the roller machines. We could hang the lip over the edge of the roller to make the curve. After a minute, he found his 10-inch-radius die. It would fit the Corvette fender's curve. "Let's try your idea," he said.

First, we had to make the 90-degree bend along the long side of the steel strip. We used the box-and-pan brake for that. Then, Jim installed the 10-inch-radius die on the Hossfeld. I had to watch closely when he did this because I'd only seen it done once before—the day he demonstrated for us all how to curve angle iron. He tucked the flange under the die as he worked the strip of fender around its radius, pulling the handle to press the sheet to the curve of the die. The sheet crimped a bit when he started, but the idea worked (Fig. 11.4).

Disassociated from an ongoing project and not targeted to my ZPD, Jim's impromptu lessons about a tool or process often fail to connect to my prior knowledge. As I noted in Chapter 4, though, Jim intends through these lessons to demonstrate to us the shop's possibilities. At least in this case, one of those lessons transferred to my future problem-solving.

Achieving Independence (Mostly)

After nearly three years at Howe's, I've developed enough cognitive and procedural knowledge to complete some fabrication projects on my own, with little or no input from Jim. The first of these was a bracket for a hog pen. Jim gave me the existing

bracket and told me to make two more just like it. Making two copies meant using of the Hossfeld bender because each bracket needed two loops attached to it, which would hold a pin. In addition, I needed to use the Hossfeld bender to make 15 new pins for the brackets out of 3/8-inch round stock. The project also involved using the ironworker to punch two holes in each bracket, as in the original. It also involved using the press brake, which I needed to make the 90-degree bend on one end of the bracket. It also involved stick welding the loops on and tig welding a stainless bolt on as well. In all of this, I had to ensure that the distance between one component and another was exactly the same as it was on the original.

I planned out the steps that I would take. With this project, for the first time, I set up the Hossfeld bender on my own, determining for myself the radius of the pin I'd use to replicate the existing bracket. After three failed attempts, I finally got the radius I wanted and managed to keep the flat bar from twisting as I bent it around the Hossfeld's pin. (Later, Jim told me that he'd found my three trial runs in the scrap bin. "I found your flat bars," he said, meaning that he'd noted that I'd goofed up before finally getting the loops to perfectly match the original.) I wrote this in my journal about challenging myself to replicate the same length past the bend: "I just found a pin with the radius and paid attention to how much was sticking out on my practice one. Then I just did the math and managed to get the rest at the same length. Success!" I made four identical loops, two for each bracket.

Then, using the ironworker, I punched two 1/2-inch holes in each bracket. At this point in my tenure at Howe's, I knew to place the slug on top of the punch to bridge the distance between the shaft and the punch and to make sure the punch and die were well tightened down. No mistakes this time. Instead of using only measurements, I laid the original beside the new brackets to make sure the holes lined up. I had learned to check my fit-up along the way.

I also used the small press brake, the Enerpac, on my own. First I measured the inside diameter of the original bracket to determine the location of the 90-degree bend on the new brackets. Then, I rotated the die so that the 2-inch V opening was on top. The die opening must be eight times the thickness of the metal you're bending, and my brackets were 1/4-inch thick. Turning the handle that moves the punch downward, I tried to watch from the side to ensure my bend was 90-degrees, and I used the combination square as I'd seen Jim do to verify that the bends were spot on at 90-degrees. After these steps, I was finally ready to start welding. I began by stick welding the four loops into place, making sure they aligned with the loops on the original. The final step was to tig weld stainless bolts onto the brackets. I knew that I should tig weld them instead of stick welding them with the 7018 electrodes we typically use. Those electrodes wouldn't work well with stainless steel. In short, in my years at Howe's I'd developed sufficient cognitive and procedural knowledge to independently assess the job and carry out the steps of bending, punching, and welding. The brackets, not to mention 15 pins for them, were ready for their hogs (Fig. 11.5).

The second fabrication project that tested my ability to manifest multiple knowledge domains competently was one that a lot of people would see: a stand for a plaque thanking the people who had contributed to a kayak launch at Ada Hayden Park in



Fig. 11.5 One of the hog-pen brackets that I made (left) and pins for the brackets (right)

Ames. Before he left for Des Moines one day, Jim told me to start on the project. Although it didn't involve any bending, the project involved drilling and tapping a hole and stick welding in a tight angle—all tasks within my ZPD. It also involved solving a problem: getting a piece of receiver tubing—the main piece that created the height of the sign—to slide easily on and off a piece of square stock—the piece that composed the sign's base. The sign's receiver tubing would slide over a piece of square stock, which was in turn attached to a base that would be bolted to the ground. The idea was that park employees would be able to lift the sign from the base in the winter to protect it from snow plows.

Jim wanted a $\frac{1}{2}$ -13 threaded hole for the bolt that would hold the tubing to the base. I looked to one of Jim's posters that listed the drill sizes for corresponding tap sizes, numbers and letters that once meant nothing to me but now were comprehensible. I wanted a 27/64 drill bit. After drilling the hole on the drill press, I started to use the dead center to line up the tap to the hole. Seeing which dead center I'd grabbed, Adam came over to tell me that I could use the spring-loaded dead center instead of the static one I had been using. It would move downward as I tapped the square stock but maintain the correct, perpendicular alignment. The spring-loaded dead center worked well, but I encountered another problem: turning the handles of the tap. I needed more leverage to cut away the steel and make the threads. Using a piece of tubing as a lever as I'd done a thousand times before when using a wrench, I started turning the tap handles. Adam must have seen what I was doing because he came over to check on me again. This time, he told me—warned me rather—that using a lever could break the tap handle. If I wanted to use a lever, I'd need to use one on both sides of the handle. Or, I could simply choose a larger tap handle in the first

place. It is easy to focus, as I have, on the scaffolded interactions that emerge between people with novice-level knowledge and people with expert-level knowledge, like me and Jim. But it's important, too, to point out the teaching and learning of embodied knowledge that goes on between coworkers in a shop like Howe's. Adam explained why my technique was problematic and then, finding a larger tap handle, left me to continue my task and my deliberative practice.

As Billett wrote, such situations are those "where the contributions of more experienced coworkers are most useful in guiding the learning of knowledge (procedures and concepts) that cannot be learnt alone."⁵ Similarly, both Adam and Zach provided motivational scaffolding when I told them that before he left for Des Moines, Jim had told me to practice the weld in the acute angle between the sign's panel and its receiver tubing. He had said that it's easy to trap slag in a tight space like that, so I should practice first. Laughing, they told me I'd developed enough stick welding knowledge to skip a practice run. I appreciated their motivating praise but, lacking confidence, I practiced the weld. In the end, my weld looked consistent and tied into the base metal. Sadly, in its tucked away location, no one would see it.

After I had the hole in the square stock tapped, I measured to find the spot to drill the hole in the receiver tubing that would slip over the base. After I'd competently drilled that hole, I tried to slip the receiver tubing over the base—but it wouldn't slide on. The seam on the inside, created by the weld process used to create hot-rolled tubing, was getting in the way of being able to smoothly slide the sign on and off its base. Pondering potential solutions to the problem, I came up with just one: using the Dynofile, a skinny-belted sanding tool, to sand off the seam. But that solution, I knew, wouldn't be entirely satisfactory because the Dynofile would reach only five or six inches into the tubing, not the eight inches required by the length of the square stock. So I decided to grind down the sides of the square stock (Fig. 11.6, left).

When Jim returned from Des Moines and saw what I'd done to the square stock, he guffawed and uttered the work philosophy that he'd imparted numerous times before: "Your work is your signature." For example, once when I was repairing a cheese slicer for the chair of my university department, I'd left a little bump where I'd spot welded the handle to the blade. Jim looked at the little bump and intoned, "Your work is your signature." This time, he thought the ground-down square stock looked sloppy and haphazard. As was the case with the cheese slicer project, I objected to the accusation that I hadn't taken sufficient pride in my work. Indignantly, I asked him what I should have done to get the square stock into the receiver tubing. He said that if I'd asked for help rather than grinding away at the square stock, he would have showed me how to mill a thin trough in the square stock that would enclose the tubing's seam. That solution, of course, would have been far more elegant than mine. And if I had waited for Jim, I would have gotten a one-to-one interaction focused on using the mill. But if I'd waited for Jim to return from Des Moines, the project would have been stalled for hours. Once again, one of the limitations on workplace learning had struck: Jim's expertise was a limited resource, and the project suffered somewhat from it.

Nevertheless, I tried to minimize the defect, pointing out that the square stock wouldn't be visible most of the time because the receiver tubing would cover it



Fig. 11.6 The ground-down square-stock stand for the park sign (left) and the completed sign for the park (right)

(Fig. 11.6, right). Listening to my excuse, Jim looked disappointed. “No one will see it” holds little water for a person like Jim who constantly aims for perfection. You do it right even if no one will see it. Jim’s philosophy is one that I heard at other fabrication shops. At Quality Manufacturing, for example, the time spent attaining tolerances and standards that surpass those of their clients is in part offset by the time employees would have spent analyzing and implementing a long list of less rigorous technical specifications. For example, some of its clients have less strict standards for surfaces that are only partially visible or that aren’t visible. An employee explained Quality’s policy:

And so we’ve got this dimension, this dimension and this dimension. So the surface that you can see is class A, which is like the hood of a Cadillac. So then this surface here that you can’t see, but it’s still facing you, we’ll say this is a class B surface. So this surface under here that’s facing the dirt, basically. This is a class D surface. So they have different perspectives. So you have to remove X amount of particulate, weld spatter. “Well, spatter off of this or this? Nothing on this.” So you’re like wasting time scratching your head, trying to figure out. What we do is, “Spatter on any surface shall be removed.”

In other words, high standards like Jim’s have their benefits as well.

Despite its flaw, I felt pride in my work on the sign. I’d completed nearly all the other steps—the drilling, tapping, punching, and welding—competently, and I was especially thrilled with the idea that something I’d made would rest in a city park. I even said as much to the city employee who came to pick up the sign. He kindly told me that he planned to install it right away. I just wish I could have signed it literally rather than simply allowing my work to be my signature.

A third fabrication project tested my ability to achieve correct angles. This time, I was to remake a drain catch basket that had been commissioned by the athletics department of the nearby university. Because employees lowered the basket into a hole, the new basket had to match the footprint of the old basket or be slightly smaller. I began by measuring the old basket's dimensions as Jim had shown me, paying attention to the angles of the bends on the corner pieces and to the angles of the trapezoids that made up the basket's sides.

I asked for Jim's input on one step. Although I knew how to set up the hydraulic ironworker, I wondered whether there might be a faster way to punch all the holes in the basket's bottom and sides. Jim told me the mechanical ironworker would get the job done faster. He demonstrated how to adjust the position of the die, which was a much more difficult process than on the hydraulic ironworker. Once we set up the ironworker, I spent an entire morning punching holes in the basket's bottom and four sides, moving row by row and moving the stop back and forth 1 ½ inch to align the holes.

The next day, I tackled the bends by myself, using an angle finder (again, as Jim had shown me) to ensure that my bends matched those of the original basket. Then came the difficult step of fixturing the basket so that I could tack the pieces in place. As I mentioned before, fixturing requires considering the best ways to get pieces to stay in place so that you can tack them. In big manufacturing facilities like John Deere, engineers make fixtures so that welders can quickly put pieces in their correct place and weld them together. In a job shop like Howe's, each fabrication project requires figuring out fixturing for yourself. Usually, I look around for short pieces of tubing or solid stock that have enough weight to keep something exactly where I want it. Critically, I had to ensure that the sides sat at 90 degrees to each other while fitting the angles of the corner pieces and that the basket's dimension stayed within the footprint of the original (Fig. 11.7).

The drain basket involved punching, bending, and welding, but it pushed forward my ability to achieve correct angles—those of the trapezoidal sides and the bends on the corner pieces and bottom. The world, after all, is full of non-90-degree angles.

Learning Outside the Box (of the Shop)

Eventually, I want to be competent—perhaps one day even proficient—in all the shop's knowledge domains, even the seemingly minor ones. Towards that end, I've tried to develop competence in tasks that keep the shop running. One of these tasks is moving Jim's portable truck out of the shop each day. Jim has one truck that is solely for portables. He keeps it parked in the shop most days, so to make room we need to drive it out the main bay garage door and park it out front. Moving the nearly 50-year-old truck, Adam and Zach warned me, takes a bit of practice. After you turn the ignition, you've got to give it some gas. Then, you can take your foot off the clutch and get it moving. After months and months of watching Adam and Zach move the truck, I determined that I needed to participate in this near-daily ritual



Fig. 11.7 Starting to fixture the drain basket (left) and the nearly finished drain basket (right)

as well if I wanted full membership in this community of practice. Learning how to move the truck would be a minor step toward membership, but a step nonetheless. So with Adam outside the driver's-side door, I turned the key, pumped the gas a bit, and drove the truck out of the shop. To do it, I had to sit on the edge of the seat with a kneeling pillow behind me, but I did it. And I did it the next day too. But I wouldn't trust myself yet to take the truck on the road.

Similarly, Zach gave me a lesson in forklift operation so that I wouldn't have to depend on a coworker to move something for me. After some deliberative practice, I'm able to move the forklift where I want it, but like learning how to drive a car, fluidity in actions takes time to develop. My herky-jerky movements indicate my knowledge level, and I wouldn't yet trust myself to use the forklift to delicately balance and lift 20-foot sticks of flat bar and angle iron off the steel truck that delivers shipments to the shop a few times per week, nor to set them onto the two-wheeled cart we use to maneuver the sticks into the main bay. Such procedural knowledge takes time, and it's certainly not part of any welding or machining curriculum. Nevertheless, that knowledge is part of what's required to function fully in a small shop like Howe's. It's part of the hidden network of knowledges helpful for or critical to working in a fabrication shop—the overlooked knowledges that many tradespeople have developed but don't recognize as knowledge. In moving toward competences in them—or at least past novice-level knowledge of them—I deepen my membership in the Howe's community of practice.

As my mentions of Howe's mobile welding truck suggest, not all the work at Howe's gets done within the shop's walls. Sometimes, we have to travel to the job. Jim calls these projects "portables," and we've all adopted the term too, yet another

example of the shared vocabulary that develops in a community. We use Jim's portable truck—stocked with a welder, clamps, tools, and grinders—to make repairs in the field. Jim and Adam have fixed nearly everything—combines, tractors, dumpsters, ladders. The list goes on. What makes portables so exciting and extra challenging for a learner like me are the limitations they pose. Jim tells me when I gripe about having to weld overhead, “In the Navy, we didn't get to flip the submarines upside down to weld on them.” What he means is that if you want to do repair and fabrication, you'll have to contort yourself into some uncomfortable positions to get a job done. Out on portables, that's even more true. In the shop we can sometimes flip or tilt whatever we're working on to work more comfortably and to weld in a flat or horizontal position. But if you're repairing a combine in a field, you can't flip it over to weld flat. On portables, we're also limited by the welder and tools on the truck. Granted, after 37 years in business, Jim has most everything he'd ever need in his portable truck. The truck's side cabinets contain hand and power tools, clamps of all sizes, and PPE like gloves and goggles. The entire passenger's seat and backseat are piled high with still more clamps and grinders and boxes of electrodes. But if you forget something—like Jim and I once forgot to bring a cutting wheel to a job—you have to improvise. In that case, Jim used a grinding wheel to cut—very roughly—the tubing that he would otherwise have cut with the far-more-appropriate cutting disc. Finally, if you're welding outside, you'll have to contend with the weather, even when it's unpleasant. Most days, Jim isn't out working somewhere else, but he does it frequently enough to have invested in a truck for that purpose. Some people run entire welding businesses from their trucks. For them, portables are an everyday occurrence and—like work at Howe's—no two workdays are ever alike.

Jim has shared lots of stories of portables with me, including stories of rarified projects. For example, the engineering college at the local university once asked him to hang the space shuttle wing they'd acquired:

Jim: I was hanging the space shuttle wing in Howe Hall [no relation to Jim], and it's a \$13-million wing, and I am hanging this over the concrete floor. I'm sticking it through a door that I got to turn it sideways. I'm driving across the parking lot with it at the back of my crane. There was a lot of potential for if we dropped it. But luckily I went through a lot of rigging in the Navy. I've got a pretty good sense of balance and squareness and all that. A lot of the guys that were helping me that were engineers or doggone aerospace dudes, that they were like, you sure you can? And it's like, “Yeah, we can.” I called NASA to find out.... But how to make a bracket to sit on the inside of an I-beam to hang up the space shuttle wing? So I was a little nervy.

That project stuck in Jim's memory because the monetary stakes were high. Other jobs stick with him because they involved close calls. One time, again at the university, Jim was to weld pipes in an elevator shaft after the construction team had drained the shaft of water:

Jim: They call up and says, “Hey, we got the east elevators ready to go.” So anyway, I go over, and sure enough they have the [water] at ground level.... So anyway, I get everything ready. People are putting in glass on third floor, they're cutting concrete, they're painting, there's sawdust everywhere, there's drywalling, the whole shebang. But they have no elevator doors on yet, because there's just a shaft there. They got something across it so people don't walk into the elevator shaft.

So I'm getting ready to go. So what you do is- It's all coated so that it doesn't rust. So I ground some of the soot off, and I took just a piece of scrap of- I had to ground it somewhere. It's eight-inch pipe, so you can't just put a ground clamp on it. So I put this piece of flat bar there and I struck an arc, and that was it. The last thing I remember, I woke up. I woke up in the corner of the elevator shaft.... It turns out that they had PVC liner on it. So there's a PVC tube that's 12-inch for this eight-inch pipe, and they had glued all the PVC pipe that morning. And the glue settled to the bottom of the pipe. So when I struck an arc, I had the world's biggest potato gun. It shot up and burned my- My coveralls were just toast. It didn't burn my arm.

When projects fall outside the controlled space of the shop, the unexpected pops up more often—sometimes dangerously, as in the case of flammable glue vapor.

Knowing that I've been interested in portables since I started at the shop, Jim takes me along, sometimes even calling me when I'm not in the shop to check whether I want to go with him. These excursions serve as a sort of synecdoche for the ongoing development of my cognitive and procedural knowledge, that is to say, a part that represents the whole. My participation in portables has progressed from observation to actual participation. To start, I was a helper during these excursions, handing Jim tools or holding something steady while he pounded it. Early in my days at Howe's, Jim brought me along when he went to fix a big door guarding the dumpsters outside an apartment building. The weld on the bottom hinge of the right-hand door was cracked. But Jim pointed out that the cracked weld wasn't the only problem with the doors. The tubing holding the left-side door had gotten water in it. Jim told me that you could tell that water had gotten inside because the concrete that had been poured into the tubing to strengthen it was creeping out the top. The damage had caused the pole to lean a few inches to the right, so the two big doors guarding the dumpsters no longer lined up. Listening to him talk, I thought about Lave and Wenger, those anthropologists who wrote that sometimes, experienced people in a community of practice don't share knowledge with newcomers. They might fear losing their higher status or losing their position.⁶ But there was Jim, sidelining the task for a moment to highlight an important phenomenon that I should be able to identify, the cement that had been pushed out the top of the tubing, and to code that phenomenon by explaining its cause. In other words, there was Jim once again manifesting wisdom-based expertise.

We would need more than the portable truck to straighten the pole, Jim said, so we'd concentrate on the task at hand—the hinge. Jim demonstrated how to use the grinder to create a bevel at the crack and how to clamp the two sides of the now-beveled hinge as close together as possible. He pointed out that the weld itself would draw the two sides in even more as the metal contracted. Then, he made a perfect vertical-up weld, filling the bevel and fixing the hinge. After observing his demonstration and attending to his explanations, I kicked back into helper mode, picking up and putting away the tools and making sure that we'd picked up any stick-electrode ends.

In the months that followed, I did more of the same. Jim took me with him to one of the engineering department's buildings on campus to set up scaffolding; the department had hired Jim to hang a drone that faculty and students had made so that

everyone entering the building would see it above them. He took me with him to the art gallery on campus. The director had hired Jim to create a system for hanging an artist's exhibition—long glass pieces—from the gallery's ceiling. Again, I mainly observed and handed Jim tools. I got to do a bit more than observing when Jim took me along on a portable to a local food co-op, where I helped him fix a banged-up cart corral. First, Jim demonstrated how to use a tool called a Strait-o-Flex, used for straightening and bending. Following Jim's instructions, I helped him straighten the corral's bent leg. He showed me how to use a mandrel to pound a flattened tube opening into round again, making it so it could once again slip over the swaged tubing on the corral's base. Months later, I'd think back to what we'd done to the corral tubing and apply this method when Jim assigned me the task of fixing a galvanized trampoline pole that had creased and bent. He told me to cut the pole where it had creased. Then I used a mandrel to get the tube back to round. I must have impressed him with my work because after I'd finished one end of the cut tube, he said, "That's not bad." A "that's not bad" from Jim goes a long way toward motivating me. After I had both cut ends sufficiently round again, Jim told me to cut a piece of tubing to rest inside the trampoline-pole tubing and act as a backing strip and sleeve. After I ground off the galvanization—an important step given the life-threatening danger associated with welding galvanized steel—I tig welded the tube back together, connecting it to the tubing inside.

My more active learning—imitating and not just observing—happened that fall when Howe's had been hired to build tracks in Boone. Before he agreed to let me work on the project, I had to prove to him that I could perform the weld we'd be doing over and over on site. In other words, although he wouldn't have said it this way, he wanted to diagnose my current level of knowledge to see whether the task fell into my ZPD. I understood why this test was important; if I made a mistake as I welded one of the brackets holding the rail to the cement base, it would be impossible to grind out. The angle was just too tight.

Before we left the shop, Jim made me get on the floor and vertical-up weld two T-joints to see whether I could make a passable weld in that position. I wrote in Chapter 3 about how Jim tested my ability to stick weld a J-groove joint. Similarly, he observed me here. As he watched me weld the first joint, he told me to change my travel angle so that I was pointing the electrode more toward the top of the joint, and he told me—as he would tell me again—to hold the sides of the weld to get good tie-in and to avoid undercut. After passing the test, I drove Jim's Dodge, the other truck he uses for portables, to Boone, while Jim took the primary portable truck. Once there, he showed me how to set up: how to pound the rail so it rested firmly against the bracket and how to clamp the rail to the bracket. Then I began making the same short vertical welds that I'd practiced in the shop.

When employees began to load a train of pedal cars with riders, Jim told me to stop welding and take a break. He didn't want to flash the customers with the bright light of our welding. I perceive this as another manifestation of Jim's wisdom-based expertise. He's aware of his environment even when—or perhaps especially when—he's out on a portable. He's thinking about the well-being of people around him. I didn't think of it until he told me. Kids were riding those pedal cars with their parents,

and they certainly wouldn't know to avoid looking at the flash from the welding. The parents might not know it either.

In the week after, I went out to Boone each day to work on the pedal-car tracks. Each day, Jim told me how to improve my work, but he kept me on the job, even letting me take the Dodge to Boone on my own. That fall week, we worked until just before sunset, stopping when passengers boarded their cars or returned after their rail trip. I loved working outside during those cool, sunny days. The work was repetitive, but the repetition allowed me the deliberative—and if I'm honest, sometimes not so deliberative—practice that I needed to progress in my knowledge of vertical-up stick welding.

After that week welding rail brackets, my contributions to portables somewhat expanded. Once, I helped Jim install a handrail that he had already repaired in the shop. Jim demonstrated how to use a core drill to create a space in the concrete stairs that would hold the railing. Once we'd cleaned out the debris from the two circular holes, we set the handrail in place. Jim told me that we had to make sure the rail was square to the house; if it wasn't, anyone coming up to the front door would notice it. So while he held the handrail in place, I stepped back to get a good sight line. Once we had it square, we lathered Rocktite into the openings. Jim explained that the Rocktite sets quickly in warm weather. Given that the temperature was expected to drop below freezing that night, he said that we'd need to cover the Rocktite with concrete blankets. On this expedition, I'd still observed, but I'd also participated more than I had in my first few portables.

The next portable advanced my learning further. This time, I went along with Adam to repair a large, tubular handrail that had broken off the stairway leading to the door of an apartment building. Just as I'm lucky to have found a patient teacher in Jim, so too am I lucky to work with Adam, a proficient welder, machinist, and portable-task completer. Adam told me that I would tack the handrail in place while he and two men from the apartment building held it steady. Then he let me weld one of the vertical bars, showing me first how to tack the pieces together and then pound the bracket back to flat. I had to close a gap as I welded, and it went pretty well, especially on the last weld, which was on the front of my pole. When I said that my welds could be more consistent, Adam reminded me, "That's the only way you learn," using the motivational scaffolding strategy of giving sympathy. Indeed, even when I got nervous and stuck my stick electrode, he waited patiently and didn't say anything. In the end, I felt good about this portable because I again got practice in squaring up a handrail and this time, I got to do some of the welding that would hold the handrail in place.

Incrementally, my knowledge grows, but in the wide-ranging realm of portables, my knowledge level depends on the task and its context. That's the beauty of portables: They add an extra layer of challenge. For a learner like me, portables are both intimidating and intoxicating.

Conclusion

More and more often, and for more complicated projects, I can complete projects on my own. I've developed sufficient knowledge and engaged in sufficient deliberative practice to bend, punch, drill, tap, and weld without more-expert oversight. Although I've developed competences, I still make mistakes, like grinding down the base of the park sign instead of neatly milling it. Competence means departing from following rules to making decisions based on context, a fact made particularly clear in the varied and unpredictable world of portables. For me, such decisions still require conscious and often lengthy deliberation, but they stem from a strengthening base of cognitive and procedural knowledge, manifesting in eventually knowing what to do. These competences, incredibly meager in relation to all Jim has learned and mastered, have developed through scaffolded interactions with Jim and with my coworkers, interactions that propel and deepen membership within a community of practice.

Notes

1. Dreyfus and Dreyfus, *Mind over Machine*, 21.
2. Dreyfus and Dreyfus, *Mind over Machine*, 30–31.
3. Dreyfus and Dreyfus, *Mind over Machine*, 28.
4. Sternberg, "Four Kinds of Expertise," 423.
5. Billett, *Learning in the Workplace*, 28.
6. Lave and Wenger, *Situated Learning*.

References

- Billett, Stephen. *Learning in the Workplace: Strategies for Effective Practice*. New York: Routledge, 2001.
- Dreyfus, Hubert L., and Stuart E. Dreyfus. *Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*. Washington, DC: Free Press, 1986.
- Lave, Jean, and Etienne Wenger. *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press, 1991.
- Sternberg, Robert. "Four Kinds of Expertise." In *The Science of Expertise*, edited by David Z. Hambrick, Guillermo Campitelli, and Brooke N. Macnamara, 419–427. New York: Routledge, 2017.

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Chapter 12

Learning Community



Abstract In this chapter, I begin by discussing questions that readers might have upon reaching the conclusion: (1) Can we generalize from this study/story? and (2) Would someone need an inordinate amount of self-efficacy to do the same thing I've done? Then, I pull together threads from the previous chapters, focusing on the ways that Howe's has been rich environment for learning, the ways I've enculturated into the community of practice, and the extent to which I've developed a vocational identity. I hope that this book will show the possibility, even if it's a slight one, of attaining the depth and breadth of knowledge—the expertises—of people like Jim.

Although in this book I've drawn from observations and interviews conducted at fabrication sites around Iowa, in my discussions of skilled-trades learning I've mostly relied on my own experiences at Howe's. You may then ask how well my account might generalize to other people working in other job shops, in other fabrication facilities, and in other skilled trades. The short answer is that I don't know exactly. But I'd hazard to guess that my journey resembles that of other people, especially other women, developing conceptual and procedural trade knowledge.

In such skilled-trade workplaces, I've argued, workers must develop a breadth of competences. Because the range of knowledge domains is broad, the learning of any individual knowledge domain, such as using the lathe for simple tasks like making spikes for a trellis, occurs more slowly because it's interspersed with learning other knowledge domains, such as finding x and y on the mill or setting a stop on the press brake or replacing the fenders on a trailer. As I've pointed out, each day at Howe's brings unique projects, including ones outside the walls of the shop. In a context where projects vary widely, opportunities for learning—and for error—multiply. My journey most directly applies to others who inhabit the job-shop context and its ever-changing tasks.

That said, I'd argue that my learning resembles the learning of fabricators in production settings, especially smaller production facilities like Custom Steel Service and Sargent's Metal Fabricating, where the projects regularly change or, at least, cycle. Stereotypic views of production work as mindless monotony¹ fail to acknowledge the project variety that exists in those settings and, more important, fail to

acknowledge the expertises developed by tradespeople in these settings. While production jobs require a narrower range of knowledge domains than does work at Howe's, such jobs nevertheless require scaffolded learning and deliberative practice and offer opportunities for sustained development. In the welding subreddit, one commenter replied to a question about repetition in production welding like this:

I'm a production welder and while everyone else just pumps out barely passable welds I make sure mine are as good as possible. I'll challenge myself when a station becomes too easy. I work on my wrap around, out of position welds, basically anything that I'm not 100% on. In the Sven [sic] months I've been with my company I've become the go to guy. Hell, they pull me and one other guy when they need long vertical uphill welds done and done right. Definitely worth it in my opinion.²

Like this welder, I've used my production opportunities at Howe's to deliberately practice, as when I stick welded fence poles and railroad brackets (Chapter 6). Stereotypical views of production work condescendingly and ignorantly overlook tradespeople's expertises.

Some readers might wonder whether my journey suggests that I have—for whatever reason—more self-efficacy than other skilled-trades newcomers and whether others would display similar belief in their own capacity to function in an unfamiliar trade environment.³ The answer to that is, once again, I don't know. After a few months at Howe's, I certainly developed self-efficacy—a belief in one's capacity to succeed in a task—in the shop's most simple tasks, like cutting flat bar and tubing. Later, after about a year and a half of work, I gained self-efficacy in more complex repair and fabrication tasks, such as making the drain basket (Chapter 11). That self-efficacy mainly arose from the learning that had taken place before, allowing me to believe that I could complete the project largely unaided. I knew how to set up the ironworker to punch the holes. I knew how to bend the steel components. I knew how to mig weld the pieces together. But when it comes to even more complex projects, such as projects that involve machining, my self-efficacy wanes. It instead depends on my knowledge that a more-expert other, likely Jim, will be available to scaffold my learning in order to complete steps within my ZPD. That is, my self-efficacy has always been and continues to be task dependent. I expect that same is for anyone performing and simultaneously learning the varied tasks of a skilled trade.

A Learning-Conductive Context

In this book I've stressed the role of scaffolded interactions in my years of learning at Howe's. With a shared understanding of the interaction's goal, intersubjectivity, a more-expert person can use teaching strategies like demonstrating and explaining to further the learner's knowledge. That progression hinges on the teacher's ability to make their demonstration or explanation or other intervention contingent on the learner's current level of understanding—to target it at the learner's ZPD. To do this, the teacher iteratively diagnoses and intervenes with instruction or cognitive scaffolding to push forward the learner's understanding. Critically, the learner must

interact with the teacher; the learner must engage. Such engagement is particularly important in deliberative practice, where the teacher and learner analyze the learner's performance, and the learner eventually practices deliberately on their own. As discussed in Chapter 3, repetition is not sufficient. The learner must attend to their own performance and analyze it to determine what works and why. The need for deliberative practice reveals the importance of "intra-personal processes as well as inter-psychological processes."⁴

But developing breadth and depth of expertise like Jim's takes time. As educational researchers Carl Bereiter and Marlene Scardamalia wrote, "It is often the case that knowledge has to be built up over a long period of time, sometimes years, before it can start to be functional in solving problems."⁵ Over time, knowledge transfer to related tasks occurs more readily, what Billett called "adaptability."⁶ For example, over iterations of deliberative practice on various projects, a learner like me can recognize when to use a gusset for support or when to use a heat sink. The next situation will not look the same as the others, but transfer has occurred when the learner can highlight and code relevant features of the problem at hand and determine the steps for implementing the task, as I did on that glorious day when I recognized the Corvette fender shared a physical characteristic of angle iron (Chapter 11). To foster adaptability, Stephen Billett called for CTE curricula that "develop knowledge that is robust enough to transcend the particular workplace."⁷ More specifically, he argued that students should experience "the diversity of practice."⁸ Billett gave the examples of a nurse trained in a teaching hospital and a rural hospital, an apprentice cook who practices across a range of restaurants, or a car mechanic who learns in a city dealership and a small-town garage.⁹ Different contexts afford different tools and machines, different expertises of coworkers, and different procedures for accomplishing the same task.

Scaffolded learning like the kind I've experienced at Howe's has come primarily from Jim, but as I've indicated throughout this book, my coworkers have done that work as well. Billett wrote that to develop robust, adaptable knowledge, learners need the teaching of more-expert others: "What is required are more experienced partners (i.e., teachers and workplace peers) who can draw out meaning, assist learners in making links with what they know and how this applies to the ways in which they need to understand and apply knowledge in circumstances that are different from those in which it was learnt."¹⁰ Here Billett pointed not just to teachers' critical role in scaffolding learning, but also in helping learners transfer what they've learned, that is, their role in helping learners understand how and where the knowledge might be employed later.

When a frayed cord on our favorite DeWalt hand drill halted my project, Adam dropped he was doing to demonstrate and explain how to rewire the drill. I watched Adam as he cut the frayed wire out and then stripped the cord to reveal unfrayed wire. He warned me that when I carry out this task in this future, I need to pay attention to where the different colored wires go when I first detach them, or I won't know where the good wires should go. After Adam's lesson, I got so enthusiastic about rewiring tools that I bought my own wire stripper. I think too about Zach's lessons in using the angle-iron coping machine and the Di-Acro bender as part of

teaching me how fabricate goat cages. I can apply these lessons to projects other than goat cages, as coping angle iron for frames and bending steel tubes for handrails are common tasks. Writing about participation in workplace tasks, Billett wrote that a “workplace’s norms and values shape and distribute opportunities for participation and, therefore, opportunities to learn.”¹¹ Like Jim, my coworkers have pushed me to learn even when I’ve been reluctant. It was easy enough, for example, to let them move Jim’s portable truck from the shop each morning, but they encouraged me to learn how to do it myself. They encouraged me to learn how to use the forklift even though I was nervous about hitting or backing into something while moving items. They’ve supplied motivational scaffolding via praise, encouragement, and empathy that has not only pushed me to continue through disappointment and frustration but has also bolstered my self-efficacy—my belief that I can succeed in a new task.

Enculturation into a Community

In his 2014 book on mimetic learning, Billett emphasized that “much learning across working lives occurs outside of direct interactions with others.”¹² Billett here wanted to emphasize that we all teach and learn even when we don’t intend to do so. Although in this book I’ve focused on how I’ve learned through one-to-one interactions with Jim and my coworkers, I’ve also tried to attend to the unintentional learning that goes on outside of such interactions, as when I’ve observed and reproduced the safety behaviors exhibited by Jim and the others, such as leaving the hoists at eye level, where they’re more readily visible. But health and safety practices constitute just one example of how people discern, learn, and enact a community’s values and in so doing become more fully enculturated into a community of practice—that concept first articulated in Jean Lave and Etienne Wenger’s germinal *Situated Learning: Legitimate Peripheral Participation*.

It’s worth dwelling a moment longer on this process of learning through enculturation, this taking up of workplace values that deepens our membership in a work community. No one told me, for example, to take pride in my workspace by keeping it clean and free from the detritus that tends to accumulate on the worktables and floor at Howe’s. I saw the way that Zach strove to keep his worktable free from Jim’s in-progress projects, boxes of electrodes, and spare parts for welding machines. I saw how Adam did the same, carefully lining up any half-used stick electrodes at the end of the day and sweeping his workspace clean after every project. I started cleaning like they did, moving Jim’s accumulated projects off my little table to the shared table and putting away Jim’s extra rods of filler metal so that I could have a clean table as I started a new project. Similarly, I started putting away pieces of steel and other metal dropped from the shear to create some sense of order in the shop and squeegeeing the metal-infused water from the surface of the band saw. Adam and Zach have taught me to take pride in my workspace like Jim has taught me to take pride in my work.

And it makes sense: Your workspace is an extension of you and facilitates—or impedes—your work. These practices accord with the *mise-en-place* philosophy that Dan Chamas advocated in his book *Work Clean*. Teachers at the Culinary Institute of America, Chamas said, “tell students to keep their cutting boards and workstations clean” and “tell them to arrange their tools in a certain order and return them to that order after they use them.”¹³ Adam and Zach battle the continuous onslaught of miscellany that finds its way into Howe’s, fighting to keep their own spaces orderly and to cultivate values like those of the culinary students featured in Chamas’s book.¹⁴ And I’ve grown enculturated into this same philosophy, striving to create organization to further my ability to produce quality work.

More broadly, as mentioned in Chapter 10, pride affords meaning to work. In prior research on the attitudes of skilled tradespeople towards their vocations, study after study has shown that tradespeople name pride in creating something tangible as a positive attribute of their work. In a study of recruitment and retention of construction workers, for example, one tradesperson talked about working on every project as if it were their own.¹⁵ Blue-collar workers in a study of work’s meaningfulness said the same.¹⁶ So too did trades students in Amy Deitrickson’s dissertation on students’ reasons for pursuing skilled-trade education.¹⁷ The pride of instantiating oneself in the world, as both research and my experience show, gives work meaning.

In addition to enculturating the value of taking pride in your work, Howe’s has also instilled the value of curiosity and continued learning. People like Jim—people who have developed expertises across domains—pursue even more knowledge. It’s as if they can’t help it. Bereiter and Scardamalia wrote, “For experts, the problems of insufficient prior knowledge never go away, however. The expert track of development keeps rising toward levels of increasing complexity of performance and understanding.”¹⁸ Even though it sometimes seems like there’s nothing Jim doesn’t already know about fabrication, he continues to push his knowledge, gaining competence, for example, in running the software system for his second, more advanced waterjet machine. And Jim continues to learn from the broader community of welders and fabricators around Iowa by attending meetings of the Iowa ironworkers. I’ve attended two of these meetings with him, seeing for myself how the group members share their experiences of running a business and adopting new technologies. More important, after over 37 years in business, Jim has cultivated a diverse group of friends with even more diverse expertises, from engineers at the university, to farmers, to other local businesspeople. Drawing from their expertises, he continues to develop his own practices and business.

Having co-constructed this large network, Jim has become a critical element in how the city and the broader region of central Iowa operate. Small and large companies rely on him. He’s repaired countless combines and other farm equipment both in the shop and in the field. He’s fabricated stainless steel countertops and repaired restaurant equipment, such as paddles for giant mixers and chutes for shake machines. Daily, he repairs equipment that enables others to run their businesses and that helps others construct and maintain the area’s roads, buildings, bridges, water system, and so on. In other words, Jim plays an outsized role in the city’s health. In this, Jim resembles Willie, the northern New York mechanic featured in Douglas

Harper's *Working Knowledge*. Harper wrote, "Simply put, Willie's combination of mechanical and engineering skill makes him indispensable to others who depend on machinery, dwellings, and vehicles that are old and often improvised from leftover parts."¹⁹ Similarly, Jim's expertises across knowledge domains and his wisdom-based concern for the community's people and organizations have sustained the area's operations.

It's concerning, then, that people like Jim—people with Jim's depth and breadth of expertises—are now not only rare but are also becoming even more scarce. Over the last few decades, trades work has failed to attract sufficient people to replace those Baby Boomers who have retired.²⁰ As people like Matthew Crawford, Jeff Torlina, and Mike Rose discussed in their books on the value of trades, a college-for-all mentality has for decades steered young people toward college, regardless of their motivations and interests. Moreover, CTE has been stigmatized as a pathway solely for underperforming students. In her dissertation examining Millennials' views of trades work, Dietrickson advised that "youth must be guided to vocational training due to interest, not bad grades and misbehavior."²¹ In her dissertation on transformative learning, Brandi Jean Love wrote that changing the image of CTE rarely includes lobbying for "the intrinsic value and personal growth" possible in skilled trades. Trades, she argued, must be "recognized as an intellectual pursuit on par with other forms of higher education." Then, she continued, "perhaps those who prefer experiential learning, working simultaneously with their hands and minds, will be more able to proudly claim their self-directed learning route, and be supported by those who influence them."²² People, especially young people choosing a career, need to understand not only that they can earn a living in a trade but also that they can find fulfillment and community in it. Jim and my coworkers certainly have. And I know I have.

Toward a Vocational Identity

That fulfillment stems at least in part from developing a vocational identity—that sense of being a member of a trade community. Kristine Smith, writing about this concept, defined vocational identity this way: "The possession of a clear and stable picture of one's goals, interest, personality, and talents that leads to relatively untroubled decision-making and confidence in one's ability to make good decisions in the face of inevitable environmental ambiguities."²³ As this definition suggests, gaining a vocational identity depends substantially on a person's competences, including the ability to make decisions independently and without substantial deliberation, even in circumstances where solutions aren't obvious or rote.²⁴ This definition makes sense to me because it explains, at least in part, the reasons that I don't yet wholly identify as a welder/fabricator. Although I've completed some projects on my own without much help from Jim, Zach, or Adam, I can't yet complete such projects consistently. And even when I do take on a project that I can complete on my own, I

still spend too much time debating what step to do next and which way to do it. But, as educational researcher Lisa Ferm and her colleagues wrote, “A learning trajectory should not be understood as a fixed timeline, but rather as a process of constant movement towards a vocation.”²⁵ And that’s how I see my journey at Howe’s and toward skilled-trade competences, proficiencies, and expertises—an unending path. But I also know that somewhere along that path, I’ll have gained sufficient competences to consider myself a full rather than a peripheral member of the community of practice at Howe’s and the larger community of metal workers. I’m on what Ferm and colleagues called “an inbound trajectory,” meaning the route of a learner who intends to become—eventually—a full participant in the community.²⁶

I’ve been lucky to land in a shop like Howe’s, where I have my coworkers, Adam and Zach, who support me in both success and failure. And of course at Howe’s I have Jim, a boss who has been willing to act as the more-expert other in countless scaffolded interactions aimed at moving me along in my knowledge. With a path that runs parallel to his, I can continue to learn and practice. In time, the identity will follow.

A Final Note

In this book, I have tried to show how I’ve developed greater conceptual and procedural knowledge as I’ve worked on wide-ranging projects that vary in the metals, processes, tools, and machines they require. I’ve tried to explain how one-to-one scaffolding from my boss and my coworkers and how my engagement in deliberative practice have moved my competences forward. I’ve also tried to show how, outside intentional teaching and learning, I’ve enculturated into the shop’s practices to become a more fully functioning member of my work community and into the larger skilled-trades community. Finally, I’ve tried to clarify how context, such as my work tasks, the customers, and the shop environment, have affected my learning (Fig. 12.1).

In addition, I wanted in this book to highlight the challenge that many women face when pursuing work in trades like welding, construction, and plumbing, especially as they begin their own learning journeys. Often, like me, they’re starting from zero knowledge, what Bereiter and Scardamalia called the “pervasive problem of how to acquire new knowledge in the absence of sufficient prior knowledge.”²⁷ My account, I hope, shows that with scaffolded learning and deliberative practice, people with histories more like mine than like Jim’s can progress toward skilled-trade competences and even, in time, expertises.

Fig. 12.1 This is me, pumping gas into Jim's Dodge after welding railroad tracks in Boone, Iowa



Notes

1. Kerbo, *Social Stratification and Inequality*; Saari, Leinonen, and Tapanila, "Sources of Meaningful Work"; Torlina, *Working Class*.
2. theluce39, "This is the way."
3. Bandura, "Guide for Constructing"; Bandura, *Self-Efficacy*.
4. Billett, *Mimetic Learning*, 50.
5. Bereiter and Scardamalia, *Surpassing Ourselves*.
6. Billett, "Toward a Workplace Pedagogy," 33.
7. Billett, "Knowing in Practice," 448.
8. Billett, "Vocational Curriculum," 14.
9. Billett, "Vocational Curriculum," 14.
10. Billett, *Vocational Education*, 245.
11. Billett, "Critiquing Workplace Learning Discourses," 62.
12. Billett, *Mimetic Learning*, 46.
13. Chamas, *Work Clean*, 4.
14. Chamas, *Work Clean*, 5.
15. Welfare, Sherratt, and Hallowell, "Perceptions of Construction Work," 6.
16. Saari, Leinonen, and Tapanila, "Sources of Meaningful Work."
17. Deitrickson, "College-for-All."
18. Bereiter and Scardamalia, *Surpassing Ourselves*, 175.
19. Harper, *Working Knowledge*, 4.
20. Veckie and Veckie, "Vocational Knowledge Transfer"; Perna, "Why Gen Z."
21. Deitrickson, "College-for-All," 195–196.
22. Deitrickson, "College-for-All," 171.
23. Smith, "The Ego Identity," 14.
24. Klotz, Billett, and Winther, "Promoting Workforce Excellence."
25. Ferm et al., "Vocational Students' Identity," 95.
26. Ferm et al., "Vocational Students' Identity," 95.
27. Bereiter and Scardamalia, *Surpassing Ourselves*, 168.

References

- Bandura, Albert. "Guide for Constructing Self-Efficacy Scales." In *Self-Efficacy Beliefs of Adolescents*, edited by Frank Pajares and Tim C. Urdan, 307–337. Charlotte, NC: Information Age Publishing, 2005.
- Bandura, Albert. *Self-Efficacy: The Exercise of Control*. New York: Worth Publishers, 1996.
- Beireter, Carl, and Marlene Scardamalia. *Surpassing Ourselves: An Inquiry into the Nature and Implication of Expertise*. Chicago: Open Court, 1993.
- Billett, Stephen. "Critiquing Workplace Learning Discourses: Participation and Continuity at Work." *Studies in the Education of Adults* 34, no. 1 (2002): 56–67.
- Billett, Stephen. "Knowing in Practice: Re-Conceptualising Vocational Expertise." *Learning and Instruction* 11, no. 6 (2001): 431–452.
- Billett, Stephen. *Mimetic Learning in and for Work: Learning in the Circumstances of Practice*. Cham: Springer, 2014.
- Billett, Stephen. "Toward a Workplace Pedagogy: Guidance, Participation, and Engagement." *Adult Education Quarterly* 53, no. 1 (2002): 27–43.
- Billett, Stephen. "Vocational Curriculum and Pedagogy: An Activity Theory Perspective." *European Educational Research Journal* 2, no. 1 (2003): 6–21.
- Billett, Stephen. *Vocational Education: Purposes, Traditions and Prospects*. Dordrecht: Springer, 2011.
- Chamas, Dan. *Work Clean*. New York: Rodale Press, 2016.
- Deitrickson, Amy. "College-for-All Meets Skills Gap: Millennials' Decisions to Pursue Certificates in Skilled Trades." PhD diss., Eastern Michigan University, 2018.
- Ferm, Lisa, Daniel Persson Thunqvist, Louise Svensson, and Maria Gustavsson. "Vocational Students' Identity Formation in Relation to Vocations in the Swedish Industrial Sector." *Nordic Journal of Vocational Education and Training* 9, no. 2 (2019): 91–111.
- Harper, Douglas. *Working Knowledge: Skill and Community in a Small Shop*. University of Chicago Press, 1987.
- Kerbo, Harold R. *Social Stratification and Inequality: Class Conflict in Historical and Comparative Perspective*, 3rd ed. New York: McGraw-Hill, 1996.
- Klotz, Viola Katharina, Stephen Billett, and Esther Winther. "Promoting Workforce Excellence: Formation and Relevance of Vocational Identity for Vocational Educational Training." *Empirical Research in Vocational Education and Training* 6 (2014): 1–20.
- Perna, Mark C. "Why Gen Z Can Solve the Skilled Labor Shortage Crisis" *Forbes*, October 17, 2023. <https://www.forbes.com/sites/markcperna/2023/10/17/why-gen-z-can-solve-the-skilled-labor-shortage-crisis/?sh=7a28c1563ac6>.
- Saari, Tiina, Minna Leinonen, and Katriina Tapanila. "Sources of Meaningful Work for Blue-Collar Workers." *Social Sciences* 11, no. 1 (2022): 2. <https://doi.org/10.3390/socsci11010002>.
- Smith, Kristine. "The Ego Identity and Vocational Identity of Secondary Education Vocational Students." PhD diss., Rivier University, 2023.
- theluce39. "This is the way." Reddit, January 30, 2022. <https://www.reddit.com/r/Welding/comments/sgk8he/comment/huxk0nk/>.
- Veckie, Vlad Walter, and Edward Anthony Veckie. "Vocational Knowledge Transfer of Craft Master Skills in Post-Industrial Era." *Annals of the Faculty of Engineering Hunedoara* 19, no. 2 (2021): 69–76.
- Welfare, Katherine, Fred Sherratt, and Matthew Hallowell. "Perceptions of Construction Work: Views to Consider to Improve Employee Recruitment and Retention." *Journal of Construction Engineering and Management* 147, no. 7 (2021): 04021053, 5. [https://doi.org/10.1061/\(ASCE\)JCO.1943-7862.0002057](https://doi.org/10.1061/(ASCE)JCO.1943-7862.0002057).

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Glossary

- A36 steel:** A structural steel alloy common in the United States.
- Allen wrench:** An (often) L-shaped metal bar with a hexagonal head at each end that is used to turn bolts and screws having hexagonal sockets.
- Alloy:** A metal created from mixing two or more metals. For example, bronze is an alloy of tin and copper.
- Angle grinder:** A handheld power tool with consumable abrasive discs or blades attached. These discs or blades spin at high speeds to grind, polish, or cut.
- Backing strip:** A metal strip affixed temporarily or permanently to the back of two pieces to help achieve full weld penetration.
- Band saw:** A saw with a continuously toothed blade stretched between two or more wheels to cut material.
- Box-and-pan brake:** Also known as a finger brake, a machine for bending sheet metal. By moving the fingers, the user can create a variety of shapes.
- Butt joint:** A joint formed by two pieces placed next to each other without overlapping.
- Carbon-arc gouging:** A thermal process for removing metal, particularly defective welds, that uses a carbon electrode and compressed air.
- Chamfer:** A sloped cut at a corner or edge, such as around a drilled hole.
- Chuck:** A three- or four-jawed device for holding a workpiece in a lathe or a tool in a drill.
- Crater cracks:** Fissures, also called star cracks, located at the end of a weld that result when the weld contracts after solidifying and does not have sufficient volume to overcome the stress of shrinking.
- Cut list:** A delineation of all types and dimensions of pieces needed.
- Di-Acro bender:** A machine for bending metal, including solid stock, tubing, and flat stock. Changing tooling allows for different bends and material shapes.
- Drop:** A piece of a metal sheet or plate left over after cutting.
- Dynofile:** A tool (made by the company Dynabrade) that uses an abrasive belt for sanding.
- Filler metal:** The metal that, along with the base metal, creates a weld.

Fillet weld: A triangle-shaped weld that joins two pieces of metal perpendicularly (in a T-joint).

Fixture: Pieces of metal to firmly hold in position the components of the item being welded.

Flapper disc: An abrasive consumable used on an angle grinder. The disc consists of overlapping layers of abrasive material of differing grits attached to a hub.

Flux: The mix of minerals, chemicals, and alloys that protects the weld puddle from the gases of the atmosphere.

Flux-core welding: A welding process that uses a flux-filled electrode. The flux shields the weld as the electrode is consumed.

Ford wrench: An adjustable wrench that usually has smooth jaws and that was originally included in Ford Model T and Model A tool kits.

Gas lens: A tig-welding accessory that uses a screen to diffuse gas from the torch, providing better gas coverage to the weld puddle.

Ground: A clamp and attached lead that complete the electrical circuit from the electrode to the workpiece.

Heat sink: A block of metal, often copper, aluminum, or brass, that transfers heat away from a workpiece during welding.

Hossfeld bender: A tool for bending metal, including tubing, flat bar, and angle iron. A Hossfeld bender uses pegs, a bullnoze, dies, and a rotary arm to create bends.

Ironworker: A multipurpose metalworking machine, either mechanical or hydraulic, that notches, punches, and shears.

J-groove: A joint with a J shape, such as when welding along the corner of a piece of square tubing.

Jig: A piece of metal used to guide a tool along a workpiece.

Keyway broach: A bar-shaped tool with teeth that is used to cut slots that fit keys or other components.

Lap joint: A fillet joint formed between two sheets or plates when one overlaps the other.

Legs: The distance between the weld root and toe.

Lincoln Tombstone: A small, affordable stick welding machine, also called a buzz box. It's shaped like a prototypical tombstone.

Lock out/tag out: A set of procedures used before maintenance to ensure equipment is shut down, de-energized, and inoperable.

Long-arcing: The act of moving the electrode too far from the base metal. Long-arcing increases voltage, produces spatter, and often causes porosity.

Mandrel: A tapered, solid tool inserted into a tube or ring to reshape it.

Mig welding: A welding process, also called gas-metal arc welding (GMAW), that uses a solid wire electrode that's also the filler metal. Shielding gas travels through the gun to protect the weld puddle.

Mill: A machine that uses rotary cutters to remove metal from a workpiece to achieve the desired form.

Morse taper: A holder to mount machining tools, such as drill bits and reamers. Morse tapers are one of eight kinds of taper. They taper at about 5/8 inch per foot.

- Multipass weld:** A welding technique that involves layering weld passes across a joint, allowing the welding of thick materials.
- Nut driver:** A hand tool for loosening and tightening nuts and bolts.
- Out-of-position welding:** Any welding position that's not flat or horizontal. Some people include horizontal as out of position.
- Overhead welding:** An out-of-position type of welding that forces the welder to work against gravity to keep the puddle from dripping.
- Oxidation:** The chemical reaction that occurs when metal meets oxygen. The metal loses electrons to the oxygen, forming an oxide that damage's the metal's surface.
- Oxyacetylene cutting:** A cutting process that uses a flame, created with a mix of oxygen and acetylene gases, to melt a localized spot of a piece of metal.
- Pipe wrench:** A hand tool for gripping and turning pipe (or other cylindrical objects). A pipe wrench has two serrated jaws designed as to grip when turning in only one direction.
- Pitch:** The distance between the centers of welds along a joint.
- Plug weld:** A weld made by filling a hole in one piece of metal so that the weld fuses with the other piece of metal lying beneath.
- Porosity:** A weld defect consisting of scattered cavities in the weld. Porosity occurs when gas gets trapped in the weld. As the weld solidifies, the cavities form.
- Press brake:** A machine used for bending sheet metal and metal plate by bringing a punch down to a bottom die with great force.
- Puddle:** The pool of molten metal produced when welding. It can consist of the base metal alone or the base metal combined with filler metal.
- Pullmax:** A reciprocating machine that shapes and cuts metal. Originally built in Sweden, the Pullmax was later made in Chicago.
- Pulse-spray transfer:** A mig welding process that switches between high and low currents. The high current propels droplets of metal into the weld puddle and the low current prevents melt through.
- Reamer:** A cutting tool used to enlarge an existing hole by a small, precise amount and to smooth the sides.
- Receiver tubing:** Square tubing sized to hold other square tubing. In addition, the seam of the electric weld on the interior of receiver tubing is removed to better fit another tube.
- Root opening:** The space between two joints. An open root allows complete weld penetration between the two pieces.
- Slag:** The byproduct of some welding processes, such as shielded-metal arc welding (SMAW) and flux-cored arc welding (FCAW). Slag forms when flux melts and then rises through the weld pool to form a hardened layer on top the weld.
- Spatter:** A common defect consisting of hardened metal droplets around the weld.
- Spot welding:** A welding process that uses two copper alloy electrodes to clamp two metal sheets together and to focus current on a small spot. Concentrating current through the spot melts the metal and forms a weld.
- Stick welding:** A welding process, also called shielded-metal arc welding (SMAW), that uses an electrode (the "stick") covered with flux.

Sugaring: A form of oxidation due to insufficient purging gas during welding. Sugaring reduces stainless steel's anti-corrosive properties.

Swaging: A metalworking process in which metal, namely a piece of tubing, is forced through a die to reduce its diameter. This process is like wire drawing.

Tapping: A machining process for producing internal threads. A tap is a thread-cutting tool that cuts into metal to form internal threads. Its inverse is threading, which is using a die to cut threads into pipe, tubing, or round stock.

Throat: The shortest distance from the weld root to the weld face.

T-joint: A joint comprising two pieces welded at a 90-degree angle to each other.

Tig welding: A welding process, also called gas-tungsten arc welding (GTAW), that uses a tungsten electrode and shielding gas. Tig differs from other processes in that the welder uses a pedal or a trigger to control the amperage.

Toe: The junction of the weld face to the base metal or another weld bead. A point of stress, fatigue often starts at the toe.

Travel angle: Along the line of the weld, the angle of the electrode away from perpendicular, usually 5 to 15 degrees.

Tungsten: The pure metal with the highest melting temperature. Gas-tungsten arc welding (GTAW) uses tungsten as the electrode.

Undercut: A welding defect that occurs when the base metal at the weld joint melts away but doesn't fill with filler metal, creating a groove that reduces the strength of the weld.

V-groove: A joint beveled into a V shape. The V allows better weld penetration into the metal.

Waterjet cutting: A process that uses a high-pressure stream of water and an abrasive (such as garnet) through a small nozzle to cut material.

Weld positioner: A device that holds and rotates an item being welded. With it, a welder can more readily make continuous and consistent welds.

Work angle: The angle of the electrode measured on the line perpendicular to the line of the weld.

Index

A

Advanced-beginner-level knowledge, 14, 99, 187
Apprenticeship, 7, 168
Autoethnography, 5, 7, 14, 15

B

Billett, Stephen, 7, 8, 10, 11, 14, 46, 68, 95, 192, 205, 206

C

Career and technical education (CTE), 7, 14, 146, 153, 154, 156, 157, 160, 205, 208
Chan, Selena, 7, 8, 46, 47, 51
Checking, 48, 54, 59, 71, 93, 140
Coding (phenomena), 98
Cognitive overload, 93
Cognitive scaffolding, 15, 51, 53, 59, 204
Community of practice, 8, 59, 82, 108, 117, 157, 166, 179, 195, 197, 200, 206, 209
Competent-level knowledge, competences, 13, 14, 148, 170, 183
Concentration, 10, 43, 56, 57, 114
Conceptual knowledge, 3, 43, 46, 47, 59, 60, 99, 100, 129, 130, 139
Conscious deliberation, 183–185
Contextualized writing course, 153, 154, 159
Contingent, contingency, 45, 46, 48, 50, 59, 63, 67, 131, 133, 204
Coxhead, Averil, 146

D

Deliberative practice, 4, 8, 11, 12, 52–59, 63, 66, 69, 71, 74, 76, 99, 102, 117, 124, 140, 141, 178, 192, 195, 200, 204, 205, 209
Demonstrating, demonstration, 11, 44, 47, 48, 51, 52, 59, 67, 139, 172, 197, 204
Describing, 8–10, 28, 36, 46, 50, 51, 97, 109, 110, 155, 156

E

Embarrassing, embarrassment, 58, 89–91, 93, 97, 102, 103, 170
Embodied knowledge, 3, 4, 7, 46, 101
Empathy, 102, 103, 206
Encouragement, 206
Enculturation, 206
Engage, engagement, 44, 46, 47, 55, 56, 59, 69, 71, 157, 158, 205, 209
Ericsson, K. Anders, 4, 7, 52–55, 58, 59
Expertise
 creativity-based, 36, 103
 wisdom-based, 35, 91, 197, 198
Expert-level knowledge, 8, 10–12, 14, 26, 58, 95, 183–185, 192
Explaining, 8, 36, 48, 51, 52, 59, 64, 67, 71, 80, 139, 155, 188, 197, 204

F

Fading
 diachronic, 48
 synchronic, 48
Feedback, 4, 7, 8, 44, 47–49, 52, 53, 66, 97
First-angle projection, 125, 126

Fixture, 12, 37–40, 51, 102, 135–138, 140, 151, 188, 194, 195
 Fordism, 110

G

Gender harassment, 174, 175, 179
 Giving sympathy, 51, 199
 Glass box method, 130, 140

H

Highlighting (phenomena), 12, 98
 Humor, 52, 175

I

Icon, 132, 133
 Imitating, imitation, 7, 8, 47, 48, 52, 198
 Independence, independent, 7, 8, 184, 190, 208
 Index, 24, 131
 Instruction, 4, 44, 47–53, 59, 68, 73, 93, 99, 132, 135, 154, 155, 159, 198, 204
 Intelligence, 129
 Interactivity, 46, 47, 51, 59
 Interruption, 67
 Intersubjectivity, 45, 46, 59, 66, 73, 95, 128, 204
 Invoice, 145–149, 153, 155, 156, 160

J

Jig, 37, 65, 66, 68, 69, 135, 136, 138, 140, 188

L

Labor cost, 148, 149
 Lave, Jean, 8, 107, 108, 118, 156, 161, 197, 200, 206

M

Masculinity, 110, 111
 Mental rotation, 129, 130
 Metric system, 80, 84, 86
 Motivation, 8, 23, 57, 58, 116, 208
 Motivational scaffolding, 51, 53, 58, 59, 101, 103, 192, 199, 206

N

Near-miss report, 109, 110, 145, 146, 149–151, 153, 155, 156

Newcomer, 8, 43, 82, 90, 108, 118, 134, 153, 157, 179, 197, 204
 Novice, Novice-level knowledge, 10, 12, 14, 52, 54, 71, 99, 124, 129, 192, 195

O

Observing, 5, 9, 45, 47, 48, 52, 175, 197, 198
 Occluded genre, 125
 Old timer, 107, 197
 Ongoing diagnosis, 45, 46, 59, 66
 Orthographic representation, 125, 133, 137

P

Peripheral legitimate participation, 107
 Practice, 4, 5, 7–9, 11, 12, 15, 43, 46–48, 51–59, 63, 66, 69, 71, 74, 76, 90, 98–100, 102, 107, 108, 111, 114, 115, 117, 118, 124, 125, 130, 137, 140, 141, 149, 154, 155, 157, 160, 166, 178, 179, 187, 190, 192, 194, 197, 199, 200, 204–207, 209
 Praise, 52, 58, 192, 206
 Procedural knowledge, 2–4, 7, 10, 40, 44, 46, 47, 56, 59, 64, 76, 89, 101–103, 108, 129, 139, 153, 187, 189, 190, 195, 197, 200, 209
 Proficient-level knowledge, 13, 183, 184
 Pumping questions, 51, 63

Q

Questions (student). *See* Topic raising

R

Referring to a previous topic, 51
 Rosie the Riveter, 167

S

Scaffold, scaffolded learning, 4, 8, 43–48, 51–54, 59, 66, 74, 76, 102, 123, 137, 140, 141, 178, 200, 204, 205, 209
 Self-efficacy, 204, 206
 7Ps, 71–73
 Seven Ps. *See* 7Ps
 Sexism, 168
 Sexual harassment, 174
 Showing concern, 51
 Solid modeling, 135
 Spatial ability, 125, 129, 131, 134, 135, 137, 140

Suggesting, [51](#)
Symbol, [2](#), [5](#), [123–125](#), [129](#), [131–134](#),
[139–141](#)
Sympathy. *See* Giving sympathy

T

Taylorism, [110](#), [152](#)
Telling, [15](#), [48](#), [51](#), [52](#), [59](#)
Template, [64–66](#), [73](#), [137–139](#), [146](#), [147](#),
[150](#), [152](#)
Third-angle projection, [125](#), [126](#)
Topic initiation, [47](#)
Topic raising, [47](#)
Transfer of learning, [69](#)
Two-sigma problem, [44](#)

U

US Customary, [84](#)

V

Vocational education, [7](#)
Vocational identity, [208](#)
Vygotsky, Lev, [46](#), [50](#), [57](#)

W

Welding symbol, [2](#), [124](#), [125](#), [132–134](#),
[139–141](#)
Weld symbol, [132](#), [133](#), [140](#), [141](#)
Wenger, Etienne, [8](#), [46](#), [107](#), [108](#), [157](#), [197](#),
[206](#)
Workarounds, [166](#), [173](#)
Writing across the curriculum (WAC), [153](#)

Z

Zone of proximal development (ZPD), [50](#),
[63](#)