18
High School Manufacturing Education

A Path toward Regional Economic Development

Benjamin Kraft

Since the Great Recession, a small but resonant body of scholarship, policy innovation, and advocacy work has coalesced around the goal of strengthening manufacturing, especially at local and regional scales in the United States. This includes land use policies to retain urban manufacturing, the creation of "maker spaces," and the formation of a national network of intermediary organizations called the Urban Manufacturing Alliance (Leigh et al. 2014; Wolf-Powers and Levers 2016).

Workforce intermediaries (Clark 2014) have factored prominently in this discourse. Long-standing programs such as the Jane Addams Resource Corporation in Chicago and the Wisconsin Regional Training Partnership, as well as innovative community college programs around the country, offer important lessons for regions attempting to cultivate sustainable manufacturing ecosystems (Buford and Dresser 2014; Ganzglass, Foster, and Newcomer 2014; Lowe 2015). Regional innovation policies that explicitly incorporate production workers and production knowledge—as opposed to narrowly focusing on research and development—can be both successful in promoting economic growth and equitable in distributing it (Lowe and Wolf-Powers 2017).

Although manufacturing training interventions usually take place at the postsecondary level, a robust body of evidence shows that the most effective and efficient educational strategies start much earlier than college (Heckman and Krueger 2003) and suggests that earlier interventions in manufacturing workforce development may be beneficial.

The purpose of this chapter is to introduce to community and economic developers the idea of teaching manufacturing in high school, profile five successful high school manufacturing programs, and offer insights about how they can be replicated as part of a community economic development strategy.

WHY MANUFACTURING EDUCATION?

Economic Rationale

Before making the case for strengthening manufacturing education in the United States, we must acknowledge its long-term decline and the devastation that plant closings left in their wake over the past half century. These individual and collective traumas are still palpable in many communities with industrial legacies.

While these conditions make for a tough sell, there is an economic case for supporting manufacturing education in the United States. Manufacturing is an important driver of growth and innovation for both national and local economies (Helper, Krueger, and Wial 2012). The industry consistently has added over 1 million jobs since 2010.[1] The portion of the workforce currently employed in manufacturing is older than the workforce overall, so even with limited growth, jobs will continue to become available as baby boomers retire (Carnevale et al. 2011). Despite stagnant real wages across all industries, manufacturing continues to pay wages that are above average for industries requiring workers with similar levels of preparation.[2]

While manufacturing employment is cyclical and will decline again, arguments that it will inevitably disappear because of offshoring and automation may be overstated. Manufacturing is less productive (and thus more labor intensive) than once thought, and the bulk of productivity improvements are concentrated in two manufacturing subsectors and related to product—not process—improvements (Houseman, Bartik, and Sturgeon 2014). Further, waves of offshoring in the 1990s and 2000s were due in part to insufficient domestic capacity and not simply the search for cheap labor (Baily and Bosworth 2014). While evidence for "reshoring" remains largely anecdotal, a significant barrier to more fully repatriating manufacturing is a shortage of skilled labor (Bailey and De Propris 2014).

Values-Based Rationale

Pragmatic economics-based arguments are not the only sources of rationale for bolstering manufacturing training at the high school level. It is important to consider the development of young adults. Students with mechanical and technical inclinations should be able to build on their interests—their options should not be limited to college preparatory work or health-care careers purely because of perceived future stability or a potential wage premium (Lowe 2015). Even for students who do not ultimately pursue manufacturing careers, effective high school manufacturing training—like the programs described in this chapter—offers valuable skills and experiences that can translate into other personal and professional realms.

As Carr and Gibson (2016) suggest, “Rather than becoming increasingly marginalized and redundant, the ability to work with materials, and to make, repair or repurpose physical things, are vital skills, for a future where such resources become increasingly limited and extreme events related to a shifting climate are more common” (pp. 298–299). These skills are also important “inheritances” in regions that have strong manufacturing cultures and legacies (Gibson 2016), and can be celebrated—rather than suppressed—in regional development strategies. Society needs people who know how to solve material problems and make things, and in an increasingly information-based world, a subset of young people will continue to need opportunities to do so.

CAREER AND TECHNICAL EDUCATION DELIVERY

Manufacturing education in high schools is delivered through a system known as Career and Technical Education (CTE).[3] This chapter focuses on the small subset of CTE that includes manufacturing training (M-CTE).

The way that CTE reaches students, or the CTE delivery model, can be categorized in various ways. For the purposes of this chapter, three basic models are shown in Table 18.1. The first is the more traditional model, whereby CTE delivery is physically and conceptually separate from traditional academic instruction. In this model, students at

Table 18.1 Career and Technical Education Delivery Models

Format	Description	Considerations
Traditional model[a]	Comprehensive high school or technical/vocational high school	Can emphasize or de-emphasize academics; vocational schools may have stigma
Integrated model[a]	Career academy or area career center	Similar to a college major; creates small learning communities, and can be resource intensive or efficient, depending on model
Apprenticeship	Paid, "on-the-job" training combined with academics at home high school	Less flexible, requires significant industry involvement

[a] These categories are based on four models defined by the Association of Career and Technical Education but have been consolidated for the purposes of this chapter.

comprehensive, academically oriented high schools take CTE credits as electives, such as auto shop or home economics. Students pursuing a more career-focused education would primarily attend a designated vocational school where larger portions of their school days would be dedicated to learning skills or trades.

An alternative integrated model has gained popularity more recently. In contrast to the traditional delivery model that treats college-preparatory academics and career and technical education as separate pedagogical realms, the integrated model combines them. The integrated model may come in the form of an "area career center," which centralizes career and technical training for students from across a district or region. It could also take the form of a "career academy," which clusters students along similar career pathways within a high school, creating what is referred to as a school within a school.[4] A third option for CTE is an apprenticeship program, which combines on-the-job training with varying forms of classroom learning (comprehensive high schools, vocational schools, area career centers, etc.). These work-based programs must require enough flexibility for students to spend all or part of some school days at the workplace.

Each model comes with benefits and drawbacks. Comprehensive high schools are often thought of as "academics first" institutions, whereas vocational high schools can underemphasize academics or be negatively stigmatized. The programs profiled in this chapter blend academic and career skills and demonstrate that these perceptions are not necessarily accurate.

Within the integrated model, the central location of area career centers minimizes the cost of facilities, equipment, and materials, but it can necessitate complex scheduling and busing arrangements to accommodate students of different ages and from different home schools. Alternatively, career academies group together students pursuing the same CTE pathway for most of the day. However, these academies can be resource intensive, especially if other schools nearby offer similar curricula. Finally, while apprentices receive their academic and basic technical training through either of the other two models, success of work-based training hinges on the engagement of dedicated industry partner(s) in the nearby area.

All five programs highlighted in this report took risks by delivering manufacturing CTE through novel methods. Even the schools that follow more traditional models—Eleva-Strum High School and Austin College and Career Academy (formerly called Austin Polytechnical Academy)—have added elements that challenge the status quo and foster supportive environments for high school students to learn about—and take seriously—manufacturing.

SMALL LEARNING COMMUNITIES

The distinguishing feature of these five programs is their creation of small learning communities (SLCs). SLCs are cohorts of "students, within the larger high school, who take classes together for at least two years and are taught by a team of teachers from different disciplines" (Hyslop 2009, p. 4). These communities encourage personalized and intimate educational experiences for students and provide opportunities to link academic concepts with CTE experiences (Hyslop 2009). SLCs often are associated with career academies, which are high schools that segment students into small cohorts around specific career themes, as previously described. Career academies have received much of the funding from the U.S. Department of Education's Small Learning Community grant program (Stern, Dayton, and Raby 2010). Hawthorne High School in Southern California, described below, is an example of one. However, the other four case studies achieve the spirit of SLCs, even if they do not meet the exact definition. While the impacts of SLCs are difficult to generalize because of the wide variety of cultures and practices within individual schools, they are part of a promising emerging approach to education (Bernstein et al. 2008; DeAngelis 2004; Stern, Dayton, and Raby 2010).

Outcomes for students who participate in SLCs are encouraging, although the strongest evidence of this is specifically associated with career academies and not alternative forms of SLCs. After controlling for self-selection bias[5] by studying a sample of students who applied to career academies programs and were accepted in a lottery system, Kemple (2008) shows that eight years after graduation, career academy students earned on average over $2,000 more per year than noncareer academy students. They also were more likely to live independently and be custodial parents.

While this study provides the most compelling evidence of the effectiveness of career academies to date, it comes with one caveat: these results apply only to males—females in career academies show no significant differences compared to their non-CTE counterparts. The limited benefit of career academies programs for female students compared to male students remains a problem.

The structure of SLCs shows special promise for manufacturing education because manufacturing workplaces are becoming increasingly modularized into small teams of workers. In fact, in a nationwide survey of manufacturers (Weaver and Osterman 2017), almost all employers reported the soft skills "cooperation with other employees" and "the ability to work in teams" as moderately or very important. While certain technical skills were in demand, the most universally demanded hard skills were basic reading and math (Weaver and Osterman 2017).

These results suggest that high schools—and perhaps even earlier education levels—may be the ideal places to expose young people to manufacturing skills and careers. That way, by the time students enter postsecondary training where technical skills are traditionally taught, they will have a foundation for skills needed for success in the manufacturing workplace.

METHODOLOGY AND CASE DESCRIPTIONS

This chapter examines and compares five high school manufacturing CTE programs. (See Table 18.2 for a list of programs and key characteristics.) They represent each of the delivery models (traditional, integrated, and apprenticeship) and a wide variety of community types—urban, suburban, and rural—across diverse geographic regions. Data were collected primarily through interviews with administrators or faculty who have roles in both the daily operations and strategic planning of the programs. Secondary sources such as program websites and media profiles were also consulted.[6]

Each of these programs has also been recognized by various media and industry sources. The Austin College and Career Academy and the Aiken Career and Technology Center's apprenticeship program have been featured in the *New York Times* (Knight 2011; Schwartz 2013), and Cardinal Manufacturing has appeared in *Modern Machine Shop*, a manufacturing trade publication (Zelinski 2012). The Association for Career and Technical Education,[7] the Partnership Response in Manufacturing Education,[8] and the M-List also have recognized several of the programs for their exceptional performance.[9]

Francis Tuttle Technology Center

Integrated model: Area career center

Oklahoma City, Oklahoma. Francis Tuttle Technology Center houses the oldest of the M-CTE programs profiled in this chapter. The manufacturing program offers all courses free to any high school in the surrounding seven school districts. The M-CTE program has been around since 1982 and has adapted over time to match industry demand. For example, program leaders terminated a plastic injection molding program because students were having trouble finding jobs upon completion. This type of flexibility is important to the sustainability of workforce development programs structured around the needs of industrial sectors (Buford and Dresser 2014).

High school students enroll in manufacturing and machining classes comprising mainly postsecondary and adult students. Danny King, the director of the Technology Center, explains that integrating high school

Table 18.2 Characteristics of Manufacturing CTE Programs Profiled

School	Location	Geography	Delivery model	Programs offered	Recognition
Francis Tuttle Technology Center	Oklahoma City, OK	Suburban	Integrated—Area Career Center	Advanced manufacturing, Precision machining	PRIME[a], Manufacturing Institute's M-List
Hawthorne High School, School of Manufacturing and Engineering	Hawthorne, CA (LA area)	Urban	Integrated—Career Academy	General manufacturing and engineering	PRIME
Austin College and Career Academy	Chicago, IL	Urban	Traditional—Technical/Vocational High School	General manufacturing	Numerous news and trade publications
Eleva-Strum High School, Cardinal Manufacturing	Strum, WI	Rural	Traditional—Comprehensive High School	Woodworking, CAD/CAM, Metalworking, Cardinal manufacturing	Association for Career and Technical Education (ACTE), Modern Machine Shop
Aiken Career and Technology Center, MTU Apprenticeship	Aiken/Graniteville, SC	Rural, suburban, small city	Apprenticeship	Industrial mechanic basic	ACTE, *New York Times*, White House

[a] Partnership Response in Manufacturing Education.

students into classes with adults can benefit the younger students. For one, lessons are highly individualized, and secondly, it creates a more mature and focused learning environment than might exist at their home high schools.[10]

Francis Tuttle highlights Oklahoma's pioneering state Technology Center system. Tuttle is one of 29 centers throughout the state, which exist outside school districts and community college districts and are funded by ad valorem local property taxes assessed only to communities that vote in favor of them. Even in a generally tax-averse state like Oklahoma, there has been consistent willingness to fund the programs.

School of Manufacturing and Engineering, Hawthorne High School

Integrated model: Career academy

Hawthorne, California. The Hawthorne School of Manufacturing and Engineering's location is both a challenge and an asset. This career academy is in a neighborhood south of Los Angeles with a high poverty rate and low adult educational attainment. However, the same small area is also home to one of the nation's preeminent aerospace manufacturing and engineering clusters, with Northrop Grumman and Space Exploration Technologies (commonly known as SpaceX) facilities only a few blocks away.

As a career academy, the School of Manufacturing and Engineering operates within the larger Hawthorne High School. Each year, 300–400 students from ninth through twelfth grades spend most of their school days together in their own wing of the school. Instructors integrate the traditional academic curriculum into manufacturing and engineering subject matter.

The school has developed a state-of-the-art manufacturing training facility with advanced technology, which is available through business and industry partnerships that the staff and program director have cultivated and maintained. For example, California-based machine tool manufacturer Haas has donated several advanced Computer Numeric Control (CNC) machines to be used for student training. These equipment donations benefit the corporate partners as well, since they help to cultivate a workforce that is proficient with their products.[11]

It is often difficult to recruit high school students into a manufacturing pathway because of the stigma of vocational school and manufacturing careers. In addition, like other manufacturing programs in career academies, the Hawthorne School of Manufacturing and Engineering must compete with other pathways that may be more appealing to students and parents, such as business. There are also several recently created charter schools nearby that use curricula similar to Hawthorne's.

Given this competitive environment, the academy implemented a multipronged outreach strategy resulting in increased enrollment over the years. Academy staff members regularly attend middle school career nights and hold workshops for local middle school students. Director Lucas Pacheco has also found that the way he and staff deliver their message to prospective students and parents makes a big difference. Rather than simply making the pitch himself, he often invites alumni of the program and representatives from local partner companies to speak to students and parents about career possibilities in manufacturing. The career academy even invites the parents of students in the program to tag along on field trips to manufacturing facilities. Finally, its well-known and perennially competitive robotics team bolsters the academy's reputation.[12]

Students in the manufacturing program tend to perform better than their peers who are not in the career academy. Aside from the impressive college placement record of the School of Manufacturing and Engineering, its 2012 high school graduation rate was 99 percent, compared to 62 percent for Hawthorne High School, as a whole, in the same year (Centinela Valley Union High School District 2014).

Austin College and Career Academy (ACCA) [13]

Traditional model: Vocational school

Chicago, Illinois. ACCA is a community development, economic development, workforce development, and educational initiative wrapped up into a small school on Chicago's west side. It was envisioned in 2001 when a comprehensive study of Cook County's manufacturing industry and workforce revealed a gap in training pathways for future manufacturing workers, especially in the metal and machinery sectors (Chicago Federation of Labor and Center for Labor and Community Research 2001). ACCA came to fruition as part of the formal manufacturing "career path" recommended by the study.

Opened in 2009, the Academy is an ongoing partnership between the Chicago Public Schools and the Chicago Manufacturing Renaissance Council, a manufacturing advocacy and workforce development organization. The school shares a rehabbed high school building with two other career and college prep academies. The Manufacturing Renaissance Council helped design the manufacturing training facility, and a full-time industry coordinator maintains ties with local industry. The school's six staff members find internship and employment opportunities for students and work with the Chicago Public Schools teachers to ensure that the skills taught across city schools keep up with local industry demands.[14]

As of 2014, ACCA faces challenges that come along with serving students in an underresourced area. For example, Austin educators must spend as much time providing students with basic academic and soft skills as they do teaching technical skills. While some students attend the school because of the manufacturing career pathway that Austin offers, many come for other reasons—for example, because it is a relatively new public school in the neighborhood or because they know others who attend. Thus, Manufacturing Renaissance staff work hard to create a highly skilled manufacturing workforce in addition to academically accomplished and well-rounded graduates.[15]

The participation and leadership of the Manufacturing Renaissance Council is crucial for the success of this model. Aside from providing a built-in manufacturing community presence, the Council's involvement shows communities interested in initiating an M-CTE program need not wait for a school district or a large employer to spearhead it—manufacturing advocacy groups, trade associations, industrial councils, or expansion and retention organizations can provide the necessary leadership.

Cardinal Manufacturing, Eleva-Strum High School

Traditional model: Comprehensive high school

Strum, Wisconsin. Eleva-Strum is a comprehensive high school in rural Wisconsin that is also home to an innovative manufacturing program. In addition to its machining, metalworking, and welding electives, the school runs an actual commercial manufacturing job shop called Cardinal Manufacturing. The shop offers contract machining and fabrication services for many types of clients. The following are examples of typical work:

- Stainless steel components for custom wood-turned wine bottle stoppers
- CNC milling custom aluminum parts for a vintage snowmobile
- Welding custom brackets for beam placement in cabin construction
- CNC milling a custom intake manifold spacer to increase the horsepower of a pulling tractor[16]

While nearby professional shops may shy away from these small custom jobs, Cardinal Manufacturing will take them on because they provide valuable learning experiences for the students, as well as revenue for the school.

Students who have taken the required introductory classes apply during their junior or senior years to be part of Cardinal Manufacturing. Because the business generates revenue, it is essentially self-funding. The profits are used for equipment, building upgrades, and a current renovation to add a professional meeting space. Student employees also receive a small portion of annual profits.[17]

Director Craig Cegielski reaches out to seventh graders to introduce them to manufacturing and future opportunities to work in the shop. In such a small school, however, students are motivated to join this elite group such that the application process for Cardinal Manufacturing has become quite competitive.[18]

Aiken Career and Technology Center

MTU Apprenticeship Program

Aiken, South Carolina. Because of concerns about finding local workers with the skills to work in its Graniteville, South Carolina, production facility, MTU (formerly Tognum, a German-headquartered diesel engine manufacturer) worked with the Aiken County Career and Technology Center to develop an apprenticeship program similar to the one that the company's workers in Germany complete. The first cohort of six high school juniors began in 2012, with 600 required classroom hours of traditional high school academics at their home high schools and technical training at the Career and Technology Center, as well as 1,000 hours of paid work and training at the MTU facility. Upon completion of the program, the apprentices will earn high school diplomas and an industrial mechanic basic certificate, a German certification recognized in the United States.

An apprenticeship program requires a substantial commitment on the part of the school, the industry partner, and the student. Students must be able to travel back and forth between their home high schools, career centers (if applicable), and workplaces, and harmonize their work requirements with high school schedules. During the summer, the MTU program requires that apprentices work 40 hours per week, beginning at 6 a.m., Monday through Friday. Not all high school students will possess the drive and focus it takes to complete the program. Finally, the apprentices must pass a rigorous four-day written and practical examination to graduate.

MTU understood the commitment necessary from industry and was an eager partner because it already had experience running apprenticeships in Germany.

As of 2014, three of the original six apprentices from the cohort that began in 2012 completed the program and passed the exam. Earning the mechanic certificate requires that they complete 1,000 additional workplace hours upon completion of the exam and graduation.

Apprenticeship programs like the one in Aiken require a special set of safety and labor law considerations. While potential partners must be vetted to ensure that their facilities are safe and that they will take the training and supervision of minors seriously, federal labor law does allow 16- to 18-year-olds to learn most manufacturing functions on the job, provided that they are enrolled in recognized trade- or school-based programs.[19]

Because the American labor market is less coordinated or regulated—and therefore less stable—than the German one (Hatch 2013a), a perfect replication of a German apprenticeship model is not possible. American firms do not have enough incentive to invest heavily in workers who may leave at any time. Nevertheless, importing elements from successful approaches used abroad may help bridge some of the cultural distance that impedes innovation in an increasingly globally collaborative world (Gertler 2004; Hatch 2013b).

PUTTING IT TOGETHER: LESSONS FOR STRENGTHENING REGIONAL ECONOMIES THROUGH HIGH SCHOOL MANUFACTURING EDUCATION

Create Small Learning Communities

Rather than thinking of shop class as an occasional break from traditional academic work, instructors in successful high school manufacturing programs try to ensure that students share a common, systematic, and evolving learning experience that prepares them for the real world. Even students who do not pursue manufacturing careers will have acquired a set of skills in making, problem solving, and teamwork that are transferable to other career pathways. Delivering manufacturing CTE in a way that partners motivated and like-minded students with teachers creates an energized community of learners. While the career academy model may be structured in a way that encourages the most straightforward application of this approach, SLCs can be achieved with any of the delivery models—traditional, integrated, or apprenticeship.

Engage Stakeholders Early and Often

While community and economic developers may have little direct influence on curriculum or instruction in high schools, they can engage stakeholders at educational institutions who do. Professionals who work with or for manufacturing intermediaries such as Manufacturing Renaissance in Chicago can communicate to schools information about manufacturing employers' skill needs. School leaders, in turn, can make clear to employers the schools' needs for funding and equipment. These lines of communication should be kept open to account for ongoing shifts in demand. Notably, high schools may be less flexible and subject to greater oversight than the traditional postsecondary training programs that intermediaries usually partner with or administer.

All the programs described in this chapter rely primarily on traditional CTE funding sources such as local taxes and Federal Perkins funds for the bulk of their budgets. Some programs, such as Cardinal Manufacturing at Eleva-Strum High School, reinvest revenue into their facilities. To keep up with technological advances, however, M-CTE programs often require supplemental funds. The Hawthorne School of Manufacturing and Engineering has built relationships with machine tool suppliers who supply equipment. These suppliers understand their mutual interest in supporting training for the region's future workforce. While U.S. employers have become less willing over time to internalize training costs, if they can share costs in the interests of creating a local skilled labor pool, the prospect may be more appealing.

Engage Parents and Understand Community Context

For training programs at the high school level, parents must be involved. Across many communities, it is likely that some level of stigma toward manufacturing exists and will have to be confronted. In the examples described here, teachers and administrators have taken it upon themselves to excite parents about manufacturing careers through information sessions, meetings, demonstrations, and even generating school spirit around their programs. Intermediaries also can be valuable partners in these engagement efforts by leveraging knowledge of and contacts with industry stakeholders. Visible support from potential employers can be convincing.

All communities have some sort of material legacy. If not directly in manufacturing, it may be in agriculture, resource extraction, or transportation. It may be worth reminding parents that the skills involved and nature of work is different from what they remember, and that students who carry on these material legacies will be indispensable contributors to sustainable local economies.

CONCLUSION

As recognition of the importance manufacturing plays within the U.S. economy builds momentum, the search for effective, twenty-first-century training strategies becomes more urgent. Proactive workforce development strategies can more effectively promote growth in manufacturing employment. High schools should be a part of a comprehensive training landscape, as the benefits of exposing high school students to "making" extend beyond economics.

While there is ample leeway for structuring high school manufacturing training, creating SLCs is a promising approach for students and future employers.

Although high school students (and their parents) may require more extensive and sustained outreach than for traditional postsecondary students, people and organizations engaged in regional economic development are well positioned to take on this challenge.

Notes

1. Bureau of Labor Statistics, Current Employment Statistics. https://data.bls.gov/timeseries/CES3000000001?amp%3bdata_tool=XGtable&output_view=data&include_graphs=true (accessed June 8, 2018).
2. Manufacturing's annual average pay in 2016 was $64,870, while that for Trade, Transportation, and Logistics was $44,764, Construction was $58,674, and Natural Resources and Mining was $56,115. Private employers, all establishment sizes. https://www.bls.gov/cew/ (accessed June 8, 2018).
3. CTE is the current name and paradigm for what was previously called vocational education. For a review of the history and evolution of vocational education in the U.S., as well as current debates, see Hoffman (2013), Lerman (2010), and Scott and Sarkees-Wircenski (2008).
4. See http://www2.ed.gov/programs/slcp/index.html (accessed June 8, 2018).
5. Because students choose to enroll in CTE classes, researchers cannot determine whether their better (or worse) performance was due to chance or may instead be attributable to the motivation and aptitude of students who decide to enroll in CTE.
6. This research was conducted during the period from May to September 2014, so some information, such as job titles and program statistics, may not be current.
7. For more information, visit https://www.acteonline.org.
8. This is a nationwide program run by the Society of Manufacturing Engineers (SME) to recognize and encourage exemplary manufacturing education. For more information, visit http://www.smeef.org/prime/page/prime-schools.
9. The Manufacturing Institutes created M-List to endorse high schools and colleges teaching manufacturing skills. For more information, visit www.themanufacturinginstitute.org/Skills-Certification/M-List/M-List.aspx.
10. Danny King, director of the Technology Center. Telephone interview with the author, June 27, 2013.
11. Lucas Pacheco, director of the Hawthorne School of Manufacturing and Engineering. Telephone interview with the author, July 24, 2013.
12. Lucas Pacheco, director of the Hawthorne School of Manufacturing and Engineering. Telephone interview with the author, July 24, 2013.

13. For more information about this program, see "Manufacturing Connect: Teaching Advanced Manufacturing Skills to Inner-City Students" by Rick Mattoon and Susan Longworth, in Volume 1 of this book, and "Youth Job Creation and Employer Engagement in U.S. Manufacturing" by Nichola Lowe, Julianne Stern, John R. Bryson, and Rachel Mulhall in Volume 2 of this book.
14. Erica Swinney, program director, Manufacturing Renaissance. Telephone conversation with the author, July 15, 2013.
15. Erica Swinney, program director, Manufacturing Renaissance. Telephone conversation with the author, July 15, 2013.
16. Craig Cegielski, director of Cardinal Manufacturing. Personal communication with the author, August 19, 2013.
17. Craig Cegielski, director of Cardinal Manufacturing. Personal communication with the author, August 19, 2013.
18. Craig Cegielski, director of Cardinal Manufacturing. Telephone conversation with the author, July 22, 2013.
19. Labor, Subtitle B C.F.R. §570 Chapter V, Subchapter A (2018). https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=48d6ee3b99d3b3a97b1bf189e1757786&rgn=div5&view=text&node=29:3.1.1.1.31&idno=29#se29.3.570_12 (accessed June 26, 2018).

References

Bailey, David, and Lisa De Propris. 2014. "Manufacturing Reshoring and Its Limits: The UK Automotive Case." *Cambridge Journal of Regions, Economy and Society* 7(3): 379–395.

Baily, Martin Neil, and Barry P. Bosworth. 2014. "U.S. Manufacturing: Understanding Its Past and Its Potential Future." *Journal of Economic Perspectives* 28(1): 3–26.

Bernstein, Lawrence, Mary Ann Millsap, Jennifer Schimmenti, and Lindsay Page. 2008. *Implementation Study of Smaller Learning Communities: Final Report*. Washington, DC: U.S. Department of Education. http://www2.ed.gov/rschstat/eval/other/small-communities/final-report.pdf (accessed June 8, 2018).

Buford, Earl, and Laura Dresser. 2014. "The Wisconsin Regional Training Partnership: The Evolution of an Intermediary, the Shifting Target of Twenty-first Century Manufacturing, and the Continuing Relevance of Unions in Labor Markets." In *Connecting People to Work: Workforce Intermediaries and Sector Strategies*, Maureen Conway and Robert P. Giloth, eds. New York: Aspen Institute, pp. 113–129.

Carnevale, Anthony P., Nicole Smith, James R. Stone, Pradeep Kotamraju, Bruce Steuernagel, and Kimberly A. Green. 2011. *Career Clusters: Fore-*

casting Demand for High School through College Jobs, 2008-2018. Indianapolis: Lumina Foundation.

Carr, Chantel, and Chris Gibson. 2016. "Geographies of Making: Rethinking Materials and Skills for Volatile Futures." *Progress in Human Geography* 40(3): 297–315.

Centinela Valley Union High School District. 2014. "Hawthorne High School: School Accountability Report Card 2012–2013." Lawndale, CA: Centinela Valley Union High School District.

Chicago Federation of Labor, and Center for Labor and Community Research. 2001. *Creating a Manufacturing Career Path System in Cook County*. Chicago: Chicago Federation of Labor, and Center for Labor and Community Research. http://www.clcr.org/publications/pdf/final MWDP report030802 .pdf (accessed June 28, 2018).

Clark, Jennifer. 2014. "Manufacturing by Design: The Rise of Regional Intermediaries and the Re-emergence of Collective Action." *Cambridge Journal of Regions, Economy and Society* 7(3): 433–448.

DeAngelis, Karen J. 2004. "School Size." IERC 2004-I-1. Edwardsville: Illinois Education Research Council.

Ganzglass, Evelyn, Marcie Foster, and Abigail Newcomer. 2014. "Reforming the Supply Side of Sector Strategies: Innovations in Community Colleges." In *Connecting People to Work: Workforce Intermediaries and Sector Strategies*, Maureen Conway and Robert P. Giloth, eds. New York: Aspen Institute, pp. 301–321.

Gertler, Meric S. 2004. *Manufacturing Culture: The Institutional Geography of Industrial Practice*. Oxford: Oxford University Press.

Gibson, C. 2016. "Material Inheritances: How Place, Materiality, and Labor Process Underpin the Path-Dependent Evolution of Contemporary Craft Production." *Economic Geography* 92(1): 61–86.

Hatch, Carolyn J. 2013a. "Competitiveness by Design: An Institutionalist Perspective on the Resurgence of a 'Mature' Industry in a High-Wage Economy." *Economic Geography* 89(3): 261–284.

———. 2013b. *Skills Gap or Training Gap: The Role of Manufacturing in Solving the Skills Gap Problem*. East Lansing: Michigan State University. https://reicenter.org/upload/documents/colearning/hatch2013_report.pdf (accessed June 8, 2018).

Heckman, James J., and Alan B. Krueger. 2003. *Inequality in America: What Role for Human Capital Policies?* Cambridge, MA: MIT Press.

Helper, Susan, Timothy Krueger, and Howard Wial. 2012. *Why Does Manufacturing Matter? Which Manufacturing Matters? A Policy Framework*. Washington, DC: Brookings Institution. http://www.brookings.edu/~/media/research/files/papers/2012/2/22 manufacturing helper krueger wial/0222_manufacturing _helper_krueger_wial.pdf (accessed June 8, 2018).

Hoffman, Nancy. 2013. "Improving Career and Technical Education in the United States." In *Preparing Today's Students for Tomorrow's Jobs in Metropolitan America*, Laura W. Perna, ed. Philadelphia: University of Pennsylvania Press.

Houseman, Susan N., Timothy J. Bartik, and Timothy J. Sturgeon. 2014. "Measuring Manufacturing: How the Computer and Semiconductor Industries Affect the Numbers and Perceptions." Upjohn Institute Working Paper No. 14-209. Kalamazoo, MI: W.E. Upjohn Institute for Employment Research.

Hyslop, Alisha. 2009. "The Role of Career Academies in Education Improvement." *Techniques: Connecting Education and Careers* 84(6): 32–35.

Kemple, James J. 2008. *Career Academies: Long-Term Impacts on Labor Market Outcomes, Educational Attainment, and Transitions to Adulthood*. Washington, DC: MDRC. http://www.mdrc.org/publication/career-academies-long-term-impacts-work-education-and-transitions-adulthood (accessed June 8, 2018).

Knight, Meribah. 2011. "A Troubled High School Celebrates a Milestone." *New York Times*, June 25. http://www.nytimes.com/2011/06/26/us/26cncaustin.html?pagewanted=1&_r=1 (accessed June 8, 2018).

Leigh, Nancy G., Nathanael Hoelzel, Benjamin Kraft, and Christopher Dempwolff. 2014. *Sustainable Urban Industrial Development: A Guide for Cities and Economic Development Planners*. Chicago: American Planning Association.

Lerman, Robert I. 2010. "Career-Focused Education and Training for Youth." In *Reshaping the American Workforce in a Changing Economy*, Harry J. Holzer and Demetra Smith Nightingale, eds. Washington, DC: Urban Institute, pp. 41–90.

Lowe, Nichola J. 2015. "Reskilling Urban Manufacturing: Workforce Solutions from the Inside Out." *Métropolitiques*. https://www.metropolitiques.eu/Reskilling-Urban-Manufacturing.html (accessed June 28, 2018).

Lowe, Nichola J., and Laura Wolf-Powers. 2017. "Who Works in a Working Region? Inclusive Innovation in the New Manufacturing Economy." *Regional Studies* 52(6): 828–839.

Schwartz, Nelson D. 2013. "Where Factory Apprenticeship Is Latest Model from Germany." *New York Times*, November 30. http://www.nytimes.com/2013/12/01/business/where-factory-apprenticeship-is-latest-model-from-germany.html?pagewanted=all&_r=0 (accessed June 8, 2018).

Scott, John L., and Michelle Sarkees-Wircenski. 2008. *Overview of Career and Technical Education.* 4th ed. Orland Park, IL: American Technical Publishers.

Stern, David, Charles Dayton, and Marilyn Raby. 2010. *Career Academies: A Proven Strategy to Prepare High School Students for College and Careers*. Berkeley, CA: Career Academy Support Network.

Weaver, Andrew, and Paul Osterman. 2017. "Skill Demands and Mismatch in U.S. Manufacturing." *ILR Review* 70(2): 275–307.

Wolf-Powers, Laura, and Annie Levers. 2016. "Planning, Social Infrastructure, and the Maker Movement: The View from New York City." *Carolina Planning Journal* 41: 38–52.

Zelinski, Peter. 2012. "Does This School Have the Formula for Manufacturing Education?" *Modern Machine Shop*. https://www.mmsonline.com/articles/does-this-school-have-the-formula-for-manufacturing-education (accessed June 8, 2018).