Pathways to Prosperity Network

AN INITIATIVE OF JOBS FOR THE FUTURE AND THE HARVARD GRADUATE SCHOOL OF EDUCATION

A NEW ERA OF ALIGNMENT IN MASSACHUSETTS' ADVANCED MANUFACTURING INDUSTRY

By Sheila Jackson

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A NEW ERA OF ALIGNMENT IN MASSACHUSETTS' ADVANCED MANUFACTURING INDUSTRY

The progressive and then sudden downturn in domestic production following the 2008 recession has pushed the manufacturing industry across the United States into a period of renewal and redesign. This transformation is no better depicted than on the modern machine floor where robotics and automation have replaced much of the dangerous and repetitive work that people used to perform, where entry-level workers are required to program machines with state-of-the-art computer aided design software, and managers oversee production with the help of iPads. The specific ways that states are working to pave new career pathways in manufacturing vary depending on different regions' economic priorities and current workforce training systems.

The purpose of this paper is to provide a case study of Massachusetts—in particular, how the state views advanced manufacturing as a leverage point in its statewide economic plan and an extension of its larger goals to support innovation and infrastructure. As a result, the state is currently in the process of aligning its economic agenda with its education and workforce development initiatives to promote advanced manufacturing as an industry and career path that creates opportunities to enter the middle class. It is worth noting that the Massachusetts Department of Higher Education is taking a strategic sectoral approach to enhancing educational opportunities and meeting employer needs and expectations; while this case study focuses on advanced manufacturing, the state has also partnered with industry to create additional workforce development plans in information technology, allied health, and nursing.[1]

To this end, this case study is designed to provide educators and state leaders with concrete examples of how secondary and postsecondary institutions work collaboratively with the business community to implement curriculum reforms that promote efficiency and continuity across the school-to-career pipeline.

A CENTRALIZED VISION IN A DECENTRALIZED SYSTEM

In 2010, the Massachusetts state legislature passed a bill requiring all new governors to draft an economic development plan during their first year in office with the help of an advisory council bridging sectors of education, academia, business, and policy. The resulting 2011 *Choosing to Compete in the 21st Century* economic development plan[2] produced by the Patrick-Murray administration set the stage for a deliberate strategy of long-term investments in education, innovation, and infrastructure. Later in 2011, the Executive Office of Housing & Economic Development published *Building Bridges to Growth: A Roadmap for Advanced Manufacturing in Massachusetts*,[3] which formally announced the state's advanced manufacturing initiative and outlined the governor's five-point agenda to improve manufacturing career pathways and partnerships. These action items include: promoting manufacturing; workforce & education; technical assistance and innovation; cost of doing business; and access to capital. Additionally, the document introduced the Advanced Manufacturing Collaborative: a partnership that has since played an integral role in mobilizing private sector engagement and collaboration with state agencies.

Among the reports and studies used to develop the state's economic plan, the Patrick-Murray administration acknowledged the findings outlined in *Staying Power II*,[4] published by researchers at Northeastern University's Dukakis Center for Urban and Regional Policy as providing key evidence for the promising future of manufacturing in Massachusetts. According to the 2012 report, Massachusetts will need to fill 100,000 manufacturing jobs over the next decade just to account for the vacancies after the current workforce retires. While it is potentially difficult to truly disaggregate the number of newly created jobs from the number of anticipated vacancies in this figure, it is evident that the state is deeply concerned, but hopeful about a new era of manufacturing in Massachusetts.

Alongside the statewide advanced manufacturing initiative as outlined in *Building Bridges to Growth*, a constellation of other initiatives, regional efforts, advisory committees, partnerships, and funding sources have been developed by both public state agencies and private sector stakeholders to improve the state's workforce development system. As a result, themes of alignment, innovation, collaboration, and accountability have largely characterized how Massachusetts has defined the main issues with the current state of manufacturing career pathways. These themes are also useful lenses through which to view how Massachusetts' "tactically focused" but "strategically cognizant"[5] vision for manufacturing has been put into practice, through a unified statewide commitment that allows for regional and local flexibility. In addition to the initiative's regional strategies and comprehensive legislative support, perhaps the most important activity that captures the state's attitudes towards best practices is the development of an employer-driven, standardized and competency-based advanced manufacturing curriculum that spans the state's secondary and postsecondary education system. This approach to an advanced manufacturing curriculum is especially designed to lead to stackable credentials and certificates appropriate for high school students, incumbent workers, and individuals hoping to transfer to four-year institutions. The Manufacturing Advancement Center Workforce Innovation Collaborative (MACWIC), Quinsigamond Community College and the Massachusetts Manufacturing Extension Partnership (MassMEP) are the spearheads of this public-private workforce training initiative that equips individuals with the middle-skills education and training to enter middle-class jobs, and will be discussed in further detail in the sections ahead.

THE ISSUES AND CONTEXT

With over 7,000 firms throughout the state, the manufacturing industry is the 5th largest employer in Massachusetts currently providing jobs with an average salary of $75,000 to over 250,000 workers.[6, 7, 8] Even in the wake of overseas production and a 13.5 percent decline in manufacturing jobs in the Boston/Metro North region following the 2008 recession, research demonstrates the resilience of manufacturing and its potential for growth in the state.[10] In fact, there is currently 50 percent more production in Massachusetts than the national average.[11] Yet even with this growth, employers and state officials are concerned with a few primary issues:

- **Finding skilled workers with the math and technology competencies employers are looking for** before the current workforce retires; over half the current workforce in MA is over the age of 45.[12]
- **Improving the image of manufacturing:** there is a perception that manufacturing is a dying industry; that manufacturing jobs are dirty, noisy, and dangerous; and that career opportunities are limited.
- **Engaging young people before high school and exposing them to manufacturing careers** and work based learning opportunities throughout high school.
- **Aligning manufacturing curriculum and competencies** between secondary and postsecondary institutions throughout the state and across the private sector.
- **Connecting manufacturing with other STEM educational initiatives.**
- **Linking innovation and research & development with production**—expanding the capacity of small and medium size companies to scale innovation and train workers on the machine floor to understand their role in the design process.

These issues, not uncommon from the concerns of manufacturers and state leaders across the country, are nuanced, complex, and vary depending on the subsector of manufacturing and employers' specific preferences. They can also produce a set of ancillary issues and challenges related to workforce training and regional economic development. Nonetheless, Massachusetts employs several salient models and approaches to building a skilled manufacturing workforce from which other states and regions can borrow to complement their own political and economic contexts.

THE STATE'S PERSPECTIVE ON GROWTH AND INNOVATION WITHIN MANUFACTURING

The Massachusetts state government has played a significant role in raising awareness, securing funding, and convening the private sector to make advanced manufacturing a priority. At a conference held in April 2014 on the future of manufacturing sponsored by Siemens and *The Atlantic*, Secretary of Labor and Workforce, Rachel Kaprielian, described Massachusetts as a state with seven different economies that each have different regional economic identities and workforce needs. However, manufacturing has been and continues to be an active industry across the state and employs workers in each region.[13]

Massachusetts' manufacturing industry benefits from the state's diversified economy. For instance, there is a symbiotic relationship between manufacturing and the top two industries in the state in terms of employment—education and health services.[14] The large number of medical schools and research facilities in Massachusetts generate a strong demand for the production of small pieces of medical equipment and instruments. Helped by the proximity to institutions of higher education and high-tech innovation, manufacturing in Massachusetts

has flourished in the bio-medical niche sector of manufacturing.[15]

The innovation process is also making its way onto the machine floor as advances in technology and production design are becoming increasingly linked to productivity. According to one state official and a global survey conducted by KPMG International in 2012, many original equipment manufacturers (OEMs) are shifting the product design costs and responsibilities to the supply-side of the manufacturing process.[16] Different from previous decades, OEMs are now often only responsible for the costs associated with the contracted price, and thus the supply chain side is accountable for the costs associated with any wasted materials. Because the manufacturing industry in Massachusetts is predominately made up of such small and medium size supply chain firms, these companies are tasked with designing and innovating the most efficient ways to cut and handle materials (skills related to precision cutting and manufacturing). This added pressure has created a need for both the leadership of the company as well as the on-the-floor workers to understand manufacturing decisions and their pivotal role in ensuring efficiency throughout the design and production processes. This shift has an impact on the level of critical thinking and problem solving skills that employers expect from their workers.

One objective explicitly stated in the state's initial *Choosing to Compete* economic development plan relates to making the state a hospitable place for both innovation and production. Historically the high tech industry in Massachusetts has seen companies leave the state following the research and development stages in search of lower costs for large scaled production manufacturing. But as researchers from the Production in the Innovation Economy (PIE) project at MIT reiterate, the health and growth of manufacturing is contingent upon state agencies, business, and education institutions working collaboratively to foster a robust "innovation ecosystem" in which design and production are intrinsically linked.[17]

The emphasis on "nurturing" innovation is evident in a new piece of legislation announced in April of 2014 called *An Act to Promote Growth and Opportunity*. Among other economic development measures, the act includes a $20 million Middle Skills Job Training Grant Fund, plans to expand the Massachusetts Technology Collaborative internship program, an R&D tax credit program, and intentions to "codify" the Governor's STEM Advisory Council.[18]

INVESTING IN HIGH CAPACITY SUBSECTORS: NANOMANUFACTURING AND BIOMANUFACTURING

Concurrent advances in technology, medicine, and the life sciences have spurred changes in certain subsectors of manufacturing and the types of products needed to support these innovations. One Illustration of the changing nature of manufacturing is the growth of nanomanufacturing and biomanufacturing. Based on research compiled by a staff writer for the Discovery Channel, several of the major ways that nanomanufacturing will become relevant in the future include: more powerful and efficient pharmaceuticals, custom manufactured organs, the production of carbon nanotubes to increase the strength of materials, and nanomanufactured robots that have the ability to prevent oil spills from spreading after accidents or crashes at sea.[19]

Even before recent national growth trends in nanotechnology, the state of Massachusetts was a hotspot for nanotechnology and nonmanufacturing. In fact, two out of the four National Science Foundation's Nanoscale Science and Engineering Centers in the United States operate out of universities in Massachusetts.[20] While each of these university centers, along with MIT, are connected to Bachelor's and advanced degree programs in nanotechnology, employers stress that there is a need for technicians and operators in nanomanufacturing facilities that obtain middle skills training and credentials.[21] In response, central hubs of nanomanufacturing like UMass Lowell are bridging outreach efforts between four-year and two-year institutions to ensure that training exists at all ends of the nanomanufacturing spectrum.[22]

Similarly, biomanufacturing in Massachusetts in particular is an essential counterpart to the bio-medical and pharmaceutical industries in the state and a recipient of large amounts of state funding. The quasi-public Massachusetts Life Sciences Center (MLSC) was created six years ago in 2008 to manage and implement the governor's charge to invest $1 billion in the Life Sciences over the next decade and sponsors paid internships for students pursuing Associate's, Bachelor's and graduate degrees in the life sciences. The Massachusetts Life Sciences Education Consortium is a separate non-profit organization that has helped 8 state community colleges develop a set of core competencies and articulation agreements for degrees and certificate programs in biotechnology and biomanufacturing. The biomanufacturing and biotech fields provide examples of

how regional partnerships can support career pathways. In 2009, the Massachusetts Biotechnological Council endorsed Pittsfield as a "bioready" gateway city. This endorsement resulted in a "2 + 2" biotech career pathway through a partnership between Berkshire Community College and Massachusetts College of Liberal Arts in which students split their time over the four-years at each institution.[23] In addition to such degree programs at two and four-year institutions, Worcester Polytechnic Institute opened a new biomanufacturing training facility that offers short term certificate programs in technical areas like "Downstream Principles" and "Techniques for Biomanufacturing" that can be earned in less than 7 days.[24]

DETERMINING THE MISSING MIDDLE SKILLS

In diagnosing the current manufacturing problem in many states across the country with a "skills gap" issue, there is a tendency to search for a singular prescriptive response to the shortage of human capital. Unfortunately, the skills gap challenge is not that simple for a variety of reasons, some of which are specific to Massachusetts while others are more universal to the manufacturing industry overall. One challenge is that employers do not have a homogenous wish list of desired skills and qualifications. A national survey conducted by Deloitte and the National Association of Manufacturers indicate that employers value the soft-skills associated with employability such as promptness and a positive attitude as well as adult basic education and English language proficiency.[25] However, the importance of these characteristics in relation to other more specialized or advanced skills like statistics or computer-aided software experience changes depending on the company's sub sector of manufacturing, or the personal preferences of the employer.

On the other hand, economists Paul Osterman and Andrew Weaver argue that the current skills gap is much more localized to the minority of firms that require high-levels of math and reading.[26] These researchers also suggest that the issues companies face with hiring and filling jobs have less to do with the supply of skilled workers and more the result of a slow post-recession economic recovery, among other complexities.[27] Additionally, Osterman and Weaver stress that the frequent innovations in production processes, also known as "technology shocks," make it difficult for incumbent workers to adapt to changes and prospective workers to develop new skills at rate that keeps pace with the industry.[28] Finally, although there is an apparent high demand for skilled workers and the average salary in Massachusetts is $75,000,[29] Osterman and Weaver argue that the comparatively lower wages of production manufacturing jobs in other regions of the country could be influencing employers' ability to fill vacancies.[30] Even with the challenges associated with pinpointing the root cause of the skills gap issue for the entire state, education and workforce development officials in Massachusetts do acknowledge a general need for young people to fill jobs as CNC operators, machinists, process engineers, and quality control inspectors.

Addressing the skills gap is further complicated by the diverse regional manufacturing specializations in Massachusetts. Again, given the concentration of supply-chain companies in Massachusetts, facilities across the state cater to a range of different manufacturing subsectors. Siemens, for instance, located in the central region of the state operates a metal technology facility and requires training in precision cutting and tool technology. While different manufacturing sectors share foundational content and competencies, the "injection molding" process integral to the plastics manufacturing companies located in the northeastern part of the state requires a different set of skills.[31] This variability and specialization within the market also has implications for how career and technical education programs of study are structured and taught in high schools. To help fine tune curricula to the local economy, regional partnerships between government agencies like workforce investment boards and local postsecondary institutions turn to higher education to collect data and conduct labor market studies. A prime example is the Berkshire Advanced Manufacturing Study prepared by the UMass Donahue Institute for Economic and Public Policy Research and presented to the Pittsfield Economic Revitalization Corporation in September of 2013.[32] The report identified opportunities for the region to expand its manufacturing profile to include semi-conductor production as well as the need to effectively communicate a master plan for the region's largest business park, among other recommendations. Moreover, the study has been instrumental in driving the development of new high school curricula and articulation agreements with two and four-year manufacturing degree programs in the region.

WORKFORCE EDUCATION AND TRAINING: THE REGIONAL PARTNERSHIP MODEL

In addition to providing incentives to manufacturers for efficient production design processes, state agencies are also promoting new regional approaches to preparing the next manufacturing workforce to thrive in a high tech innovation economy. The regional partnership model is central to the state's approach to carving out advanced manufacturing pathways. Regional partnerships are collaborations among employers, workforce investment boards and academia to help regions develop sustainable and effective workforce development programs that respond to industry needs. Chief among their strategies is the employer voice in all aspects and stages of workforce development initiatives. Currently in Massachusetts, these partnerships are identified by a geographic location, like Berkshire County, or by a specific project like Manufacturing Advancement Center Workforce Innovation Collaborative (MACWIC), which represents over 100 executives from manufacturing companies across the state. The Precision Manufacturing Regional Alliance Project in Hampden County is an example of a partnership centered around a specific subsector of manufacturing. The regional partnerships and their programs are funded through competitive grants awarded by three state agencies: Housing and Economic Development; Labor and Workforce Development; and Education. In every case, the partnership selects a regional lead that might be a workforce investment board, a community college, or in the case of MACWIC, the Massachusetts chapter of the Manufacturing Extension Partnership (MassMEP), which is supported by a mix of federal and private funding.

To support and strengthen these regional partnerships, the state invests in considerable technical assistance resources. The Advanced Manufacturing Collaborative has published materials that highlight strategies and characteristics of "high-functioning regional partnerships." The state has also created the Advanced Manufacturing Regional Partnership Academy (AMPRA), which serves as a clearinghouse of best practices and common competencies, according to one state official. AMPRA also brings together manufacturers, researchers, and workforce investment boards during academy sessions to improve the effectiveness of regional manufacturing sector strategies by providing tools and opportunities for peer learning. Funding for AMPRA comes from the same three state agencies that support the regional partnerships, as well as the University of Massachusetts and the Commonwealth Corporation—a quasi-public state agency that is the state's "innovation incubator for workforce development." In addition to the AMPRA Academy Sessions, the AMC also sponsors an annual Advanced Manufacturing Summit. Through these convenings, state officials hope to develop a "culture of co-collaboration and co-accountability" that will sustain regional partnerships moving forward.

ADVANCED MANUFACTURING WORKFORCE EDUCATION AND TRAINING

The 15 community colleges in Massachusetts are vital arteries of the advanced manufacturing pipeline. Currently, the colleges serve nearly 200,000 students and comprise over 55 percent of all undergraduate enrollments in the state.[33] All community colleges in Massachusetts offer some type of degree and/or certificate program related to manufacturing ranging from three-semester biomanufacturing certificates, to programs that award credit for prior learning, to two-year Associate's degrees in Engineering Technology. Certain community colleges in Massachusetts already have longstanding relationships with local employers and offer programs that have specific regional relevance. For example, the Manufacturing Technology in Plastics program at Mount Wachusett Community College has a direct partnership with the nearby plastics manufacturing facility, Nypro, Inc.[34] Similarly, North Shore Community College received a $145,000 grant from the Massachusetts Technology Collaborative in 2012 to develop an advanced manufacturing program that prepares graduates for jobs as repair technicians and operators at General Electric's aviation plant located in Lynn, MA.[35]

The prevalence of specialized workforce development initiatives supported by Massachusetts community colleges has many benefits and meets a diverse set of educational needs, but historically state officials felt the system operated in regionally bound silos that ultimately did not serve the best interests of students. For instance, articulation agreements between high schools and community colleges across the state were previously based on their geographic proximity to one another. Thus if a student moved away or attended a community college in a different part of the state, courses taken at his or her high school's career and technical program would not be awarded credit at the new institution. One state official believes this lack of alignment across the system could be attributed to a degree of skepticism that colleges felt about the quality of instruction and the curriculum taught at different institutions. Recognizing this issue, in 2011 the Massachusetts Community College Executive Office created statewide articulation agreements between all community colleges and all regional vocational technical high schools.[36]

The secondary education piece of the training puzzle and often offers students hands-on, project-based manufacturing training and education. Massachusetts benefits from an extensive system of career/vocational and technical education (CVTE) in both comprehensive and vocational-technical high schools throughout the state. While the majority of these programs are housed within regional vocational technical high schools, over 40 percent are offered at comprehensive "local" schools.[37] Over 55,0000 students or nearly 20 percent of all MA high school students are currently involved in a CVTE program.[38] Each high school occupational cluster must have an advisory board of industry professionals to align the curriculum and instruction with current industry needs and practices. Additionally, schools offering chapter 74 career and technical programs of study have a legal obligation to ensure counselors and other support staff work with students to map out a career plan.[39] Nonetheless, Massachusetts is unique in that 40 percent of its population holds Bachelor's degrees,[40] and according to one state official, the governor would like the state to develop the same reputation for middle skills credentialing and education.

Currently, the career and technical high schools serve as a major source of manufacturing talent and in some cases, the drivers of innovative educational reform and

experimentation. For instance, with $90 million dollars in state and federal grants and the leadership of Principal Sheila Harrity, Worcester Technical High School has been successful in leveraging career and technical education to transform the school's overall academic performance on state assessments.[41] In 2012, just six years after the school's new facility opened, the number of students performing advanced or proficient on the state's MCAS tests nearly tripled,[42] and in early June of 2014, President Obama traveled to Worcester to deliver the high school's commencement speech and to commend Worcester Tech as an exemplar of secondary education.[43]

In spite of standardized frameworks for each occupational cluster, and the requirement that CTE programs have industry advisory boards, the ways in which competencies are taught are not necessarily transparent to students or to prospective employers. One issue is that curricula related to advanced manufacturing are embedded within several different categories like Machine Tool Technology, Robotics & Automation, or Metal Fabrication & Joining Technology, all of which fall under the occupational cluster of Manufacturing, Engineering & Technology. In practice, however, the occupational concentrations, or at least the skills and competencies of each program are more fluid. Students in the Metal Fabrication program may spend the majority of their time learning the principles of welding, but they will also likely gain experience operating and programming a CNC (computer numerical control) machine, which is typically associated with the Machine Tool Technology program. One way of addressing this challenge is to incorporate nationally recognized industry credentials into the programs' scope and sequence. However, there is not broad-based integration of these credentials within the industry.

While earning a 10-hour Occupational Safety and Health Administration (OSHA) certification in high school appears standard across all manufacturing clusters, the expectation to earn other industry recognized certifications endorsed by professional associations like The National Institute for Metalworking Skills is less consistent. Students will often wait to see what type of job they obtain before spending the time and money to get certified in a specialized technique, such as grinding technology, which they may not utilize in the workplace.[44] On the other hand, students in welding and fabrication programs may choose to become certified by the American Welding Society in certain techniques such as vertical, horizontal, flat, or overhead welding because these certifications are often requisites for working on government-funded projects like bridges and nuclear pipelines. Moreover, other quality control sectors that produce medical instruments and surgical implants may also require these certifications prior to employment.

Secondary schools confront several challenges to incorporating nationally recognized industry credentials into their curriculum. The tests themselves are expensive, particularly for students who may not work in the sector, placing a burden on the school budget. Further, a certified inspector must administer examinations for such industry-approved credentials. Unless the school's instructor is a certified inspector, students need to perform the appropriate welding tasks at the school's machine shop and send the product to a third party inspection agency endorsed by the American Welding Society. Consequently, although in theory the career and technical education programs at the high school level prepare students to earn value-added certifications that signal the middle skills that employers want, it is difficult to assign a fixed credentialing plan and/or career pathway for each student because of the overlap between and variability within occupational clusters.

CONNECTING MANUFACTURING TO COLLEGE AND CAREER READINESS

Alongside the governor's five-point agenda for advanced manufacturing, there is a concurrent state agenda deployed through the Department of Elementary & Secondary Education (DESE) that echoes the same call for cross-sector alignment found in the state's economic plan. From an institutional perspective, there are numerous visible efforts to align academics, college planning, and career development on a systems level throughout the education pipeline. In 2012, DESE created the Task Force for the Integration of College and Career Readiness, which published a report that included a statewide "common definition of college and career readiness" as well as recommendations for how districts and schools could better support students in their transition from education institutions to the workforce.[45] The report resulted in the creation of additional funding from the state to continue efforts to infuse career preparedness and development into core academic subjects.

The Connecting Activities program is a long-standing initiative managed by DESE that partners with local workforce investment boards and employers to provide students with internships in a professional setting. Beginning in the mid-1990's following the creation of the National School to Work Opportunities Act, Connecting

activities plays a key role in exposing many students to their first, oftentimes paid, work experiences. In spite of this infrastructure and tradition of supporting career and technical education at the secondary level, educators, state officials, and employers are still faced with challenges related to student interest, skill development, and curriculum alignment with respect to articulation agreements between institutions and employer expectations. In 2013, nearly 10,000 Massachusetts high school students were placed in just over 3500 employer sites.[46] However, manufacturing only represented 3 percent of all work-based learning activities, while industries like childcare attracted over 25 percent of all students participating in the Connecting Activities program.[47] According to one state official, the low participation rate for manufacturing may be caused by low student interest as well as the manufacturers' concerns about liability issues from having students under 18 on the machine floor. Evidently, while there is state-level infrastructure in place to expose students to the advanced manufacturing industry, the level of student interest and employer buy-in can ultimately determine how well work-based learning programs are operationalized at the school level.

Regardless of the overall low participation rates in manufacturing internships, there is evidence that connecting activities can make a significant impact on students' lives by creating opportunities to explore professions in engineering and manufacturing they would have never considered otherwise. For example, the "Women in Technology" (WIT) internship program, sponsored by the North Central Workforce Investment Board and manufacturing companies Tyco and Simplex/Grinnell, has successfully encouraged hundreds of female high school students to pursue careers and postsecondary degrees in STEM fields for more than a decade.[48] But for students and/or parents who may not be as willing or as curious as the students in WIT, the state has launched a campaign called AMP It Up! to raise awareness about the range of career opportunities in advanced manufacturing. Among other features of the campaign, AMP It Up! supports Connecting Activities by awarding grants of $10,000 to regional workforce investment boards that coordinate work-based learning with local high schools in the area.[49]

ADDRESSING THE IMAGE PROBLEM EARLY

While less pronounced than what is offered at the high school level, there are measures to pique student interest in manufacturing careers in middle and elementary school by delivering STEM and manufacturing curricula through more interactive, project-based instruction. Project Lead the Way is a STEM curriculum provider that offers scaffolded K-12 programs, which position students to earn college credit and/or virtual badges endorsed by the National Manufacturing Badge system.[50] Additionally, privately sponsored out-of-school opportunities like the Massachusetts FIRST LEGO League Alliance, partners with Worcester Polytechnic Institute to host a global robotics tournament for kids ages 9 to 14.[51] LEGO has also created online manufacturing platforms such as MINDSTORMS that several STEM programs in Massachusetts offer to elementary and middle school students over the summer.[52] Many of these STEM enrichment and out-of-school opportunities oftentimes occur with the help of a postsecondary partner either through direct sponsorship or simply providing the location. PlayWell TEKnologies is an organization that travels to one Massachusetts community college to offer manufacturing workshops and even engineering themed birthday parties for students in grades K-8.[53] Makerspaces like MIT's Fab Labs and other hands-on STEM activities that are presented under the auspices of "play" appear to be popular strategies and best practices for introducing younger students to the field of manufacturing.[54]

As elementary and secondary education extend efforts beyond and before high school to engage students in advanced manufacturing, the Department of Higher Education is also expanding its locus of responsibility and influence to reach students prior to college. The Department's agenda for higher education, called the Vision Project, calls on the public to understand that academic excellence in the state's school system sits within a larger goal of preparing students to pursue and obtain meaningful and financially sustainable careers.[55]

In addition to aligning academic progress with career development, the Vision Project reaffirms other state initiatives that see STEM as a powerful lever for creating new jobs, and in particular, views advanced manufacturing as an extension of the STEM agenda in Massachusetts. In November of 2013, the Governor's STEM Advisory Council published "Version 2.0" of *A Foundation for the Future: Massachusetts's Plan for Excellence in STEM Education*.[56] The plan is an update from an earlier document that outlined the state's intentions to bolster student engagement and performance in STEM subjects, especially for students of color, and to better align STEM curricula with workforce needs.

While these initiatives are interrelated outcomes of the governor's economic plan and statewide agenda for manufacturing, they still demonstrate unique perspectives and approaches to the same issue. Consequently, even if there is a general consensus that advanced manufacturing and targeted career planning are relevant to conversations about raising academic standards, increasing college enrollment, and preparing more students for careers in the STEM fields, the initiatives together do not necessarily represent a cohesive response to an advanced manufacturing career pathway. In 2013, the Pathways to Prosperity Network at JFF helped the Hampden County Regional Employment Board launch a 9-14 advanced manufacturing pathway that works to promote continuity between employers and the education system. Furthermore, the pathway is intentionally designed to partner a comprehensive high school, West Springfield High, with the state's only technical community college, Springfield Technical Community College, where students can earn an Associate's degree in Mechanical Engineering Technology. (*See the "Work in Progress" section of the*

appendix for more details about 9-14 pathway in Hampden County.)

In addition to early exposure and aligned 9-14 pathways, other tactics aimed at changing the image of manufacturing include site visits to facilities. As one panelist from *The Atlantic* conference suggested, young people need to be able to see first hand the high standards of technology, cleanliness, and professionalism that characterize modern manufacturing plants before they can see themselves working in them. The AMP It Up! campaign tries to accomplish this by posting videos of current young manufacturing workers explaining what their company does and their favorite part of their job. Amp It Up! also coordinates job shadows and plant tours on National Manufacturing Day.[57] As Siemens leaders, Helmuth Ludwig and Eric Spiegel write, the most common tool seen in the hands of machine workers and managers in auto plants in North Carolina and Tennessee is an iPad, not a screwdriver.[58] As such, making connections to things kids are already interested in and revealing the manufacturing behind these products is another strategy for engaging young people.

Though not specific to Massachusetts, a web video series called Edge Factor demonstrates where and how manufacturing plays a pivotal role in making products like snowboards and motorcycles, as well as parts for life-changing prosthetics. The founder of Edge Factor has also created "EduFactor" marketing tools and resources that work to convey the "coolness" of today's manufacturing industry.[59] In September of 2013, Edge Factor partnered with a local cable station in Arizona to air episodes of a similarly inspired series called LaunchPoint.[60]

The private sector is also beginning to take more responsibility for engaging and educating the next generation of advanced manufacturing workers. In April of 2014, Siemens announced a $660 million in-kind grant of its Product Lifecycle Management (PLM) software to 13 career and technical high schools and postsecondary institutions across Massachusetts. As President of Siemens PLM software, Chuck Grindstaff remarks, the industry is seeing a "convergence of disciplines" between "software, electronics, and hardware" in both the products and the production process itself.[61] Consequently, employers feel that replicating the conditions under which this type of technology is used through simulated software will add to the market value of students' skills upon entering the workforce. Lastly, in addition to the size of the grant that some say is a "game changer" in terms of expectations for private sector investment, the number of recipients is also unique. Grindstaff noted that equipment grants are typically awarded to a single institution, but the 13 recipients of this most recent grant from Siemens seems to symbolize a shift toward thinking about how the private sector has the potential to make a statewide impact.

PUTTING THE PIECES TOGETHER: AN EMPLOYER-DRIVEN, COMPETENCY-BASED STACKABLE CERTIFICATION PATHWAY

The previously described initiatives at the state level, the school level, and in collaboration with the private sector paint a picture of Massachusetts with pockets of alignment in certain regions or between institutions, but none quite demonstrate an effort to unify all stakeholders around a common understanding of the issue and a shared commitment to implementing a comprehensive solution. As mentioned in the introduction, the Applied Manufacturing Technology Certification pathway was launched through a collaboration between the Manufacturing Advancement Center Workforce Innovation Collaboration (MACWIC), Massachusetts Manufacturing Extension Partnership, and Qunisigamond Community College. The basic philosophy behind the pathway, as characterized by MACWIC steering committee chair and Director of Strategic Planning at Waters Corporation, Thomas A. Wesley, is taking one slice of the manufacturing problem, the skills gap in Machine Tool Technology in this case, and fixing it from the ground up.[62] Different from a "layered" approach, as Wesley describes, that tries to solve multiple training issues at once, the MACWIC model brings together over 100 manufacturing employers in Massachusetts to identify the problems, and provide specific recommendations to develop a flexible, competency-based curriculum that serves to benefit a large proportion of manufacturing workers and employers throughout the state.[63]

Another unique feature of the certification pathway is that there are multiple points of entry and re-entry for students, even as they work. The first two introductory levels of the credential can be earned in high school, and translate to three college credits toward the Associate's degree in Manufacturing Technology at Quinsigamond Community College. Upon successful completion of Level 2, the MACWIC collaborative agree that students would be eligible for positions such as machine operators and inspectors. Once students reach Level 3, they will complete 280 hours of coursework and training offered through MassMEP and begin logging their 600 on-the-job training (OJT) hours, which together allow students to earn up to 26 credits toward the degree. Upon successful completion

of the Level 3 exam and necessary OJT, students can earn a Certificate of Applied Manufacturing Technology at Level 4 of the pathway. At the 5th and final level of the pathway, students who have earned 26 credits from previous training and OJT, will theoretically enroll at Qunisigamond Community College to satisfy the remaining requirements of the Associate's degree in approximately one year. Regardless of the point or level at which high school students or incumbent workers enter the program, the driving principle behind these stackable credentials is that students are able to maintain momentum and labor market value even if they do not follow a linear educational timeline.[64]

In addition to alignment with employers and flexibility within the credentialing process, another key piece of the pathway is its alignment with high schools. Levels 1 & 2 of the MACWIC exams were specifically designed to complement the 2012-2013 Machine Tool Technology frameworks approved by the Department of Elementary and Secondary Education.[65] MACWIC also partnered with the postsecondary institution, Worcester Polytechnic Institute, to offer "curriculum in a box" lesson plans and software free of charge to all Massachusetts high schools. Furthermore, successful completion of Level 2 means that students are eligible to receive an industry recognized "pre-apprenticeship program" certificate that complies with the Massachusetts Division of Apprentice Standards[66] for acceptance into a manufacturing apprenticeship program. Lastly, for out-of-school and incumbent workers MACWIC developed a computerized program called "Learn CNC" which can be purchased by individuals or employers for under $400 and corresponds to approximately 55 hours of instruction in Mill and Lathe CNC technology.

While Quinsigamond College is currently the only postsecondary institution that offers the MACWIC/MassMEP machine tool technology program on-site, MACWIC is in the process of expanding the curriculum to other community colleges with the intention of standardizing the machine tool technology certification and associate's degree across the state. Additionally, state officials hope to build a transfer pathway to a 4-year degree in Engineering Technology at Fitchburg State University. Since its introduction in Massachusetts, the MACWIC model has been recognized by the Center for Law and Social Policy (CLASP) as an example of an effective statewide strategy for developing a career pathway and was included in the organization's Alliance for Quality Career Pathways initiative.[67]

CONCLUSION

The history of manufacturing in Massachusetts, coupled with its robust system of career and technical education at the secondary and postsecondary levels provide an interesting contrast to the state's reputation for high-tech innovation and its concentration of 4-year institutions. Yet, over the last four years, the governor's advanced manufacturing initiatives demonstrate the necessity of these seemingly disparate economic and educational spheres to intersect in order to support the next era of advanced manufacturing in Massachusetts. Moving forward, however, the state will have to create policies to maintain these points of intersection. In addition to recruiting young people and moving students through certification pathways, both the state and schools will need to target outreach to win the support of parents so they also understand the range of career opportunities within the manufacturing industry. Additionally, the state must ensure a sufficient supply of manufacturing instructors in high schools.

Currently, an experienced technician's salary is much higher than a high school instructor's, and thus policies and initiatives will likely be developed to incentivize qualified professionals to earn teaching credentials. Similarly, schools will need to continue to offer professional development and externship opportunities to instructors so teaching staff stay up to date on current practices and technology in the industry. Above all, state officials emphasize that employer involvement will remain at the core of all future initiatives. One way to increase widespread support from the business community is to give employers options for different levels of commitment, ranging from curriculum development, to formal partnerships, to internships and one-time equipment grants. However, as state agencies and educational institutions implement these strategies to meet employers' immediate needs, state officials acknowledge that Massachusetts is still in the process of mapping out the long-term future of advanced manufacturing. This planning will likely entail ways to restructure the entire secondary education system from the outside in, to make sure what happens in the classroom is sustainable in the labor market.

APPENDICES

APPENDIX A

TABLE 1: STATE SNAPSHOT OF MANUFACTURING	
Number of Manufacturing Employees	250,700
Percentage of State Workforce	7.5%
Percentage of State GDP	10.3%
Number of Manufacturing Firms	Approx. 7,000
Total Output (2012)	$41.6 Billion

Source: National Association of Manufacturing; Bureau of Labor Statistics

TABLE 2: GOVERNOR PATRICK'S 5-POINT AGENDA FOR THE STATE'S ADVANCED MANUFACTURING INITIATIVE	
Promoting Manufacturing	› Amp it Up: Statewide promotional campaign to engage young people in the field and provide funding to regional workforce investment boards and high schools. › National Manufacturing Day › Advanced Manufacturing Summit
Workforce and Education	› Advanced Manufacturing Regional Partnership Academy: a clearing house for best practices › Expand regional networks › Pilot Master Apprentice Program
Technical Assistance and Innovation	› Launch a "Modeling and Simulation" center › Expand MassMEP- ISO collaborative; offer certifications for employment in Small and Medium Sized enterprises.
Access to Capital Resources	› Launch new capital resource program: Working Capital Loan Guaranty for Manufacturers › Online Resource Guide to Capital Resources for Manufacturer–Rapid Access Manufacturers Portal (RAMP)
Cost of Doing Business	› Massachusetts Manufacturing Energy Collaborative (MassMEC) › Statewide regulatory reform on small business regulation

Source: Massachusetts Office of Housing and Economic Development

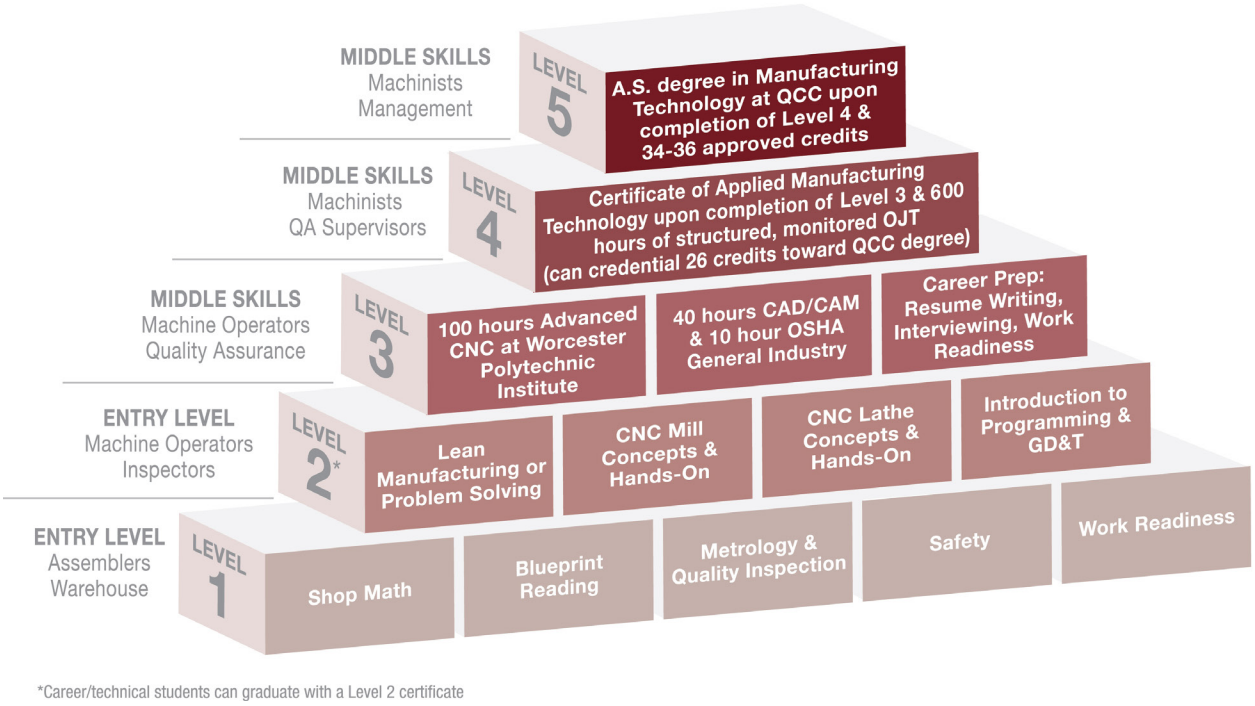
TABLE 3: PUBLIC FUNDING SOURCES		
Workforce Competitiveness Trust Fund	$1.4 million	The Executive Office of Labor and Workforce Development and the Commonwealth Corporation
Five-Year Capital Investment Plan	$5 million- includes grants for state vocational programs	Governor Patrick
MassWorks Infrastructure Program	$1.2 million to Springfield Technical Community College Mechanical Engineering Technology program	Patrick-Murray Administration
R&D Matching Grant Program	$50 million	Massachusetts Technology Collaborative
Workforce Training Fund	$23 million	Commonwealth Corporation
Advanced Manufacturing Futures Fund	$18.75 million	Governor Patrick
Massachusetts Manufacturing Extension Partnership (MassMEP)	$2 million	Federal Government
AMP It Up!	$100,000	MassDevelopment
Smaller Business Association of New England Matching Grant	$250,000	MA State Legislature

Source: Massachusetts Executive Office of Education

TABLE 4: CURRENT WORK IN PROGRESS- 9-14 ADVANCED MANUFACTURING PATHWAYS IN HAMPDEN COUNTY	
Partners	› West Springfield High School › Springfield Technical Community College › Hampden County Regional Employment Board
Credentials	› Students in 9-14 pathway receive a high school diploma & option to earn an Associate's degree in Mechanical Engineering Technology
Number of students	› 40 students in 2013-2014 cohort › Accepted 40 more fro 2014-2015 academic year
Key Components	› The secondary institution is a traditional comprehensive school in which a rigorous college preparatory curriculum enhances the machine tool technology program. › Leadership at both the high school and community college were excited and eager to develop such a pathways program. › Employers willing to help fund and develop the pathway with the understanding that they would not see any return on investment for at least 6 years. › The Regional Employment Board served as the key convener, and dispelled skepticism from both school officials and employers. » In approaching the school board, the REB deliberately did not ask school board for funding; they ensured school officials that they would take on the responsibility of fundraising. » The REB's involvement instilled confidence in employers that the pathway was both a worthy and substantiated cause. › REB began with grants from foundations, but structured the business plan in such a way to be self-sustaining with the employer partnerships. › Students develop a strong foundation in math and science in 9th and 10th grades before they begin the college level mechanical engineering curriculum; students are also encouraged to take AP courses throughout high school. › Students are given a holistic view of the manufacturing industry and relevant stakeholders: i.e. the "business of manufacturing" and "the role of the banker and the attorney." This allows students to see the many places and jobs the industry offers. › Students participate in 6-week paid summer learning opportunity at the community college and working in the employers' facilities.

APPENDIX B

INDUSTRY RECOGNIZED APPLIED MANUFACTURING TECHNOLOGY CERTIFICATION PATHWAY AT QUINSIGAMOND COMMUNITY COLLEGE

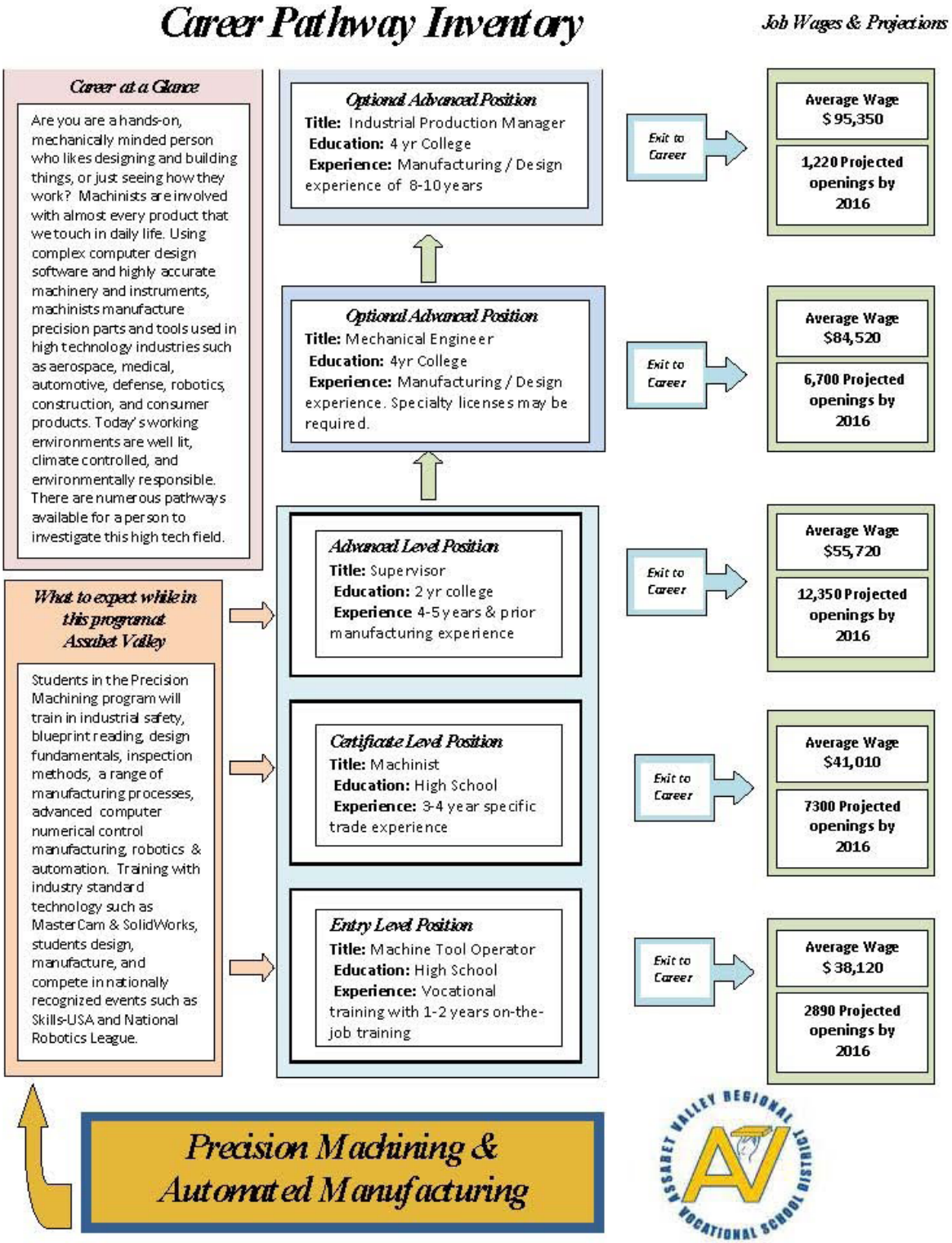


*Career/technical students can graduate with a Level 2 certificate

Source: MACWIC

APPENDIX C

ASSABET VALLEY REGIONAL TECHNICAL HIGH SCHOOL-CAREER PATHWAYS



Source: Assabet Valley Regional Technical High School, http://www.assabettech.com/pages/AssabetValley/Technical_Programs/Manufacturing_Engineering_Clus/Precision_Machining__Automate/Career_Pathways

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