



WORKFORCE LEARNING ECOSYSTEMS FOR ADVANCED MANUFACTURING:

A New England Benchmark

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The Research Team

Michael Dedek, Communications and Curriculum Specialist, Office of Open Learning

Steve Nelson, Senior Manager, Office of Open Learning

George Westerman, Senior Lecturer, Sloan School of Management, and Principal Research Scientist, Office of Open Learning

*Global Opportunity Forum,
Office of Open Learning
Massachusetts Institute of Technology*

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Introduction

By 2028, manufacturing in the United States is predicted to have a shortage of 2.4 million workers.¹ Surprisingly, according to Deloitte, the shortage will be caused in large part by technologies associated with advanced manufacturing and Industry 4.0. Rather than shrinking workforces, such technologies are expected to spark new job growth. Moreover, new job growth will be in positions requiring skilled employees. Anticipating these changes, stakeholders in manufacturing across the U.S. have been looking for methods to build better workforce learning ecosystems for advanced manufacturing.

Workforce learning ecosystems, or WLEs, are complex systems that provide training and education relevant for work. WLEs include not only schools, but other stakeholders as well—such as employers, government agencies, nonprofit organizations, and learners. All of these stakeholders either provide or influence training and education.

Because WLEs are complex, stakeholders in manufacturing have sought to understand how they can be influenced, altered, and improved. In the case of manufacturing in the U.S., which has faced persistent workforce shortages, stakeholders have been trying to create WLEs that can efficiently teach advanced-manufacturing skills on a large scale.

In this report, we present findings from a qualitative study of WLEs for advanced manufacturing across New England. This study has aimed to understand the readiness of WLEs in the region to teach skills—and produce other outputs—needed for advanced manufacturing at a scale required in the region.

The workforce challenges faced by manufacturers across the U.S. are mirrored—and perhaps magnified—in New England. New England's states have populations that are among the oldest in the U.S., a demographic composition that suggests manufacturing in the region, compared to manufacturing nationally, will face an even more dramatic wave of retirements. Furthermore, even as New England's populations age, manufacturing in the region is expected to experience job growth, an estimated 41,000 additional jobs between 2020 and 2030 (see Appendix B).

¹ Deloitte Insights. (2018, November 13). *2018 Deloitte skills gap and future of work in manufacturing study*. <https://www.deloitte.com/global/en/our-thinking/insights/industry/manufacturing-industrial-products/manufacturing-skills-gap-study.html>

For this study, we have interviewed 30 key leaders across all six states of New England. Interviewees represent a diverse spectrum of stakeholders: higher education institutions, workforce development boards, non-profit organizations, and manufacturing companies.

To understand the status of New England's WLEs, we developed the WLE readiness framework, a detailed set of criteria which can be used to understand the extent to which a WLE is prepared to provide advanced-manufacturing skills at the needed scale. This framework is informed by interviews conducted for this study as well as by our previous research for MassBridge (see "Background" below).

The WLE readiness framework examines four interrelated dimensions, which are defined in greater detail in the report:

1. **Sufficient learner demand**—Enough learners enroll in learning programs to meet industry needs.
2. **High-quality learning programs**—Learning programs teach needed skills effectively, support learners, and help learners connect with employers.
3. **Multi-stakeholder collaboration**—Stakeholders meet regularly to align learning programs and industry needs.
4. **Financial sustainability**—Learning programs and collaborations have sustainable funding models.

By meeting these criteria, a WLE will be able to reach its main goal: *providing the right skills to the right people in the right way*. More technically, a WLE that meets these criteria will have an equilibrium between market demand and educational output of skilled employees. In such a WLE, manufacturers can find skilled employees, and skilled employees can find work.

This report offers both regional and state-by-state assessments of WLE readiness for advanced manufacturing. But perhaps more importantly, this report offers novel recommendations for improving WLEs in New England. Our research finds that the strongest WLEs in the region are centered on large employers. These types of WLEs are notable enough to warrant a special term: Allied Large-Employer Led Learning Ecosystems, or ALELLEs.

In this special type of WLE, large employers have assumed leadership roles, helping to coordinate all stakeholders involved. Large employers have helped convene, guide, and share information with other employers (usually smaller, local manufacturers in their supply chains), educational institutions, and government agencies to sustain and improve the WLE. In this report, we describe three ALELLEs in New England to illustrate why they are effective and suggest improvements.

ALELLEs are the greatest asset for workforce learning in advanced manufacturing in New England. For that reason, we recommend that future workforce-learning strategies in the region should focus on them first, even as they develop additional approaches for areas that do not have large employers. More specifically, we recommend a two-step process for the future development of New England's WLEs:

1. Devote resources and attention to increasing demand for learning programs in advanced manufacturing.
2. Identify ways for existing ALELLEs to include additional stakeholders, both inside and outside of the current catchment area of the ALELE.
3. Fund efforts to improve ALELLEs—for example, by assisting them with collaboration, developing educational standards, and marketing careers.
4. Create mechanisms to facilitate information and resource sharing among ALELLEs on statewide and regional levels.
5. In areas where ALELLEs do not yet exist, identify key employers, or other stakeholders, that can be the cornerstone of a WLE. Then provide support and advice to make progress.

Beyond these high-level recommendations, we also identify numerous detailed findings and recommendations. Most significantly, everywhere in New England, interviewees said that too few people are enrolling in advanced-manufacturing learning programs to build a skilled workforce large enough to satisfy industry demand. Attracting enough learners – both new employees and existing workers – to advanced manufacturing is the most urgent objective for WLEs everywhere in New England. With too few learners, not only will there be too few skilled workers; learning programs will also struggle to continue operating due to low enrollment. However, the challenge of learner demand will not be met through marketing only. It will require making changes in all four dimensions of the WLE framework.

These recommendations and more are explained in more detail throughout this report. In the next section, we overview the background for the project. Next, we present our WLE readiness framework. Then, we describe three ALELLEs that have proven successful in the region. Finally, we present recommendations and findings for improving the region's WLEs.

Background

Research Objectives

This study and report have been completed for The New England Defense Industry Collaboration (NERDIC), which has requested that MIT Open Learning (OL) assess the readiness of WLEs for advanced manufacturing in New England.

Specifically, NERDIC has asked MIT OL to achieve three objectives on its behalf:

Objective 1: Create an assessment framework, based on MIT OL's prior research for MassBridge, to understand the readiness of advanced-manufacturing WLEs in New England.

Objective 2: Interview key stakeholders to assess state-level readiness to meet skills needs of advanced manufacturing.

Objective 3: Draft a report about regional workforce ecosystem readiness, with recommendations for improvement.

Previous Research from MassBridge

Our current study builds on benchmarking research previously performed by MIT Open Learning for the MassBridge project—a DoD-funded project to plan and develop advanced-manufacturing programs for community colleges and vocational-technical high schools in Massachusetts. Notably, MassBridge aimed to develop a model for advanced-manufacturing education that could be exported to other states. MIT's research for MassBridge has informed our current WLE readiness framework, by showing what features characterize effective technician programs in advanced manufacturing, and served as the basis for further interviewing to improve and apply the framework in the region.

Among the most important conclusions was that effective advanced-manufacturing programs have certain characteristics:

- Collaboration between employers and educators
- Scalability
- Inclusiveness for incumbent employees and people experience underemployment
- Continuous improvement
- Relevant learning programs

Numerous analyses and examples in the three main MassBridge research reports from MIT OL showed how workforce learning systems across the US are building these features.

In building our initial models for a WLE assessment, we drew upon the reports from MassBridge,² other reports on the New England manufacturing environment,³ and other sources.

An Archetype for WLEs: Ohio TechNet

One of the many excellent manufacturing workforce-learning programs identified in the MassBridge research is an exemplary WLE in Ohio. This WLE illustrates how decentralized educational institutions and manufacturers—like those across New England—can collaborate to address shared challenges in workforce development.

The WLE is composed of two major organizations: (1) the Ohio Technical Skills Innovation Network, or Ohio TechNet; and (2) The Ohio Manufacturers' Association (OMA). These two groups have worked closely to align learning programs with industry demand.^{4, 5}

Ohio TechNet was founded in 2014 with 11 members and has since grown to include more than 40 colleges, universities, and technical centers in the state. It performs two main functions for the WLE:

- It serves as a **centralized point of contact** for educational institutions to collaborate with manufacturers and other stakeholders, including five Manufacturing USA Institutes. In this capacity, Ohio TechNet helps update educational institutions about emerging trends in workforce needs.
- It serves as a **centralized clearinghouse for training materials**, such as courses and lessons. By doing so, Ohio TechNet disseminates free teaching and learning materials and reduces redundancy of effort, as learning programs and teachers can adopt premade instructional materials.

While Ohio TechNet coordinates educational institutions, OMA coordinates manufacturers throughout Ohio. Currently, the OMA reports that it has 1,292 member manufacturers, about 50 percent of which have fewer than 50 employees.

² MassBridge. (n.d.). Bridging the gap in manufacturing technician training in emerging technologies. <https://cam.masstech.org/massbridge>.

³ Future iQ. (2019, June 13). *New England Regional Defense Industry Collaboration think-tank workshop report*. <https://lab.future-iq.com/wp-content/uploads/2019/09/new-england-regional-defense-industry-collaboration-think-tank-report.pdf>.

⁴ OhioTechNet. (n.d.). <https://ohiotechnet.org/>.

⁵ The Ohio Manufacturers' Association. (n.d.). <https://www.ohiomfg.com/>.

Together, Ohio TechNet and OMA have implemented successful workforce learning initiatives. For example, Lorain County Community College (LCCC), a leading school in Ohio TechNet, and OMA have identified credentials—and the curricula and assessments that come with them—to align the skills and competencies taught in learning programs with what manufacturers consider most important. Now, all community colleges in Ohio can draw on the list of credentials and competencies, thus better ensuring that students learn what industry needs.

Ohio TechNet has also worked with the OMA on earn-and-learn programs, including by expanding apprenticeships. One such program is TRAIN OH, which was launched in 2016 with a Microelectronic Mechanical Systems (MEMS) program, at LCCC. The program includes paid part- or full-time work-based learning for students who are working toward associate degrees. As of when our MassBridge report was written, the MEMS program had a 100% job placement rate. Given that success, the earn-and-learn model from the MEMS program was expanded to more than 100 job opportunities with 125 employer partners. With such earn-and-learn programs, LCCC works with manufacturers—including small ones—as co-designers of the college curriculum.

Ohio demonstrates that collaboration is a key element in a successful WLE. Collaboration is especially needed to design and update manufacturing curricula and to connect students with employers. Moreover, collaboration has proven important for widening access to high-quality learning programs. By working as an association, manufacturers in Ohio—regardless of size—have been able to communicate needs with educational institutions and collaborate on building school-to-work pipelines, in part through earn-and-learn programs. Finally, such collaborations can make WLEs more efficient by standardizing how skills are taught, assessed, and documented or credentialed. As a result, such collaborations can increase skills visibility, enabling employers to hire employees who have demonstrated competency in a skill rather than hiring employees based on experience alone, an imperfect proxy for skills.

WLE Readiness Framework for Advanced Manufacturing

Our past research for MassBridge⁶ identified key elements of high-quality WLEs through advanced-manufacturing programs throughout the U.S. We built on those findings, plus a review of other ecosystem literature to build an initial readiness framework. We then improved and extended the initial framework through 30 interviews with key stakeholders in New England (see Appendix C).

We define a workforce-learning ecosystem (WLE) as a complex system that creates value for individuals, businesses, and economies by advancing and teaching work-relevant skills, knowledge, and habits of mind.⁷ In manufacturing and other industries, WLEs rarely conform to political boundaries like state lines. Instead, they form a multi-level web of connections defined by linkages between manufacturers and their suppliers of components and raw materials - whether hard resources or human ones. The boundaries of a WLE tend to be dictated by costs and distance of travel rather than by any specific political boundary. Furthermore, these boundaries can change over time as conditions change for producers or suppliers.

In advanced manufacturing, WLEs include four main groups of actors:

- The workforce
- Educational institutions
- Manufacturers
- Facilitators—any stakeholder group, like workforce boards or industry groups, that organizes actors in the WLE or eases their interactions.

WLEs are shaped by what these actors are, do, and believe. Moreover, an action or change in one place can ripple across the ecosystem. For example, when manufacturers raise pay, more workers may seek relevant skills; educational institutions offer additional courses and hire more teachers; the skilled workforce may grow; and productivity and innovation may rise. Thus, the

⁶ Our MassBridge research produced several informative reports and events, most notably Westerman et al. (2021, September 24). *Benchmarking advanced manufacturing education: From the MassBridge workforce education program*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/sites/default/files/2022-06/Benchmarking-Phase1-Report-Sept2021.pdf>.

⁷ This definition borrows language from Altman et al. (2021, April). *Workforce ecosystems: A new strategic approach to the future of work*. <https://www2.deloitte.com/content/dam/Deloitte/de/Documents/human-capital/Workforce-Ecosystems-Study2021.pdf>

health of a WLE is determined not only by the state of educational services but by every stakeholder involved.

WLEs are shaped too by contextual factors, which in turn are affected by economy, culture, politics, and geography. For example, in some WLEs, the workforce may have little interest in learning skills for advanced manufacturing because the broader culture devalues or stigmatizes manufacturing jobs. In other WLEs, workers may be discouraged from learning new skills because schools are simply too far away.

WLEs enable numerous independent actors to innovate, individually or collectively, to meet their goals. When they work well, they align individual incentives with broader goals and self-orchestrate to maximize benefits. When not working well, they can devolve into ineffectiveness. Although external influence and investment can steer WLEs in effective directions, it is rarely effective in “managing” the ecosystem. Rather, powerful actors in the ecosystem tend to shape the nature of interactions. External influence, then, can incent good behavior and reduce less-desired ones, without controlling specific decisions among WLE participants.

We conceptualize WLEs this way to reveal possible root causes and points of leverage, some of which may be surprising. In an assessment of a WLE, it is important to know not only whether there are relevant and effective learning programs or employers. One must also examine other dimensions of the WLE framework to understand, for example, whether and why the workforce seeks or avoids learning in-demand skills.

Among its greatest benefits, an ecosystem approach enables analysts to examine multiple sources of value. As needed, analysts can take an aerial view of the broad economic impact of a WLE, or they can zoom in on the value generated for individual schools, employers, and other stakeholders in the ecosystem.

In the following, we are interested in the health of New England's manufacturing WLE and the WLEs of its individual states. We ask: How well are these WLEs functioning? Are they creating as much value as they can? And what can an WLE approach do to provide recommendations for improvement?

Criteria for a healthy WLE

A healthy WLE efficiently teaches the right skills to the right number of people, is sustainable, and can adapt to fluctuations in demand. More technically, a WLE must meet this condition:

Equilibrium between industry demand for skills and the output of programs that deliver those skills to individuals.

For WLEs to meet that primary condition, they must meet four multifaceted criteria. Here, “learning programs” include any means by which the workforce learns relevant skills. Schools offer learning programs, but so do employers, both formally and informally. We should emphasize that this includes training new employees as well as reskilling existing ones from inside or outside the manufacturing industry.

1. **Sufficient learner demand:** Enough learners enroll in learning programs to meet industry needs. To create this demand, an WLE attracts learners through various means:
 - *Good jobs.* Employers offer secure jobs that pay well and offer career advancement, especially for employees who learn relevant skills.
 - *Effective marketing and attraction programs.* Stakeholders provide widespread visibility about manufacturing jobs and careers to potential learners and employees.
 - *Inclusiveness and accessibility.* Stakeholders recruit and offer appropriate learning support for diverse learners. Such support could include low-cost programs, scholarships, and earn-and-learn programs. Learners of interest include youth learners, returning adults, incumbent workers, people experiencing underemployment, rural learners, and people from backgrounds historically underrepresented in the field.

2. **High-quality learning programs:** Learning programs teach needed skills quickly and effectively, support learners, and help learners connect with employers:
 - *Instructional objectives aligned with employer needs.* Programs are designed to teach human and technical skills that are in demand among employers in the WLE.
 - *Effective instructional methods.* Programs use instructional methods known to promote learning such as hands-on learning, project-based learning, and experiential learning.

- *Complementary learner support.* Learning programs offer students learning assistance such as financial aid, additional academic preparation, and wrap-around support, like transportation and childcare.
 - *Support for incumbent workers.* For incumbent workers, programs provide accommodations such as online courses, night courses, and courses delivered at employers' facilities.
 - *On-ramps and off-ramps to education.* Programs are designed so that courses and short-term programs, like boot camps and 12-week certification courses, provide students with valued competencies that serve as signals to employers (off-ramps) and starting points for additional education (on-ramps).
 - *Valued credentials.* Programs issue badges, certificates, degrees, and certifications recognized and valued by employers in the WLE.
 - *Availability of work-and-learn programs.* The WLE provides work-and-learn programs—including apprenticeships, co-ops, and internships—that benefit students, who can gain work experience and earn income while learning, and employers, who can benefit from learners' labor.
3. **Multi-stakeholder collaboration:** stakeholders work closely to align learning programs and industry needs:
- *Collaboration between schools and employers.* Schools and employers collaborate to promote the health of the WLE by, for example, communicating industry trends, creating school-to-work pipelines for learners, and generating demand for learning programs.
 - *Collaboration among employers.* Employers collaborate to promote the health of the WLE by, for example, sharing workforce intelligence, establishing standards, attracting workforce, sharing equipment, and aggregating demand for learning programs.
 - *Collaboration among schools.* Schools collaborate to promote the health of the WLE by, for example, sharing curricula, course design, instructional materials, instructional methods, and equipment.
4. **Financial sustainability:** Learning programs and collaborations have effective funding models that can survive after initial seed grants end.
- *Cost-effective learning.* Learning across the WLE is as cost-effective as possible. To be cost-effective, redundancies in collaboration, program

offerings, program administration, equipment acquisitions, and instructional effort are minimized. Programs may also use new ed-tech when appropriate—such as recycled online lectures, augmented reality, virtual reality, games, and simulations—to reduce costs.

- *Funding availability.* The WLE has sustained funding for learning programs to promote program development and purchase equipment. This may be from a combination of grants, employer contributions, tuition or other sources.
- *Clear standards.* There are clear standards for learning programs, including standards for assessing competency and issuing credentials. Such standards make designing and operating learning programs more efficient, and provide clearer information about applicants' skills to the labor market, allowing potential employers to understand more clearly applicants' competences.

WLEs in Action: Three Cases from New England

The strongest WLEs in New England are neither statewide nor regional. Instead, they are local and led by large manufacturers. Like the WLE in Ohio that we described above, these WLEs include collaboration to align learning programs with manufacturers' needs, but on a more local scale. Furthermore, these ecosystems demonstrate the need for stakeholders to collaborate on generating demand for learning programs, through good jobs, demand-generation programs, well-aligned curricula, and other methods.

Here we describe three local ecosystems to illustrate how WLEs work in New England and offer insights on how these WLEs could improve. We discuss the following ecosystems in order:

1. General Dynamics Electric Boat in Eastern Connecticut
2. BAE Systems in the Merrimack Valley of New Hampshire
3. General Dynamics Bath Iron Works in the Mid-Coast of Maine

Each of these ecosystems are examples of **Allied Large Employer-Led Learning Ecosystems, or ALELLEs**, a special kind of WLE. In each ALELLE discussed here, a large company serves as a leader and coordinator for the ecosystem. Although the companies in these ALELLEs are defense contractors, they could conceivably be run by any large company, such as auto manufacturers in South Carolina and Tennessee.⁸

To improve workforce learning for advanced manufacturing in New England, we recommend that ALELLEs, like the three described here, be the focus of attention. Interviews suggest that these ALELLEs have the greatest potential to scale up to meet industry workforce needs. Still, each ALELLE faces unique challenges. Such challenges--and likely others--will need to be understood and addressed in future stages of building New England's ecosystems.

General Dynamics Electric Boat (Eastern Connecticut): the Eastern Advanced Manufacturing Alliance Regional Sector Partnership

The ALELLE in Eastern Connecticut is the strongest that our research uncovered in New England. This ecosystem excels mainly due to sustained and formalized collaboration. Led by Electric Boat (EB), manufacturers in the area have banded together to form an alliance that addresses workforce challenges in the industry. This alliance has helped to align activities across manufacturers, educational

⁸ Westerman et al. (2021, September 24). *Benchmarking advanced manufacturing education: From the MassBridge workforce education program*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/sites/default/files/2022-06/Benchmarking-Phase1-Report-Sept2021.pdf>.

institutions, and workforce investment boards. Stakeholders are collaborating in the local region on curriculum development, on establishing school-to-work pipelines, and on generating learner demand.

Stakeholders

At the center of this ecosystem is the Eastern Advanced Manufacturing Alliance Regional Sector Partnership, or EAMA RSP. This alliance includes more than 35 manufacturers led by EB. The EAMA RSP serves as a forum for manufacturers to communicate their needs to partners in education and workforce development. As an alliance, EAMA RSP works with the local workforce board—the Eastern Connecticut Workforce Investment Board (EWIB)—and three community colleges: Three Rivers Community College, Quinebaug Valley Community College, and the Community College of Rhode Island in Westerly.

Learning programs and results

Together, these collaborators have established a training and employment program called the Manufacturing Pipeline Initiative, or MPI. Launched in 2016, MPI has been built and updated with input from EB and other manufacturers that are a part of the EAMA RSP. MPI aims to meet the hiring and skills needs of local manufacturers, and its curriculum is recognized by all members of the EAMA RSP. Among the positions for which MPI trains are machine operating, welding, plastics, pipefitting, shipfitting, and design and drafting. Courses are short-term, lasting between 2.5 and 10 weeks, and are offered online and in person through local community colleges.

The MPI offers participants help with finding jobs upon graduation. According to undated online sources, the MPI has helped more than 3,900 people secure jobs. MPI offers program participants assistance with elements of the job application process—like writing resumes and interviewing—and with securing interviews with local manufacturers.

Collaboration on Curriculum and Hiring

Interviewees told us that collaboration among stakeholders, especially those involved with the EAMA RSP, is frequent and effective. According to interviewees, a committee meets every other month to review curriculum and improve implementation. Moreover, there is what one interviewee called “constant feedback on what is and is not working.” Interviewees told us that ongoing discussions help community colleges incorporate industry needs into their education.

High schools are involved in collaboration and coordination as well. Local high schools now offer the same manufacturing programs offered to adult learners in community colleges. Building on the success of the MPI, the EWIB has launched

the Youth Manufacturing Pipeline Initiative (YMPI). The YMPI currently has 18 participating high schools and has placed over 100 students in jobs. For this program, students complete 150 hours of hands-on learning in manufacturing during normal class hours. It also provides program graduates with a YMPI certificate that, in at least some cases, can provide students with college credit.

Collaborations are helping to build connections among high schools, community colleges, and manufacturers. And these collaborations are helping to secure better employment by aligning curriculum with employers' needs and helping graduates find jobs with manufacturers.

Stimulating and Aggregating Learner Demand

Stakeholders in this ALELE have also established outreach and support programs to attract youth learners. One interview said that they have created outreach programs for children in the 4th grade, which the interviewee called an “inflection point when they [children] might start thinking about what they'll do.” The YMPI has also expanded beyond high school and into elementary and middle school by offering exposure programs, such as field trips to manufacturing facilities and classroom visits by speakers who work in manufacturing. These outreach programs are in addition to the YMPI's educational offerings to high school students, offerings which also increase learner demand for manufacturing programs.

Learner demand is also increased by offering support to adult learners. EWIB pays tuition for eligible adults accepted by MPI programs. The MPI program also assists students in accessing American Job Centers, which provides supports such as childcare, transportation, and incidental costs to help learners overcome financial and other barriers to learning. Moreover, at least for some learners, MPI offers learners a stipend for successful completion of classroom training benchmarks. To provide appropriate academic support, the MPI requires applicants to complete a 16-question multiple choice “Skills Inventory,” which gathers information about skills such as critical thinking, reading comprehension, spatial reasoning, and emotional intelligence. For students who receive a score below a threshold, the MPI provides either an “Education Refresher Class” or directs applicants to an American Job Center.

Through EAMA RSP, manufacturers are also aggregating demand for learning programs. As a main stakeholder in the region, EB recognizes that they can't be the only voice - that the other manufacturers in the region need to be an alliance and work with EB on challenges facing the region.

Remaining Challenges

Despite how well stakeholders are collaborating in the ALELLE, interviewees told us that improvements are still needed.

One challenge appears to be sustainable funding. Employers may also benefit from financial assistance with offering experiential education, like internships or finding ways to underwrite some of the experiential learning as well.

Despite the ALELLE's successes, interviewees believed that more people needed to be attracted to careers in manufacturing. Among the solutions they called for were expedited paths to citizenship, more youth outreach, and increased usage of internships. There is evidence too that manufacturers are hiring and providing training independently.

It is also unclear whether the ALELLE is attracting learners at the needed scale. One interviewee told us that EB will need 3,000 new workers per year for the next 10 to 20 years. Another interviewee said that EB would need 28,000 employees at facilities in Groton, CT in the next decade. Government sources support these predictions. According to the Connecticut State Office of Military Affairs, EB anticipates hiring 5,750 employees in 2023 alone.⁹ While not all these job openings will be in production, the high number of new employees needed—for a single employer—suggests that current training programs are not yet meeting employers' needs. For comparison, it's useful to consider that the MPI claims to have secured jobs for more than approximately 3,900 since it began operating in 2016.¹⁰ This number does not reach EB's total predicted hiring for 2023, but the MPI is also not designed for everyone; it serves people who have a right to work in the U.S. and are experiencing unemployment and underemployment. As effective as the MPI and YMPI have been, they can be expected to satisfy only a fraction of manufacturers' workforce needs.

Despite such potential shortcomings, the ALELLE has a strong record of collaborations, and there are indications that employers are taking new actions to attract more employees. Interviewees with the EWIB said they bring together employers to talk about workforce issues, especially the issue of offering higher wages and are encouraging employers to look at “the non-traditional

⁹ Hallenbeck, B. (2023, February 28). Electric Boat hopes to hire 5,750 employees this year. Connecticut State Office of Military Affairs. <https://portal.ct.gov/OMA/In-the-News/2023-News/Electric-Boat-hopes-to-hire-5750-employees-this-year>.

¹⁰ Eastern CT's Youth Manufacturing Pipeline Initiative. (n.d.). Eastern Connecticut Workforce Investment Board. Retrieved December 13, 2023, from <https://www.ewib.org/ympi>.

workforce” and “at hiring people without skills that are willing to learn and grow with the job.”

BAE Systems (Merrimack Valley, NH): Informal Associations and Industry-Education Partnerships

Unlike the ALELLE in Eastern Connecticut, this ALELLE is not supported by an official organization, like EAMA RSP, but by collaborations led in large part by Nashua Community College (NCC) and the defense contractor BAE Systems, which, according to SENEDIA, received 59.8% of all prime defense contracts in New Hampshire between 2020 and 2022.¹¹

Working with smaller suppliers, BAE Systems has collaborated with high schools, community colleges, and universities in New Hampshire and Massachusetts to create programs in advanced manufacturing, including for test technicians, soldering, and microelectronics. While the programs serve in part as feeders for BAE Systems, they have also proven beneficial to small manufacturers, which have been able to hire among program graduates and send incumbent employees to learning programs. While this ALELLE benefits small suppliers, it also strengthens the main primary defense contractor, BAE Systems, by providing a more resilient supply chain.

Collaboration on Short-Term Programs

BAE Systems has teamed up with smaller suppliers to communicate with community colleges. Notably, industry partners have collaborated with Manchester Community College (MCC) and NCC to create short-term certificate programs for machining, test technicians, and microelectronics. Together, the community colleges and industry partners have co-designed a curriculum recognized by local employers. Industry partners also communicate their hiring forecasts to community colleges and hire liberally among program graduates.

Success with Boot Camps

The programs that appear to have had the most success are delivered in a boot-camp format. For example, NCC offers a 10-week boot camp for microelectronics, designed with industry input. At the end of the boot camp, students are guaranteed an interviewee with BAE Systems. The boot camp runs for 40 weeks per year. The boot camp has graduated 300 people (as of Mar. 2023) and has had a hiring rate of 98 percent (as of Feb. 2024). Graduates have been hired by Mercury and Draper Labs, in addition to BAE Systems.

¹¹ SENEDIA. (2023, May). The economic impact of the defense cluster in New England. <https://senedia.org/economic-impact/>.

BAE Systems and other industry partners have collaborated with NCC, MCC, and other colleges, including Great Bay Community College, on boot camps in other fields as well, including for soldering and test technicians.

For manufacturers, boot camps have provided the benefit of enabling them to observe students before hiring them - which has created in effect a ten-week interview process with very little risk.

Nimble, Relevant Programs

Boot camps and other short-term non-credit programs have also proven attractive for educators because they can be created and changed more easily than credit programs and because they have reliable success with placing graduates in jobs. Interviewees noted that people who complete short-term programs and boot camps often return to school for the long term too, either to continue learning manufacturing skills or engineering, or to study in lateral fields, like business.

Diversified Partnerships

While BAE Systems has fueled collaborations in the region, NCC also has been a nexus for other collaborations among manufacturers in the defense industry. NCC has about 20 companies in reserve, that is, companies with which they collaborate, especially on hiring graduates as well as constant contact with workforce boards in the region.

In addition to working with BAE Systems and other partners, NCC recently created a precision manufacturing boot camp with funding from SENEDIA. So far, that program has had one cohort of students. According to NCC's data, the cohort began with 10 students, but five stopped out (for relevant reasons, mentioned below). However, among the 5 graduates of the program, all were hired.

Overall, such short-term programs have proven effective with high rates of hiring for graduates. For example, it's common for students in the microelectronics 10-week boot camp to receive job offers by the third week. Subsequently, the students work part-time while completing the boot camp.

Forays into Apprenticeships

In addition to short term programs, BAE Systems has collaborated with the Community College System of New Hampshire (CCSNH) on an apprenticeship program for precision inspectors. The program lasts two years and requires 4,000 hours of paid on-the-job training and 288 hours of employer-paid instruction at NCC.

However, despite their well-known benefits, apprenticeship programs have presented drawbacks to stakeholders in the ALELLE. Apprenticeships are expensive and sometimes too heavy an investment for some industry leaders. Some felt that bootcamps may be more favorable than apprenticeships in that they can deliver skills – and allow employers to identify top candidates – more quickly. However, bootcamps are limited in the number and depth of skills they can provide, meaning that apprenticeships and other longer-term programs still have an important role to play. The ability to learn-and-earn is another important consideration, whether in bootcamps, apprenticeships, or other programs.

Remaining Challenges

While this ALELLE in Southern NH has enjoyed successes, there are signs that it has yet to scale up to meet the needs of both employers and educational institutions. Learner retention poses a challenge as well.

Interviewees mentioned that class sizes are down to as low as 5 to 8 students per cohort. As a result, industry leaders and educators alike are trying to find new ways to recruit students. Currently, at least some boot-camp programs are not running at full capacity. The goal is to have at least 12 students per microelectronics boot camp, an increase from only 8 students in the last cohort.

This reduction in cohort size poses a challenge for long-term financial sustainability. Staffing costs do not drop when a classroom is only partially full, but tuition revenues do. Further, aging equipment has become a problem. Interviewees mentioned that a lot of the equipment is six or seven years old. As a result, some of the equipment needs to be repaired or replaced. NCC has enough equipment for the students they are currently teaching, but that could change if enrollments increase.

A well-known problem too is that many students often leave learning programs for social, health, and financial reasons. One interviewee mentioned a student who had to assume care responsibilities for a younger sibling because his mother experienced a health crisis. Unable to find childcare, the student was forced to leave the program. As students experience such challenges, learning programs are increasingly helping students find support services. Now instructors need to assume the role of not only content specialists but also social workers in some cases.

General Dynamics Bath Iron Works (Mid-Coast Maine)

Stakeholders

General Dynamics Bath Iron Works (BIW) leads an ALELLE in Mid-Coast Maine. The ecosystem includes at least three educational institutions that provide

instruction in manufacturing: Maine Maritime Academy (MMA), Southern Maine Community College (SMCC), and York County Community College (YCCC).

On March 1, 2024, officials announced the formation of the Maine Defense Industry Alliance (MDIA), which aims to attract and train workers for manufacturing jobs in Maine's defense industry, especially jobs at BIW and Pratt & Whitney in North Berwick.¹² This alliance may prove to be a major stakeholder in Maine in the future.

Learning programs

Two community colleges, MMA and SMCC, provide learning programs in coordination with BIW. BIW also offers its own training to employees, in part through the BIW Training Academy, a facility in Brunswick Landing, ME.

MMA offers two "joint" apprenticeship programs with BIW: ship design and ship production. At the completion of these programs, students earn an Associate of Science degree.

SMCC offers three short-term programs in partnership with BIW: welding, marine design, and manufacturing technician. Two of these programs—welding and manufacturing technician—offer students a \$500 per week stipend as an incentive. The other program—marine design—is free of cost to students. SMCC also offers a 1-year pre-apprenticeship program for BIW.

BIW has run an extensive apprenticeship program for decades. They offer both basic and advanced apprenticeships. These programs prepare learners for positions ranging from machinists and marine electricians to marine engineers and surveyors. Upon completion of advanced apprenticeships, learners receive at least an associate degree or complete coursework toward a bachelor's or master's degree.

BIW has also created extensive in-house training programs, which in one recent year trained about 2,900 new hires. The in-house program has at least four staff devoted to developing courses and curriculum.

MDIA—announced in Mar. 2024—is helping to fund an expansion in manufacturing programs at YCCC. As part of this expansion, YCCC is building a 10,000-square-foot welding lab. YCCC is spending \$6.5 million for this expansion:

¹² Sullivan, Shawn P. (2024, Mar. 1). Maine colleges, leaders unveil \$6.5M plan to train thousands for defense workforce. *Foster's Daily Democrat*. Retrieved 1 Mar., 2024: <https://www.fosters.com/story/news/local/york-star/2024/03/01/maine-defense-workforce-portsmouth-nabal-shipyard-pratt-whitney-bath-iron-works/72791917007/>.

\$3.5 million from MDIA, \$1.5 from YCCC, and \$1.5 from federal funds.¹³ YCCC expects to train as many as 1,500 workers per year.¹⁴

Collaborations

Collaborations appear to be improving in Maine as of Mar. 1, 2024, when the workforce alliance MDIA was announced. While details of MDIA are forthcoming, it includes at least the Maine Community College System, the University of Maine System, BIW, Pratt & Whitney, and The Roux Institute of Northeastern University. These recent collaborations appear to be durable and happening at a high level within participating organizations.

Even before MDIA, BIW has collaborated with SMCC by providing input on curriculum and course design and providing some physical space, technical services, and instructors. BIW similarly collaborates with MMA on curriculum and course design. Collaborations are at least in part paid for by grants.

Challenges—Geography, Disunified Colleges, Cost Sharing, DoD compliance

Located in Bath, Maine, BIW has limited options for partners in the Maine community college system. The Maine system is a bit fractured and partnering with community colleges has been challenging due in large part to communication issues, and the disjointed nature of the education system. However, with the introduction of the new MDIA, industry leaders are hopeful educators and industry leaders will collaborate more in the future to increase productivity in the state – particularly with regards to SMEs in the region.

Cost sharing between community colleges and manufacturers that partner on grants has not been as effective as industry leaders would like. Research suggests that partnerships for grants cover college costs but do not adequately compensate business partners. In the future, benefits from such programs should be made clearer to the industry partners who may find these partnerships cumbersome. However, MMA and SMCC do have some current programs that provide services to local manufacturers, indicating that such partnerships are providing benefits to industry stakeholders.

Two final issues appear to be possibly unique to workforce learning in the defense industry and among businesses that contract with the government: a need for secrecy and a need for compliance. These were highlighted in interviews for BIW, but are likely to be true for all three ALLELEs due to their center

¹³ Ibid.

¹⁴ Singer, Stephen. (2024, Mar. 1). Maine colleges, universities partner with defense industry to recruit and train thousands of workers. *Portland Press Herald*. Retrieved 1 Mar., 2024: <https://www.pressherald.com/2024/03/01/maine-colleges-universities-partner-with-defense-industry-to-recruit-and-train-thousands-of-workers/>.

on Defense-related manufacturing. Manufacturing employees of BIW learn skills operating what interviewees called “sensitive equipment.” Consequently, interviewees said BIW is limited in its partnerships; partner colleges appear not to be permitted to teach certain needed skills.

Moreover, interviewees told us that the DoD requires each defense contractor to maintain records certifying that employees are competent in particular skills, for example welding. These records appear not to travel from company to company with an employee, causing each new employer, if they are a defense contractor, to test the employee anew--and redundantly. In short, employers retest new employees to reduce liability. The non-transferability of employee records—specifically records that document skills in a valid and verifiable form—is a problem with credentialing which is common to training offered by employers. Employees learn skills, but they have no “proof” to show future employers.

Assessment of WLEs for Advanced Manufacturing in New England

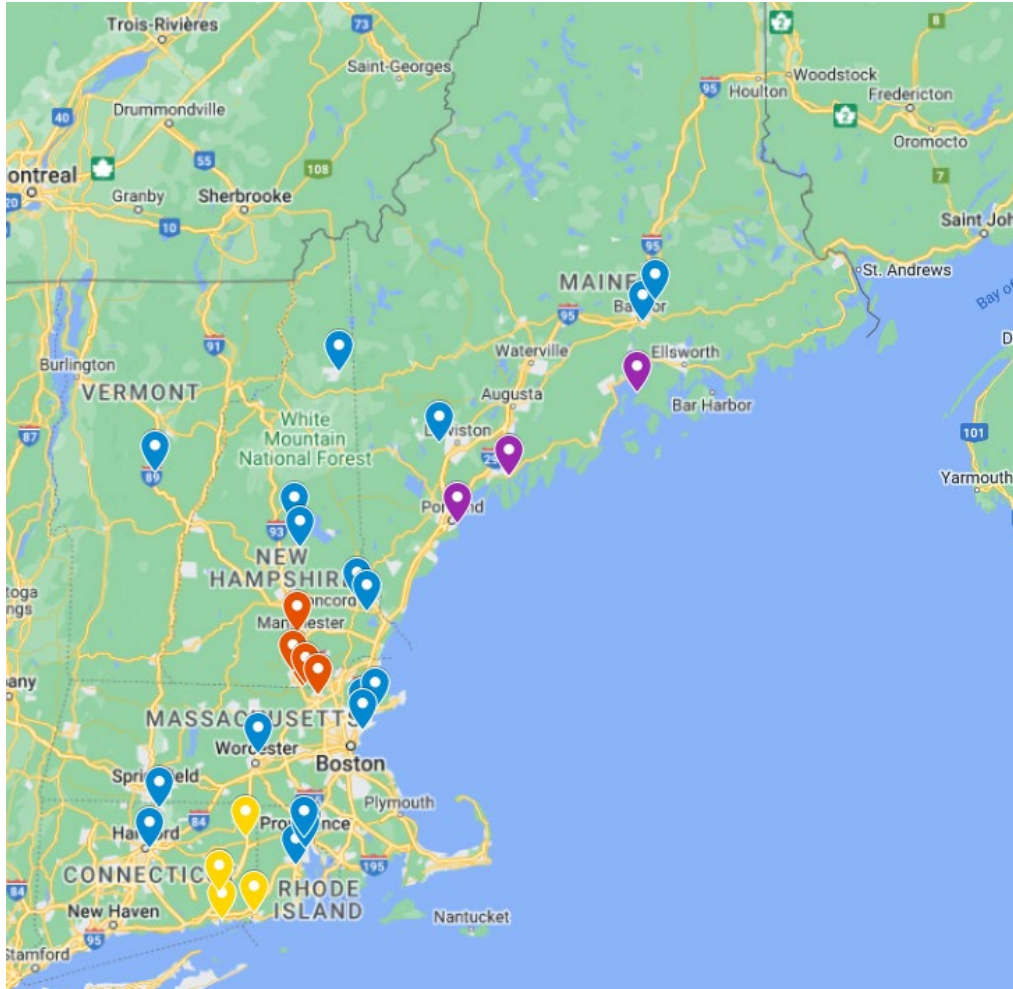


Figure 1. ALELLES and interviewed educational institutions and manufacturers. Pins in this map show the locations of organizations mentioned during interviews. Yellow pins represent organizations associated with the ALELLE of Electric Boat; red pins, BAE Systems; and purple pins, Bath Iron Works. These ALELLES have more members. Only members mentioned in interviews are pinned. (Made with Google Maps.)

Main Findings and Recommendations

Our research looked across the Northeast region with a WLE lens. We conducted 30 interviews to understand conditions in each of the six states of the region (see Appendix C). Building upon these expert interviews, plus past interviews and findings for MassBridge, our analysis identified the following findings and recommendations.

NERDIC has conceptualized the ecosystem approach at the level of states or the region as a whole. That approach, however, does not match our data. Strong WLEs exist in New England, but they are localized and operate largely independently from one another.

Currently, the region lacks a unified WLE for learning programs in advanced manufacturing. Instead, it is home to multiple local WLEs that function largely independently of one another. These WLEs tend to center on, and be led by, large employers, such as Electric Boat in Eastern Connecticut and BAE Systems in Southern New Hampshire. We call these WLEs Allied Large-Employer-Led Learning Ecosystems, or ALELLEs.

For the stakeholders that have plugged into them, ALELLEs appear to work well. Within them, it can be easier for employers to find the workers and programs they need. Schools, with advice from industry partners, can build programs focused on relevant skills. And learners can gain valued skills and connect with employers. While ALELLEs may each have some ongoing challenges, stakeholders in their orbit seem to be doing well.

Still, workforce learning across New England needs improvement. Our assessment shows that, at a regional level, New England needs enhanced—that is, sustained and effectual—collaboration on workforce learning. Our analysis has also uncovered other strengths and weaknesses within each criterion of the readiness framework.

Therefore, our first recommendation is clear, although it may be uncomfortable for some members of the NERDIC collaborative. Rather than trying to build statewide and regional ecosystems, the focus should be on bolstering a few existing local WLEs and then developing coordination mechanisms so that the region can learn from and collaborate across the local WLEs.

Beyond this recommendation, our findings suggest several other steps that stakeholders can take to improve the state of workforce learning in the region.

The biggest problem facing WLEs—one that was mentioned by every expert we interviewed—is low learner demand for advanced manufacturing programs. There are not enough students enrolling in programs to make learning programs sustainable and to provide a sufficiently large skilled workforce in manufacturing. And yet, this demand challenge is not related only to marketing or awareness. It is tied to challenges within, and among, all four dimensions of the WLE readiness framework.

Considering these factors as well as information from the assessment that follows, we recommend the following:

1. Devote resources and attention to increasing demand for learning programs in advanced manufacturing.
2. Expand existing ALELLEs to include additional stakeholders, both inside and outside of the current catchment area of the ALLELE.
3. Fund efforts to improve ALELLEs—for example, by assisting them with collaboration, developing educational standards, and marketing careers.
4. Create mechanisms to facilitate information and resource sharing among ALELLEs on statewide and regional levels.
5. In areas where ALLELEs do not yet exist, identify key employers, or other stakeholders, that can be the cornerstone of a WLE. Then provide support and advice to make progress.

Below we provide additional information related to each recommendation.

Learner Demand

All stakeholders agree that too few workers are seeking careers in manufacturing to meet industry needs. Low demand causes critical problems for WLEs across New England. Educational institutions cannot run sustainable programs when learner demand is inconsistent or low. When enrollment is low, instructional costs per student rise.

Some educational institutions report being unable to offer courses that manufacturers need because too few students enroll to cover instructional costs. Also due to low enrollment, some educational institutions have delayed repairing or purchasing advanced-manufacturing equipment necessary for instruction. As a result, if demand were to suddenly rise, educational institutions may not be able to meet demand immediately due to equipment shortages.

Interviewees mentioned a few common causes for low interest in manufacturing careers and learning programs:

- Uncompetitive pay in manufacturing
- Low awareness of “good” manufacturing careers
- Stigma on manufacturing work
- De-emphasis on vocational career paths in high schools

Interviewees also mentioned that demographic challenges have reduced the manufacturing workforce. Two key factors were aging populations and high costs of living across the region.

Another was competition from entry-level jobs offering better pay and benefits. Some respondents mentioned that jobs offered by Amazon offered higher pay and benefits than local entry-level manufacturing ones, and required less education. As wages for entry-level and “middle-Skill” occupations in healthcare and other industries continue to rise, the competition for entry level workers will increase.

To increase learner demand, we suggest the following actions:

1. Intensify marketing and outreach for both younger and older workforces, especially among populations experiencing underemployment.
2. Ensure manufacturing jobs are attractive and competitive—that is, they must offer high pay and career-advancement opportunities. Provide financial incentives to learners—such as low-cost tuition, free tuition, stipends, and earn-and-learn programs.
3. Provide potential learners—including both new entrants and incumbent workers—with career counseling to show how specific learning programs will enable them to make progress in specific career pathways.
4. Guarantee that learners who successfully complete manufacturing programs receive interviews with employers.
5. Give students access to academic and social support—like courses on academic basics, transportation assistance, and childcare—where needed.
6. Offer courses that are accessible to incumbent workers—like courses held at worksites, online courses, and night courses.
7. Aggregate demand when possible—rather than offering many courses that each have few students, offer few courses that each have many students.
8. Provide non-degree options for upskilling, so that learners can gain skills quickly, even if the courses do not eventually lead to a degree.

WLEs across New England are already taking some of these actions, but even the best WLEs have experienced insufficient learner demand. One interviewee suggested that manufacturing needs “a *Top Gun* moment,” that is, a cultural phenomenon that causes interest in manufacturing careers to skyrocket. Even if manufacturing cannot provide the same cinematic fuel as fighter jets, stakeholders in manufacturing may need to think about how they can change current cultural narratives about the industry, especially the narrative that manufacturing jobs are dirty, dangerous, and difficult. Examples such as the MassBridge advanced manufacturing awareness modules for high school students, or the MassTech career day, can help in these goals. However, more is needed, especially for adults who are already working.

But perhaps most importantly than advertising good careers in manufacturing, it will be essential to ensure that there are good careers. Manufacturers will need to be able to offer pay and career opportunities competitive with employment in other industries.

High-Quality Learning Programs

In manufacturing, learning programs are offered in multiple formats: college courses, co-ops, internships, apprenticeships, employer-offered training. Whatever format is used, high-quality learning programs must satisfy various stakeholders' needs, most notably those of learners.

Where stakeholders have collaborated across sectors in New England, learning programs appear to be strongest. In these cases, learning programs are aligned with needs across the WLE well enough that students are being hired at high rates.

There are at least four potential reasons for these strong outcomes:

- Employers and schools codesign curricula.
- Employers provide support for learning programs, such as equipment, space, and even instructors.
- Employers and schools work closely to get graduates hired.
- Stakeholders (including learners) have access to funding—such as loans, state grants, tuition reimbursement, and stipends.

In some cases, the collaborations were so close that schools shared students' projects—completed as course requirements—with employers so that hiring employers could observe students' performance and ability.

One learning program format that has succeeded is the short-term course, or course that lasts 12 weeks or less. Interviewees mentioned that this format is flexible and achieves what one interviewee called “quick hits”—helping colleges to enroll more students and get good job outcomes fast. Learners who complete such short-term programs sometimes earn college credit too, but respondents indicated that for-credit programs tend to be slower and more difficult to align with changing employer needs.

Despite successes, access to high-quality learning programs is inconsistent across the states. Most manufacturers said they were satisfied with graduates from community colleges. A few interviewees said colleges could better teach professional and human skills, like communication and time management. But there was also evidence that community colleges in some areas—especially rural areas beyond manufacturing centers—may struggle to address technical

components of training. Some schools find it difficult to hire or retain technically qualified faculty. Others have poor access to advanced equipment currently used in industry.

Aside from programs offered by educational institutions, manufacturers offer an array of experiential education programs, most commonly internships, apprenticeships, and pre-apprenticeships. Generally, manufacturers are pleased with the outcomes of such programs, but they can be burdensome to operate. Registered apprenticeships were singled out as especially onerous—requiring too much paperwork and time. Yet, our prior research has found ways that community colleges already can make registered apprenticeships work well for educators, employers, and learners.¹⁵

Another challenge arises from the lives that many learners are forced to lead. Many adult learners must support families on low-wage jobs while working to learn skills for better-paid jobs in manufacturing. They may lack transportation to campus, or childcare while there. They may also struggle with questions of self-efficacy or expected benefits from learning because of poor experiences in past educational environments.¹⁶

Across New England, schools provide varying degrees of support to their learners. All states currently help pay tuition or training costs, but some of those programs will expire once pandemic-related stimulus runs out. Community college tuition programs are usually available only to first-time students too, excluding a potentially large demographic of returning students.

In manufacturing specifically, some employers are starting to pay tuition or a stipend or both to any learner who persists in certain publicly advertised manufacturing programs. Such support programs are likely to encourage learners to enroll, persist, and complete.

Based on these assessments, we recommend that stakeholders help educational institutions to

¹⁵ Nelson, S., Bonvillian, W.B., and Westerman, G. (2022, June). *Community college's role in building apprenticeships*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/massbridge>.

¹⁶ Clochard and Westerman (2020) *Understanding the Incumbent Worker's Decision to Train: The Challenges Facing Less-Educated Workers*. MIT Work of the Future Task Force Working paper WP09-2020, [MIT Work of the Future](https://workofthefuture.mit.edu)
Killada, L.A. (2022, May). *Understanding the attitudes of incumbent manufacturing workers toward training opportunities*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/massbridge>.

1. Hire and train qualified faculty, or lend current employers to teach courses.
2. Create stronger school-to-work pipelines to help students find work opportunities.
3. Provide access to up-to-date advanced-manufacturing equipment.
4. Align curriculum and credentials with changing market needs.
5. Access shared instructional materials (e.g., lessons, courses, and hands-on activities) and best practices—for example, through an online clearinghouse or repository.
6. Build short-term programs responsive to changing industry needs.

Beyond these aids to specific educational institutions, NERDIC stakeholders may be able to adopt other creative approaches to the challenge.

One approach is to help employers to participate in apprenticeship programs. These programs provide valuable hands-on experience and wages for workers while helping employers fill near-term low-wage jobs and screen candidates for longer term higher-wage work. Community colleges across the country are actively choosing to play the role of registered apprentice intermediary so that employers can more easily participate with much less administrative burden than before. Outside of the realm of registered apprenticeships, stakeholders can develop creative approaches to provide experiential learning to students while allowing employers to identify high potential candidates.

Educators could also consider consolidating their curricula at a statewide or broader level. For example, rather than each Massachusetts community college struggling to fill a full slate of courses from its local population, it could share the students, and teaching burden, with other institutions. Consider, for example, a statewide manufacturing curriculum where each campus teaches a few courses virtually to all learners in the state, and then learners converge on local facilities to practice their hands-on skills. Together the campuses can teach a full curriculum to full classes of students, while each needs to hire only a fraction of the faculty that a full local curriculum would require.

Collaboration among stakeholders

Collaboration is common across New England, but effectiveness varies. Most commonly, individual employers (not associations of employers) collaborate with individual schools (not associations of schools). Larger employers appear more likely than smaller employers to collaborate with schools, since they can hire at a

scale that justifies investment in shaping educational programs. Yet, as Ohio does with OMA, it is possible to, in the words of Van Ton-Quinlivan, “connect the garden hoses to the fire hose.”¹⁷ In other words, to align and standardize the needs of multiple smaller employers so that they can consume a full classroom of students from a training course.

Collaborations in New England were strongest where these conditions are met:

1. Employers form associations to identify needs and communicate them regularly to schools.
2. Employers, colleges, and K-12 schools collaborate to align curricula.
3. Public officials or publicly funded organizations (such as the Office of Manufacturing in CT and the Vermont Manufacturing Extension Center) oversee and facilitate collaborations in an WLE.
4. Large employers lead collaborations and appoint an employee for liaison with other stakeholders.
5. Stakeholders meet frequently.
6. Stakeholders equitably share costs—for example, by loaning equipment, providing space for classes, co-submitting grant applications, or subsidizing tuition.

Financial Sustainability

WLEs in manufacturing will need to be made financially sustainable for New England manufacturing to thrive in the long term. Sustainability is intertwined with the criteria already considered. Not only do individual learning programs need to have sustainable funding, but funding and governance structures must be in place for collaborations and outreach programs to succeed.

Our interviews uncovered a few potential obstacles to sustainability:

- Inconsistent funding through grants
- Insufficient funds for purchasing equipment to be used by learners
- Low learner demand, which makes operating learning programs too costly per learner

The best solution to these problems may be to generate greater demand for advanced-manufacturing programs. Part of this demand will need to be created through marketing and outreach; the other part can be created by manufacturers creating jobs that individuals want to have. Manufacturers may need to do more to

¹⁷ Ton-Quinlivan, Van. (n.d.). Wicked challenges in the workforce: Van Ton-Quinlivan (CEO Future Health). Interview. Global Opportunity Forum, <https://gof.mit.edu/news-research/podcast/episode2/>.

- Incentivize incumbent employees to learn advanced-manufacturing skills
- Aggregate demand across employers—employers should send their incumbent employees to the same programs, to reduce training redundancies and make the training programs that exist more financially stable.
- Communicate as one voice with educational institutions--to reduce redundancies in effort and communication that result when individual manufacturers partner with individual schools.

Beyond these suggestions, we point readers toward our MassBridge research which recommended additional ways that learning programs can operate more efficiently. Among those recommendations are these:

- Curate instructional materials rather than create them--for example, by adopting premade instructional materials available through online repositories or portals.
- Use new instructional technologies, such as virtual reality, when they can substitute for more costly options.
- Share equipment among stakeholders--schools may share with schools, manufacturers, or manufacturing centers.

We found evidence that some learning programs are adopting such steps, but with our data, it is unclear how often such steps are being taken.

In the end, financial sustainability will require connecting across the four pillars of the WLE readiness framework. Better jobs will attract more students. Better programs will attract students and help them finish their learning experiences. Collaboration will create better programs that include real-world experiences for learners and opportunities for employers to meet students even before they finish their learning programs. And scale in all four pillars will make the programs more cost-effective to deliver, less costly for students, and provide more value to employers for each learner upskilled.

Connecting the Region's Local WLEs

Focusing on local WLEs will not be enough to meet the challenges of manufacturing across the region. Without collaboration across these WLEs, New England manufacturing could struggle to compete with other manufacturing hubs throughout the U.S. and the world.

Balkanized localization subjects the region to at least three types of risk:

1. **Monoculture:** Each WLE may become tethered to the fate of a small number of companies in a limited subset of the industry making each WLE more vulnerable to disruption.

2. Educational bias: Schools within them may favor teaching only the skills required by collaborator businesses, making the local area unable to adapt to changes or to welcome businesses in new subsectors.
3. Excluding SMEs: SMEs and innovative new businesses unlinked to the current WLEs may struggle to find a foothold in the local area.

For large manufacturers, current localized WLEs work fairly well. They consistently supply large employers with skilled employees. Still, even large employers report that they need to recruit workers outside of New England. However, the WLE approach tends to work less well for small to mid-sized enterprises (SMEs) than their larger collaborators.

Although large employers often collaborate with local educators, this is less common for smaller employers. Our interviews suggest SMEs are less likely to partner with schools to plan courses, design curricula, and build workforce pipelines. This may be because SMEs have fewer resources to spend on collaboration, or because they hire fewer employees and thus get less attention from educators. A few SMEs have been able to partner individually with schools, but SMEs appear to enjoy the greatest access to WLEs when they are able to join collaboratives or associations that focus on workforce development.

Recommendations for collaborating across WLEs—and creating new ones

Because large employers have already begun to build successful WLEs in their vicinity, NERDIC and New England manufacturers may wish to turn toward these large employers and their ecosystems; they may wish to build upon the successes that large employers have already secured. We recommend that NERDIC focus on existing WLEs rather than trying to create new local or super-local WLEs. However, WLEs can benefit from sharing practices and resources with other WLEs, on a voluntary basis.

We recommend that NERDIC start to play an active role in fostering collaboration across WLEs. This would not, for example, include a single integrated training program or supply chain. However, NERDIC could foster sharing of course materials or upskilling approaches across educational institutions, enrolling people from different localities in ongoing courses, or learners in one locality link to employment opportunities in others. NERDIC could potentially play a role as apprenticeship intermediary, or assist local community colleges in doing so. It could also find ways to help large employers develop links to smaller SMEs in other localities that meet production needs they cannot find locally.

In doing so, NERDIC should work not only with employers and educators, but with other key stakeholders in each local area. In Vermont, VMEC—the state's MEP—is

playing a strong role in creating a local WLE by fostering collaboration among smaller employers. Massachusetts workforce boards in NE region and central Mass also have a history of helping smaller employers to find resources and people they need to thrive.

MEPs may also be able to help manufacturers identify technologies most useful to them and to help them plan their workforce-learning needs accordingly.

Conclusion

The Northeast region is rich in manufacturing companies and employees, but this richness is not enough to thrive in the future advanced-manufacturing economy. Demographic changes, local costs, and a constantly changing competitive environment will require innovative new ways through which employers--collaborating with other stakeholders in the region--will meet the demands of the coming decade.

Employers will need to lead in finding solutions to workforce shortages and building WLEs. It is unlikely that the solution will come from the outside, from other stakeholders in community colleges or government. Still, other stakeholders must contribute.

Workforce development boards are well-positioned to help underemployed and unemployed workers identify and access learning and career opportunities. In some situations, they have also proven adept at forming multi-stakeholder collaboratives.

Community colleges seem best positioned to scale up education to meet industry-wide needs. Community colleges may be the best option for teaching general advanced-manufacturing skills—skills that are transferable across manufacturers, opposed to employer-specific skills needed in an individual employer's production line (such employer-specific skills are best taught by the employer themselves, and in such cases, it may help to provide funding assistance for training workers, as some states are already doing).

Our research suggests that the most viable approach is not to build a regional manufacturing ecosystem, but rather to build a network of local WLEs. Starting with WLEs that already exist in CT, NH, Maine and, to some extent, Vermont, NERDIC can help those ecosystems to improve their readiness on all four dimensions of the WLE readiness framework that we introduced in this study. NERDIC can also foster learning and sharing across the local WLEs. This can be good in itself by helping each WLE to improve in collaboration with others. It can also provide materials, knowledge, and opportunities to engage companies and

educational institutions outside of current WLEs into thriving WLEs elsewhere in the region.

Our report provides a number of detailed recommendations based on the WLE readiness framework. These provide insights on learner demand, high quality programs, collaboration, and financial sustainability for workforce learning programs. The appendices provide state-level information based on the interviews we were able to conduct in each state, as well as potentially useful background information on the sector and our past research.

These recommendations will not be easy to implement. Nor are they the full solution. However, they will go a long way to help the six states in the region to foster healthy manufacturing economies, and the healthy communities that arise when employees have the good jobs, with good wages, that advanced manufacturing can provide.

Appendices

Appendix A: Assessments of New England state-level workforce-learning ecosystems

Our 30 interviews covered six states and the region as a whole. These interviews provided some detail about the context in each state. However, they do not provide sufficient breadth of information to allow our team to make clear recommendations at the state level. We have included the vignettes below to describe the situation in each state but focused our findings and recommendations at the regional level.

Connecticut

Demand

- CT manufacturers are experiencing workforce shortages.
- Low pay coupled with a high cost of living may be depressing interest in manufacturing.
- The state has strong outreach and marketing for K-12 and adult learners.
- A reputation for good jobs at a large manufacturer may be driving interest.
- Employers are collaborating to aggregate demand for learning programs. Some community colleges need larger student cohorts to justify costs.

Learning programs

- Well-coordinated learning programs are recognized by state manufacturers.
- Advanced-manufacturing programs have established pipelines with employers.
- Experiential learning is common.

Collaboration

- A partnership of over 50 manufacturers aggregates demand for learning programs, helps align curriculum at community colleges, and sets up pipelines.
- Collaborations are robust across stakeholder types.
- Individual manufacturers have independent collaborations with individual colleges.

Sustainable Funding

- The state has made sustainable investments in growing manufacturing.
- General Dynamics Electric Boat has provided sustained leadership on collaborations across the ecosystem.

Manufacturers in CT face the familiar challenge of attracting employees and learners for advanced manufacturing. However, compared to other New England states, CT has strong and durable WLEs. As described above, one notable WLE is centered on General Dynamics Electric Boat (EB). Most notably, EB along with about 50 smaller manufacturers—members of the Eastern Advanced Manufacturing Alliance Regional Sector Partnership (EAMA RSP)—have collaborated with community colleges and workforce boards on a project called the Manufacturing Pipeline Initiative (MPI). Administered by the Eastern Connecticut Workforce Investment Board (EWIB), MPI provides learning opportunities for both K-12 students and adults at no cost. MPI also helps graduates connect with employers and secure work. Other stakeholders in the state are engaged in similarly productive outreach, collaboration, education, and training.

Learner demand

According to our interviews, demand for learning in advanced manufacturing in CT is being depressed by familiar factors. Interviewees mentioned housing, transportation, childcare, stigma on manufacturing jobs, and low awareness among younger people about career paths in manufacturing. However, across the state, stakeholders have taken steps to attract workers and learners to manufacturing.

Youth outreach appears to be common. All stakeholders mentioned efforts to make K-12 students more aware of manufacturing careers. For example, Ready CT has coordinated with CT's Chief Manufacturing Officer, Paul Lavoie, to offer the Manufacturing Careers Roadshow.¹⁸ The roadshow travels around the state to demonstrate manufacturing jobs. There are efforts to destigmatize manufacturing jobs too.

Demand for learning programs in CT could also be driven by a reputation that manufacturing offers good jobs. Several interviewees mentioned that EB has been able to attract employees for entry level positions because it offers careers, or a stepped approach to moving entry-level workers into higher-skilled, higher-paying jobs.

However, low pay across the sector may stifle interest in manufacturing careers and learning programs, though pay may be rising. Workforce boards have been pushing manufacturers to offer higher wages. But small and medium-sized manufacturers often cannot compete with larger employers, inside and outside

¹⁸ Ready CT. (n.d.). Manufacturing Careers Roadshow. Retrieved December 13, 2023, <https://readyct.org/manufacturing-careers-roadshow/>.

the sector. Employers need to think of hiring skilled workers at a higher pay scale as an investment.

High-quality learning programs

Manufacturing programs in the state teach needed skills, reach diverse learners, and use effective instructional methods.

Stakeholders have designed learning programs specifically for K-12 students to teach job-relevant skills. In addition to operating MPI for adult learners, EWIB runs the Youth MPI (YMPI). Like its counterpart for adults, YMPI is a collaboration among EWIB, EAMA RSP, and two community colleges—Quinebaug Valley Community College (QVCC) and Three Rivers Community College.

Many programs for K-12 students enable them to earn credit for community college while learning skills valued by employers. Such programs expose younger people to manufacturing careers and offer an onramp to higher education. An interviewee said that a state program—called Pledge to Advance CT (PACT)—pays for high-school students to earn up to 72 credits at community colleges while they are still in high school. Also, as part of MPI, high schools and community colleges are sharing curricula, with the result that high-school students who complete manufacturing courses can earn college credit too.

Manufacturers and learning programs also are taking steps to be inclusive of diverse learners. MPI is “designed for unemployed and under-employed individuals,” according to the program’s website.¹⁹ It also appears to accept learners with far-ranging experience and preparation. Efforts are also underway to attract learners from underrepresented groups, including women workers, in the field. EB has created outreach programs: Boat for Women and Boat for Everyone.

Learning programs in the state appear to be teaching skills industry needs. MPI again stands out for offering courses recognized by, and designed with, manufacturers across the state. Similarly, Asnuntuck Community College (ACC) partners with multiple manufacturers to create and update courses and programs as needed.

There is evidence that experiential education is widespread. Companies are offering apprenticeships and internships. Multiple interviewees said that the state and community colleges are helping companies work on standards and

¹⁹ Eastern CT manufacturing pipeline. (n.d.). Eastern Connecticut Workforce Investment Board. Retrieved December 13, 2023, <https://www.ewib.org/pipeline>.

accreditation for apprenticeships. QVCC and Three Rivers already have pre-apprenticeship approval built into their manufacturing programs.

Collaborations

Perhaps one of the best signs of the WLE's health is its long-standing collaborations. Collaborations on MPI, which include all types of stakeholders and have been led by EB, have been running for about seven years, since 2016, and interviewees continue to speak glowingly about it.

The state too has invested in coordinating the WLE, most notably by creating the Office of Manufacturing and, in 2019, the first Chief Manufacturing Officer in the U.S., a position devoted to growing and advocating for manufacturing in the state. Three out of five interviewees mentioned that Lavoie, the current Chief Manufacturing Officer, has been effective in coordinating the WLE.

Sustainability

Such long-term collaborations and investments suggest learning WLEs will be sustainable for the near future. With widespread youth outreach programs for manufacturing, manufacturers may be reaping rewards for years to come.

Stakeholders, however, will need to ensure that learning programs have steady streams of learners and large enough cohorts to cover instructional costs. One community college administrator noted that they have "state-of-the-art equipment" and can run short-term training programs in demand among manufacturers, but the pipeline for students is small and, like most areas, they struggle to fill seats.

Maine

Demand

- Maine is offering free community college for recent high-school graduates. (This program is temporary.)
- There seems to be low interest in manufacturing careers among younger workforces.
- The workforce is aging.
- Transportation difficulties may lower access to learning opportunities.
- Maine's workforce is at risk of being siphoned off by southern New England states.

Learning programs

- Experiential learning is common.
- Use of apprenticeships and pre-apprenticeships appears to be growing but may be low among small employers.
- Online courses have recently become more common.
- Some community college programs are aligned with large manufacturers' needs.
- Training for incumbent employees is mostly provided by employers independently from community colleges.

Collaboration

- At least one large manufacturer collaborates with community colleges.
- Manufacturing executives often advise colleges and universities to align programs with emerging needs.
- Collaboration is made difficult by geographic distance, especially in northern Maine and across northern and southern Maine.
- We found no evidence that manufacturers are collaborating with one another on workforce learning.

Sustainable Funding

- Maine is offering free community college for learners who graduate high school between 2020 and 2025, but this program appears to be a one-time investment.
- Maine Community College System (MCCS) offers help to employers to create registered apprenticeships.
- More funding may be needed for training programs and for marketing manufacturing careers.
- There is evidence that at least large manufacturers share equipment with colleges.

Demand for learning programs

The biggest challenge facing Maine is increasing demand for learning programs in manufacturing. Stakeholders in the state are providing learners with incentives, but they have yet to entice sufficient numbers of learners.

All interviewees from Maine said that workforce attraction is the biggest problem faced by manufacturers in the state. Interviewees identified four causes for low interest in manufacturing careers:

1. An aging workforce
2. Changing work preferences among younger people
3. Loss of workforce to southern New England states where interviewees said pay was better.
4. Difficulty finding or affording transportation to relevant learning programs.

To solve these problems, two interviewees proposed that more funding be devoted to marketing manufacturing careers. The industry needs marketing, the interviewees proposed, that would make manufacturing a less stigmatized job. One of these interviewees also proposed marketing the advantages of working in Maine in general—such as attracting a workforce by leaning into Maine's reputation for outdoor recreation—to draw migrants to the state and retain the workforce it has. Moreover, one interviewee expressed his belief that interest in manufacturing careers is low because high schools in Maine guide students toward college pathways and neglect other vocational pathways. He suggested greater funding for vocational school programs. This same interviewee mentioned that representatives from his company visit elementary schools and demonstrate welding with Cheese Whiz to raise awareness of manufacturing careers among K-12 students.

Despite issues with workforce attraction, training for incumbent employees appears to be widely available. Most of it is offered by employers. One education stakeholder estimated that community colleges provide 20 percent of the training that incumbent workers receive. The other 80 percent is provided by employers or through third party trainers. They also mentioned that, through a program called the Maine Workforce Development Compact, the state offers matching funds to employers for training incumbent employees. The Compact has about 1,000 member organizations—both in- and outside manufacturing—and offers up to \$1,200 in matching funds to employers for training an employee for one year. However, the compact appears to be funded only through 2025.²⁰

Support for younger learners at Maine's community colleges is currently strong too. The state has committed to offering free community college to all students who graduate from Maine high schools between 2020 and 2025. Such financial support could be expected to raise demand for all programs, including in manufacturing.

Quality of learning programs

Our interviews yielded little direct information about instructional methods, credentials, and content taught in learning programs for manufacturing. Still, in a positive development, we learned that experiential learning is common and may be increasing.

According to interviewees, apprenticeships and pre-apprenticeships are rising in the state. For instance, one interviewee claimed that twelve years ago, there

²⁰ Maine's Community Colleges. (n.d.) Workforce Training. Retrieved December 13, 2023, <https://www.mccs.me.edu/workforce-training/maine-workforce-development-compact/>.

was only one apprenticeship program in the state—in the funeral industry. Now Maine currently has 290 registered programs in various industries. Pre-apprenticeships are on the rise as well: 75 percent of the new programs are in manufacturing.

However, so far, apprenticeships may be difficult for SMEs to access. One leader from a small manufacturer—which employs roughly 30 people and plans to add 50 percent more soon—said that it had not used any apprenticeships to date. They did note that the company has plenty of internship work available and that they've been open to hiring interns. In contrast, General Dynamics Bath and Iron Works (BIW) has offered apprenticeships in a range of trades since 1950.²¹

Collaboration

Stakeholders within WLEs are collaborating, but from our interviewees, it is ambiguous how effective these collaborations are.

The strongest collaborations we observed centered around General Dynamics Bath and Iron Works (BIW). Two interviewees said that BIW partners with Southern Maine Community College and Maine Maritime Academy on manufacturing programs. They also mentioned that BIW collaborates with colleges by loaning equipment and developing engineering, leadership, pre-hiring, and pre-apprenticeship programs.

Collaborations may be weaker and less sustainable in other parts of the WLE. One industry leader said that they participate on an external advisory board for the University of Maine and that they speak directly with the school once a year to let them know what new things are coming down the pipeline. News from the University of Maine suggests that the partnership with local industries has generated a strong workforce pipeline.²² However, interviews suggest manufacturers have experienced difficulties in collaborating with community colleges on technical programs. In one case, a manufacturer partnered with local community colleges on a certificate program, but the partnership folded after the college could not find qualified teachers.

MCCS collaborates in diverse ways with stakeholders across the WLE, though the quality of these collaborations was unclear. MCCS now operates what's called the Maine Workforce Development Compact to provide employers with matching funds for training workers (see the above discussion under “Demand for learning programs” in Maine). MCCS also offers other opportunities for

²¹ BIW Apprentice School. (n.d.). General Dynamics Bath Iron Works. Retrieved December 13, 2023. <https://gdbiw.com/careers/apprenticeship-programs/>.

²² UMaine engineers are growing Maine's economy. (2017, August 14). The University of Maine. <https://mcec.umaine.edu/2017/08/14/compotech-inc-knows-get-engineers/>.

businesses to collaborate on training incumbent workers and running apprenticeships.²³

Financial Sustainability

In large part as a response to pandemic-related upheavals, Maine has increased funding for education and job training. Funds are available for college tuition, incumbent worker training, and assistance with setting up apprenticeships. However, much of this funding appears to be set to expire after 2025.

We found evidence of only one program for equipment sharing—a cost-saving measure—between BIW and local colleges. But equipment sharing may become more common. MCCS is looking into creating mobile learning labs, to make equipment available to learners across the state, especially in rural areas.

Multiple interviewees told us that geography poses an intractable problem: many learners, especially in Northern Maine, cannot access learning programs simply because of distance. As a result, employers in many regions may continue to struggle to find and to train employees in new skills in advanced manufacturing.

²³ Workforce training. (n.d.). Maine's Community Colleges. Retrieved December 13, 2023, <https://gdbiw.com/careers/apprenticeship-programs/>.

Massachusetts

Demand

- Learner demand is too low to meet employer needs and sustain learning programs.
- Demand is being lowered by systemic factors common across New England, such as stigma on manufacturing jobs and changing educational norms.
- Stakeholders are calling for greater marketing and outreach to attract learners to manufacturing programs and careers.

Learning programs

- Learning programs across the state have been designed with employer input.
- Employers are hiring advanced-manufacturing program graduates at high rates.
- Program quality may be limited by teacher shortages and other resource shortages, such as insufficient access to equipment and space.

Collaboration

- Stakeholders collaborate regularly to update curricula and coordinate hiring and experiential education.
- Employers need to collaborate more to ensure colleges have steady streams of new students and incumbent workers.
- Stakeholders should form, or participate in, associations focused on advanced-manufacturing learning programs to align ecosystems more efficiently.

Sustainable Funding

- Low learner demand threatens the sustainability of ecosystems in the state.
- Stakeholders will need to increase enrollment in learning programs by attracting new entrants, encouraging incumbent workers to enroll, and aggregating learners to increase cohort sizes and reduce instructional costs.

Massachusetts is home to 15 community colleges, strong public schools, and internationally renowned universities. It arguably has the most highly educated population in the United States. Still, the state struggles with learner demand for advanced-manufacturing programs. Right now, not enough learners are enrolling in advanced manufacturing to make WLEs in the state sustainable. In general, advanced-manufacturing programs in the state appear to be successfully teaching needed skills to learners, but they are not graduating them at the rate needed to fill jobs in industry.

Like other states, Massachusetts has programs in place but not enough students interested in these programs. One possible solution will be greater collaboration and intensified campaigns to create interest in advanced-manufacturing careers. Current collaborations tend to consist of employers participating on advisory boards for colleges. While these collaborations appear to help, they may also be inefficient and may miss opportunities for more coordinated actions across WLEs.

Learner Demand

Like other states, Massachusetts appears to have insufficient learner demand, as familiar systemic factors lower interest in manufacturing. Stakeholders are working to increase interest by marketing careers in manufacturing. Still, interviewees believe marketing and outreach will need to intensify and expand. Currently, stakeholders in the state are trying to lift demand for learning programs by offering learners funding to study advanced manufacturing. The state also recently approved free tuition for community colleges for eligible learners.

Demand is being suppressed by familiar factors: a stigma on manufacturing jobs, a push for high-school students to attend four-year colleges, sometimes poor access to transportation, and a high cost of living. Suppressors of demand vary by location. In Western Massachusetts, potential learners may be leaving for what an interviewee called “higher opportunity areas.” Elsewhere, on the North Shore, one employer mentioned talent pools need to be rebuilt because the number of high-school students on vocational tracks has dried up.

Stakeholders are trying to build learner demand with marketing and outreach. Some employers frequently visit schools to promote manufacturing careers. One midsize employer claimed to visit schools weekly. At least one organization annually showcases manufacturing jobs at an event for manufacturing month. How widespread and how coordinated such efforts are is unclear.

Stakeholders are also trying to attract learners among incumbent manufacturing employees, people experiencing underemployment, and other populations of interest. One interviewee with knowledge of community colleges across Massachusetts said there was a big push and funding available for education and training to get incumbent workers reskilled for the new jobs of the future. They also mentioned they are thinking a lot about non-traditional workers and programs for finding jobs for veterans. It is unclear how successful these outreach, marketing, and incentive programs have been.

Interviewees proposed that marketing should intensify and show manufacturing jobs as attractive. According to interviewees, marketing should make younger people aware that manufacturing offers good long-term careers. Interviewees also said marketing should remove stigma by showing that manufacturing is high tech and clean.

Community colleges appear to have low enrollment that makes it difficult to run manufacturing programs. One solution may be for manufacturers to send more incumbent employees to colleges to reskill and upskill. One college administrator said that employers--satisfied with past graduates--now need to fill the college

pipeline with incumbent workers. Without such feeders, college programs may struggle to remain sustainable.

Interviewees also suggested offering greater support and incentives to learn, especially for adult learners who need to work. One interviewee suggested that learners should earn a stipend while they study. Another suggested hybrid arrangements, in which an employee is paid their hourly wage while they learn. For adult learners, spending 20 hours per week on courses can be too much of a burden. Adding a learn and earn element to training may help students who are struggling with the idea of leaving a current position or starting over in hopes of finding a new position with more upward mobility. However, another interviewee pointed out that, for employers, such an investment may seem risky. An employer might attract learners by paying them to learn, but may eventually lose those employees to larger competitors. Poaching has been a problem in the industry for years.

Currently, Massachusetts is raising learner demand by offering free and low-cost manufacturing programs. The Northeast Advanced Manufacturing Consortium (NAMC) offers no-cost training for eligible learners through AMTEP (The Advanced Manufacturing Training and Expansion Program). The state also recently launched MassReconnect, a program that pays community college tuition for adults who are at least 25 years old and do not have a college degree.

High-quality programs

Graduates of advanced-manufacturing programs appear to be hired at high rates, suggesting that programs provide needed skills and valued credentials, but high hiring rates could also simply suggest that the need for manufacturing workers is deep. In either case, even as interviewees expressed a need for more graduates, they seemed pleased in general with the quality of learning programs. Many programs have been built through collaborations between educational institutions and manufacturers, with the result that curricula are designed with employers in mind and with current industry intelligence. Still, some interviewees said that learning programs may need to focus more on teaching human and professional skills. In some cases, learning programs may also be impaired by shortages of qualified faculty.

One notable curriculum has been designed by NAMC—a consortium which includes participants from education, industry, and state workforce boards. How widely the NAMC curriculum has been adopted is unclear, but NAMC lists 23

“educational partners.”²⁴ The NAMC curriculum seems to have enjoyed success. An interviewee from a technical high school said that students who graduate from the NAMC curriculum receive job offers at a rate of 90 percent.

Though stakeholders collaborate on curriculum, employers' needs are not always met. One large employer said that they train in-house because they have unspecified skills not provided by educational institutions. Multiple interviewees said program graduates still need to learn human and professional skills. Interviewees named skills like communication, critical thinking, responding to criticism, and arriving at a worksite when scheduled.

A teacher shortage may be lowering program quality. Multiple interviewees who work in education said too few faculty can maintain and teach with new equipment. One interviewee said qualified faculty have left midcourse to pursue more attractive work elsewhere.

Whether schools teach academic basics successfully was unclear, but one interviewee from a community college said, often, too few students need basic courses—such as in math and physics—to justify offering them. Most students are able to test out of the basic courses.

Apprenticeships appear to be underused. When prompted to talk about apprenticeships, nearly all interviewees said that they have been unable to find success with them due to red tape and strict regulations.

Interviewees proposed at least two changes to improve the quality of learning programs. One proposal was to imitate how healthcare—where demand for a skilled workforce is also urgently high—has “streamlined credentials.” Another proposal was that learning programs should be as short as possible so that learners can get to work quickly. Both proposals—to streamline credentials and accelerate learning—indicate an incompletely satisfied need for learning-program models that rapidly and dependably deliver essential skills and make those skills visible through industry recognized credentials.

Collaboration

In general, stakeholders are collaborating well in local pockets. But most stakeholders collaborate individually with other stakeholders rather than as associations. Such individualized collaborations may be inefficient and unsustainable. Collaborations may need to be more communal—for example,

²⁴ Northeast Advanced Manufacturing Consortium. (n.d.). Retrieved December 13, 2023, <https://namcnetwork.com/>.

through consortiums or industry associations—and more inclusive of a greater number of manufacturers.

Most commonly, stakeholders collaborate through advisory committees for schools and colleges. In general, this collaboration format appeared to satisfy interviewees. However, interviewees also said that these committees sometimes meet as infrequently as once per year, casting doubt on their effectiveness for aligning the WLE.

This form of collaboration may also cause redundancy as employers participate on multiple committees. One midsize employer said that, in an attempt to build workforce pipelines, they participate on the advisory committees of four schools and colleges. Additionally, this same employer said they work with state agencies and a local career center on creative ways to get people excited about manufacturing careers.

In this committee-heavy arrangement, small manufacturers may be the most likely to be excluded. There are two reasons for this: (1) small manufacturers may tend to collaborate intermittently, seeking partners only when they urgently need training programs; and (2) small manufacturers, when they go it alone, cannot provide enough learner demand to motivate an educational partner to run courses they need. The challenge is that there are many small employers, and when they have a hiring need, it's usually for just a few employees.

The state facilitates other kinds of collaborations too. Massachusetts is home to NAMC (discussed above), which was established in 2012 to help education and industry communicate. It mostly operates in eastern Massachusetts and includes more than 200 manufacturers, 5 community colleges, and 12 technical high schools. One interviewee said that NAMC recently reviewed and revised their curriculum and, in general, update the curriculum frequently. According to an undated page, NAMC has graduated 750 students in 11 years of operation.²⁵

A few interviewees critically remarked that the state's 15 community colleges operate independently and differently, making it difficult for employers to keep up with each school and their various programs.

Massachusetts currently has positions dedicated to improving collaborations across community colleges and employers. Such efforts may warrant more resources.

²⁵ About. (n.d.). Northeast Advanced Manufacturing Consortium. Retrieved December 13, 2023, <https://namcnetwork.com/>.

According to an interviewee from MassHire, the state has used funds from the American Rescue Plan Act to create “Market Maker” roles—for multiple industries including manufacturing—as part of a program called Future Skills, which aims to provide work-relevant learning.²⁶ The Market Maker role connects community colleges and industry partners. Interviewees said this program may be hindered by insufficient funding, which currently is paying for one person to cover more than half the state.

Similarly, the Massachusetts Association of Community Colleges (MACC) also has a Director of Workforce Development. This position serves as what an interviewee called a “single point of contact” for the state’s community colleges. “Anything with a statewide reach needs to be understood and handled at a central point,” said the interviewee. Among the Director’s responsibilities is determining what stakeholders “should be included in each conversation when there are statewide issues.”

Despite the prevalence of collaborations, interviewees expressed a desire for improvement and offered proposals.

One interviewee implied that manufacturers do not see community colleges as equal partners. Another interviewee from a midsize manufacturer expressed a need for improvement in interoffice communications among the state’s workforce boards, which are a part of MassHire. MassHire currently consists of 16 local boards and 29 career centers.²⁷

Noting that schools often lack up-to-date equipment, one interviewee proposed a consortium approach, in which colleges, vocational schools, and manufacturers share equipment.

Finally, another interviewee proposed that the state create a “Skill Net.” Such a Skill Net would require manufacturers—including competitors—to meet regularly to collaborate on, and fund, a coordinated strategy on education. The interviewee proposed that the Skill Net be funded by matching state funds equal to what employers provide. The Skill Net, the interviewee explained, would empower employers to “pick content and curriculum.”

²⁶ Future Skills. (n.d.). Commonwealth of Massachusetts. Retrieved December 13, 2023. <https://www.mass.gov/futureskills>.

²⁷ MassHire State Workforce Board. (n.d.). Commonwealth of Massachusetts. Retrieved December 13, 2023. <https://www.mass.gov/masshire-state-workforce-board>

Financial Sustainability

Multiple interviewees made remarks suggesting that community colleges lack sufficient funding. Colleges also appear to struggle to enroll enough students to ensure long term financial sustainability.

One manufacturer said they struggled to collaborate with a local community college due to poor funding. To provide learning programs with more sustainable funding, interviewees suggested that cohort sizes need to grow. Running classes with too few students is unprofitable for schools. Interviewees from schools said they want employers to send incumbent employees to them, to continue feeding them with students.

Relatedly, due to low funds, colleges may be struggling to provide learners with current equipment. One interviewee observed that, even when colleges in the state have enough money to buy equipment, they may not have the space to house it or the funds to repair it.

As noted above, learning programs have struggled to find qualified faculty for advanced manufacturing—a threat to long-term sustainability for the WLE. Additionally, pointing out a problem related to instructional staffing, one interviewee said that many faculty are experiencing poor mental health. Consequently, some colleges, unable to find replacement instructors, have had to cancel courses.

Aside from increasing cohort sizes, interviewees proposed using instructional technologies—namely online education and virtual reality—to reduce instructional costs, especially when cohorts are small.

New Hampshire

Demand

- Learner demand for learning programs is too low to meet industry needs.
- High cost of living may put employment and learning programs out of reach for many students.
- Workforce is aging, and younger populations may be leaving the state.
- Public higher education in New Hampshire is underfunded, raising costs for students.
- On-the-job learning programs may become more common as the state gives employers matching funds for training.

Learning programs

- The quality of learning programs varies across the state, with higher quality programs concentrated in southern coastal regions.
- Apprenticeships are underused.

Collaboration

- Collaboration on manufacturing workforce development appears to be poor.
- There is no centralized association for collaborations.
- Individual businesses have struggled to work with public colleges on manufacturing programs.

Sustainable Funding

- The sustainability, efficiency, and equity appear to be poor.
- Public K-12 and higher education are underfunded.
- Due to low collaboration, no mechanism exists to efficiently communicate employers needs for learning programs.
- Relevant learning programs may be largely unavailable outside of southern coastal regions.
- The state does, however, currently have good cash-matching programs for training employees.

Like other states in New England, New Hampshire faces challenges attracting a sufficient workforce—of any skill level—to manufacturing. Part of the reason for this is systematic. New Hampshire has tended to have low unemployment, especially since its recovery from the Great Recession, and its population is also among the oldest in the U.S.

In 2022, the average unemployment rate in N.H. was 2.5 percent, and from Feb. 2020 to February 2023, the total number of residents who were working or looking for work decreased from 777,800 to 770,000, a decrease of about 7,800.²⁸ The New Hampshire Fiscal Policy Institute (NHFPI) reports that this decrease occurred despite an overall increase of 17,700 in the state's population between Apr. 2020 and July 2022.

²⁸ Sletten, P. (2023, March 23). A snapshot of New Hampshire's workforce and the impacts of the COVID-19 pandemic after three years. New Hampshire Fiscal Policy Institute. <https://nhfpi.org/blog/a-snapshot-of-new-hampshires-workforce-and-the-impacts-of-the-covid-19-pandemic-after-three-years/>.

According to the Population Reference Bureau, 19.3 percent of the N.H. population was 65 or older in 2020.²⁹ Similarly, NHFPI reports that the age groups with the largest populations in the state are between 50 and 69, suggesting that the state is experiencing, or will soon experience, mass retirements. Moreover, the New Hampshire Employment Security Office projects that 1,829 manufacturing jobs—not all of which require advanced-manufacturing skills—will be created in New Hampshire between 2020 and 2030.³⁰ This increase is projected even as manufacturing workers retire at high rates.

Workforce shortages were felt by our interviewees. One respondent told us that manufacturing students are in such great demand that they usually have multiple job offers before they complete a degree program, resulting in them stopping out before the program ends. Manufacturing stakeholders in New Hampshire appear to be facing headwinds, as the WLE attracts too few people to manufacturing careers and learning programs.

Learner demand

Our interviews suggest that demand for advanced-manufacturing programs is low in N.H. There appear to be two main reasons—the first is simpler, the second more complex: (1) an aging and retiring workforce and (2) poor workforce attraction in manufacturing. While N.H. may need to do more to sustain its working-age population, stakeholders in the manufacturing WLE will still need to make manufacturing jobs more attractive and may benefit from taking measures to increase participation in the labor market.

As in other states, interviewees mentioned that, culturally speaking, manufacturing jobs have become devalued. Interviewees said that there's a stigma on manufacturing and said, now, the norm is for all high-school students to be guided toward four-year degrees, to the detriment of other vocational pathways. As a solution, interviewees proposed that high schools in N.H. needed to show students that manufacturing offers good careers, many of which do not require a four-year degree. Interviewees called for better youth outreach in the state too and said that awareness programs need to be delivered to students as early as middle school.

Interviewees also said that manufacturers need to ensure they do, in fact, offer good jobs and careers. One stakeholder with the N.H. Department of Business

²⁹ Kilduff, L. (2021, December 22). Which U.S. states have the oldest populations? Population Reference Bureau. <https://www.prb.org/resources/which-us-states-are-the-oldest/>.

³⁰ New Hampshire Employment Security. (2022, January). New Hampshire employment projections by industry and occupation. <https://www.nhes.nh.gov/elmi/products/documents/2020-2030-longterm-projections.pdf>.

and Economic Affairs (BEA), suggested that the best recruitment is current employees, and if they are unhappy with work, they will not invite people to join them. The interviewee said responsibility lies with management teams to be better to employees.

One reason that manufacturing careers may now seem unattractive in N.H. could be that they may not be offering competitive wages, or wages high enough to ensure a satisfactory standard of living. However, without precise data on wages in advanced manufacturing, it's difficult to say whether they are competitive. According to the Bureau of Labor Statistics (BLS), as of May 2022, the median hourly wage in production occupations in N.H. was \$21.47, while the mean hourly wage in those occupations was \$23.14. Still, it's unclear whether these median and mean wages are representative of wages in advanced manufacturing. These wages are calculated for occupations as diverse as meat, poultry, and fish cutters and trimmers (who have a median hourly wage of \$14.62) and computer numerically controlled tool programmers (median wage of \$30.64).

Regardless of wages, interviewees told us that living costs, especially housing and childcare, make it difficult to attract workers to N.H. manufacturing. N.H. manufacturers struggle to compete for workers as housing costs drive away employees. Some interviewees claimed employees can move to areas where housing costs less but where pay is just as high as in N.H. While it's unclear whether workers are in fact doing that—moving to where housing is more affordable—evidence does suggest that manufacturers may need to increase pay and offer other support to attract a sufficiently large workforce.

Our interviewees' claims about childcare and housing costs are supported by economic data. NHFPI reports that housing costs have risen rapidly in the last six years: the median cost for a single-family home increased from just above \$250,000 in Dec. 2017 to just below 450,000 in Mar. 2023.³¹ Furthermore, between 2011 and 2022, median monthly rental and utility costs have increased nearly 500 dollars and vacancy rates have dropped nearly to zero. NHFPI also reports that, in a recent survey, 3.7 percent of non-working adults—or 15,000 workers across the state—said that they were prevented from working because they were caring for children.

An additional problem in N.H. may be the high cost of higher education due to underinvestment by the state. These costs may be partially responsible for driving

³¹ Sletten, P. (2023, June 15). Labor force trends in New Hampshire. New Hampshire Fiscal Policy Institute. <https://nhfpi.org/assets/2023/06/NHFPI-Labor-Force-Trends-in-New-Hampshire-6.15.23.pdf>.

students to seek education outside N.H. NHFPI offers this stark assessment of the state's public higher education system:

New Hampshire provided the smallest amount of state and local funding, both relative to state population and to personal income, for public higher education of any state in the nation in fiscal year 2022. Both prior to and during the pandemic, New Hampshire increased investments into public higher education, but still lagged behind every other state.³²

NHFPI also notes that, among all states in the U.S., New Hampshire has the highest percentage of high-school graduates leaving the state to attend a four-year college elsewhere. While this fact suggests that in-state tuition costs either are prohibitively high or too unattractive to retain students in the state, much of this migration of students can be explained by the nearness of other states in New England. It's notable that other New England states, compared to national averages, also have high rates of high-school graduates who cross state lines to attend four-year institutions.

Together our interviews and available data suggest that too few people are seeking out both careers and learning opportunities in manufacturing in the state. As elsewhere, this trend may be difficult or impossible to reverse quickly. Still, stakeholders in N.H. may wish to increase wages, offer manufacturing jobs with clear career paths, offer stronger wraparound support for learners (including childcare and tuition assistance), and ramp up outreach and recruitment efforts.

Perhaps the strongest action that New Hampshire is taking to increase learner demand is offering support for adult learners and for incumbent workers. The state's BEA department mentioned that adults qualify for up to \$6,500 as a lifetime training and education benefit and that employers can move those benefits a little higher by providing matching funds. The state offers money to employers to "ease employees into their new field while still making some money to make sure they can pay their bills while learning a new trade."

Learning programs

Our interviews produced mixed results about the quality of learning programs in manufacturing throughout the state. Our interviews suggest that Manchester Community College (MCC) and Nashua Community College (NCC) have built strong programs in advanced manufacturing, but other evidence suggests that community colleges across the state may not be meeting the WLE's needs.

³² New Hampshire Fiscal Policy Institute. (2023, March 27). New Hampshire policy points: Education. <https://nhfpi.org/blog/new-hampshire-policy-points-education/>.

Experiential learning appears to be common, but small employers may be struggling to take advantage of the benefits it offers, resulting in missed opportunities for both employers and learners.

Students in the MCC program who graduate often receive multiple job offers, and many students who complete only part of the program are hired before they complete it (as mentioned above). While such strong hiring may in part result from workforce shortages in manufacturing, strong hiring also suggests that MCC's advanced manufacturing programs are teaching students marketable skills in a variety of automated manufacturing processes. MCC offers three pathways, or concentrations, for students: mechatronics, mechanical engineering technology, and robotics. Interviewees tell us that, throughout MCC's advanced manufacturing program, students also learn human skills.

MCC also appears to be using effective teaching technologies. MCC offers online courses and emphasizes active student engagement in learning. Their program is looking into using virtual reality and augmented reality to enhance learning. In a digital format, MCC has exact copies of a robot and one CNC machine.

Access to high-quality learning programs through community colleges appears to be unevenly distributed throughout the state, with learning programs most available near the southern coastal region of New Hampshire.

According to NCES data, Lakes Region Community College graduated five students in programs clearly related to manufacturing during the 2021 – 2022 academic year: 4 students earned an associate degree and 1 student a certificate in the category “manufacturing engineering technology/technician.” The New Hampshire Technical Institute, in Concord, N.H., had similar graduation rates: 1 certificate and 3 associate degrees were awarded for “mechatronics, robotics, and automation engineering”; 2 associate degrees were awarded for “manufacturing engineering technology/technician”; and 1 certificate was awarded for CNC machining. Comparatively, MCC appears to be graduating students with manufacturing skills at higher rates. In the 2021-2022 academic year, MCC awarded 1 certificate and 15 associate degrees for “manufacturing engineering technology/technician,” 2 certificates for “robotics technology/technician,” and 9 certificates and 12 associate degrees in “welding technology/welder.”

Aside from information about community college programs, our interviews suggested that apprenticeships and funding for them are available but that they are underutilized. Even if funding is available to employers, it may be difficult to

access, or employers may be under informed about opportunities. Apprenticeships, at least with smaller employers, may therefore be uncommon.

Collaboration

We found mixed evidence of collaboration among stakeholders. Collaboration appears to be effective within the ALELLE centered on BAE Systems (see the case study on BAE Systems in this report). Elsewhere, collaboration may be more difficult, especially for small manufacturers. One industry leader portrayed higher education as disconnected from industry, saying that manufacturing students are in “silos” and that none of the community colleges are talking to each other because none have enough “fire power.” Fractionalized goals were one of the complaints from industry leaders at large.

Financial Sustainability

Funding appears to be available for adult learners and incumbent workers, as well as for employers who offer training. But funds appear to be inadequate and unsustainable for community colleges.

Funds for community colleges appear to be insufficient. One college leader suggested money is the biggest issue facing learning WLEs in the state. Another college leader said they had nonfunctioning equipment they could not repair due to insufficient funds. They added that, consequently, the college would not have enough working equipment for instruction if enrollments were to increase even by as few as 5 students per cohort. New Hampshire's low investment in higher education in general, as noted above, also suggests that funding for manufacturing programs at community colleges is inadequate in the state.

Rhode Island

Demand

- Learner demand may be insufficient to meet industry needs.
- Stakeholders are taking action to increase demand.
- Multiple education programs are free too learners.

Learning programs

- In general, learning programs have been designed with manufacturers
- Program graduates tend to have improved job outcomes.

Collaboration

- Stakeholders across industry and education have collaborated on program design
- Existing statewide manufactures associations offer an opportunity for future collaboration.

Sustainable Funding

- We have insufficient data on sustainable funding for the state.

Rhode Island hosts strong learning programs in advanced manufacturing, but data suggests that these programs are not graduating learners in great enough numbers to meet industry needs.

There is strong evidence that learning programs are using curricula codesigned with—or at least informed by—manufacturers. Some programs appear to maintain workforce pipelines with manufacturers too. As a result, learning programs seem to be teaching in-demand skills and helping learners find employment.

It's unclear how inclusive collaborations in the state are. At least some learning programs entail collaboration between education providers and manufacturers—to update curriculum and maintain pipelines—but collaboration may be occurring among only a limited set of stakeholders. It may be that collaborations do not include enough manufacturers to ensure that the needs of a critical number are understood and addressed. But the precise state of collaborations in Rhode Island is unknown; data is scarce.

Like other states, Rhode Island manufacturers are struggling to find skilled labor. The state's MEP, Polaris MEP, surveyed manufacturers in the state and discovered that they consider low "availability of skilled labor" to be the top obstacle limiting growth.³³ By itself, this finding suggests that WLEs in the state are not producing enough output—enough graduates with needed skills—to meet demands in the industry's labor market. The low availability of skilled labor also suggests too few new entrants and incumbent workers are seeking out training programs in advanced manufacturing.

In short, manufacturers appear to be experiencing shortages of skilled labor despite the strengths among learning programs in the state. Learning programs that we identified tend to have high job placement rates for graduates. And they offer good financial support to learners. Despite these strengths, it is likely that programs in the state are not operating at the needed scale; they appear not to be graduating enough learners to meet employment needs, and the reason may simply be that too few learners are seeking to learn advanced-manufacturing skills.

Solutions to skilled workforce shortages in Rhode Island do not differ substantially from solutions required in other states in New England. Greater efforts will need to be devoted to drawing more stakeholders into collaborations and, most importantly, to raising demand for careers and learning programs in manufacturing.

One possible unique circumstance may be Rhode Island's size and population. It is the smallest state in New England but has the second highest population density of all states in the U.S.³⁴ Rhode Island's population is less than all states in New England except Vermont. As discussed above, at least some stakeholders in Rhode Island are collaborating across state borders by participating in the WLE that has sprung around General Dynamics Electric Boat in Groton CT. It may be that cross-state collaborations are more urgent for Rhode Island than elsewhere.

The following discussion of Rhode Island should be viewed with circumspection. Only one stakeholder with whom we requested an interview agreed to be interviewed. To compensate for a shortage of data, we have supplemented this interview with other research.

³³ Polaris MEP. (2022). *State of manufacturing: Rhode Island*.

<https://polarismep.org/state-of-ri-manufacturing-study/>.

³⁴ Statista. (N.d.) Population density in the U.S. by federal states including the District of Columbia in 2021. Retrieved Dec. 13, 2023,

<https://www.statista.com/statistics/183588/population-density-in-the-federal-states-of-the-us/>.

Learner demand

Learner demand is likely low, as the Polaris MEP suggests. However, it is possible that learner demand is high but access to learning programs is low: R.I. learners could have inadequate access to training. But it's more likely that interest in manufacturing programs and careers is low. Learner demand across New England is consistently low, and Rhode Island likely is not an exception.

Regardless, stakeholders in the state are working to raise demand, but the effectiveness of such efforts is unknown. Multiple programs are free to learners—a feature that may fuel demand:

- Fast-Track to CNC Manufacturing, offered by the Community College of Rhode Island (CCRI)
- Welding and machining, at the Shipbuilding and Manufacturing Institute (SAMI)
- General manufacturing, materials handling, and industrial sewing through We Make RI
- CNC through the Jane Addams Resource Corporation, Rhode Island (JARC-RI)

Available data on program cohorts are another indicator of demand. CCRI's program, Fast-Track to CNC Manufacturing, has trained 19 cohorts, each with 12 – 15 students, according to an interviewee, for a total of 228 - 285 learners. In contrast, undated web materials for the program claim that, since 2016, the program has trained 175 CNC machinists.³⁵

Other programs in the state have reported enrolling greater numbers. Between 2016 and 2018, SAMI graduated 514 learners, according to a study of SAMI's program outcomes.³⁶ More recent and complete data on SAMI and other programs was unavailable.

³⁵ Polaris MEP. (n.d.). Getting Rhode Islanders on a fast track to a career in manufacturing. Retrieved December 13, 2023, <https://polarismep.org/videos/fast-track-to-cnc-manufacturing-extended-cut/>.

³⁶ Parker, P.E. (2019, January 6). Jobs training pays. *The Providence Journal*. <https://www.providencejournal.com/story/news/education/2019/01/07/sami-works-graduates-of-job-training-program-at-neit-got-higher-quality-work-and-wages/6368484007/>.

In comparison, the state's manufacturing industry was estimated to employ more than 37,000 workers in 2020, and that number is expected to grow to nearly 39,000 by 2030.³⁷

Learning programs

Available data show signs that training programs in the state are high quality. They appear to be teaching in-demand skills, and program graduates seem to be hired at high rates. At least one program, the fast-track program at CCRI, has the added benefit of providing college credit to graduates, who can apply it toward degrees.

Another positive sign is that programs appear to have been designed with employer input. An interviewee with knowledge of the CNC machining program at CCRI said it is designed with employer perspectives. Similarly, SAMI acknowledges that the Rhode Island Manufacturers Association (RIMA)—a statewide industry advocacy association—and other agencies have contributed to the success of the SAMI program, suggesting that manufacturers may have provided input for the SAMI program as well.³⁸

Hiring of graduates appears to be robust. Before learners complete the CCRI program, at least some of them are connected to hiring employers. Marketing materials for the program claim: "Through our partner, Polaris MEP, interviews are set up and job placement is often achieved at the end of Phase 1" of the two-phase program. Similarly, other programs operating in the state have proven successful. JARC—which runs manufacturing programs in Chicago, Baltimore, and Rhode Island—claims that 90% of program graduates are placed into full-time employment, but JARC's public materials do not break down placement by site.³⁹

At least the fast-track CCRI program has features shared by other high-quality programs too; namely, it provides college credit, hands-on learning, job shadowing, and some professional skills, such as interview prep. The CCRI program also issues a certificate in advanced manufacturing to graduates, and the certificate appears to be recognized by at least local employers.

³⁷ Department of Labor and Training, State of Rhode Island. (n.d.). 2020 – 2030 industry & occupational projections. <https://dlt.ri.gov/labor-market-information/data-center/2030-industry-occupational-projections>.

³⁸ New England Institute of Technology. (n.d.). Shipbuilding and Advanced Manufacturing Institute at NEIT. Retrieved August 11, 2023, <https://www.neit.edu/sami>.

³⁹ Jane Addams Resource Corporation, Rhode Island. (n.d.). Documents & publications. Retrieved December 13, 2023, <https://jarcri.org/mission-impact/documents-publications/>.

More information that would be needed to assess the quality of learning programs is lacking. There is inadequate information on apprenticeships, availability of qualified faculty, access to up-to-date equipment, and learner support.

Despite what appear to be effective learning programs in the state, one study on SAMI's performance between 2016 and 2018 suggests that program graduates did not enjoy a boost to their chances for gaining employment.⁴⁰ Compared to other workers, graduates from the SAMI program did not experience a statistically significant increase in employment rates, though their earnings were 29 percent higher than other workers during the three months after the program ended. Still, even if graduates' employment rates did not increase, their higher earnings suggest they were able to secure relatively high paying jobs because of their training.

Collaboration

There is evidence that stakeholders are collaborating across sectors, but it's unclear how effective and inclusive collaborations are.

Multiple education and training providers have collaborated with industry partners. As mentioned above, multiple programs—such as those offered by CCRI and SAMI—have designed curricula and maintained pipelines with regional manufacturers.

Polaris MEP also has reached out to community groups to promote manufacturing education. Such broad collaborations—linking the WLE to stakeholders beyond manufacturing, education, and economic development—might help spark interest in manufacturing careers and education by meeting people where they are.

The state's manufacturers' association, RIMA—which is listed as at least an advising organization for SAMI—offers an opportunity for manufacturers to collaborate on identifying needs and communicating them to education providers. But the extent to which RIMA is facilitating collaborations on workforce learning is unclear. RIMA's website lists 48 sponsors for 2023 and claims that the association aims “to be the unified voice of Rhode Island's 1,600 manufacturers.”⁴¹ RIMA thus appears to be well situated to facilitate

⁴⁰ Parker, P.E. (2019, January 6). Jobs training pays. *The Providence Journal*. <https://www.providencejournal.com/story/news/education/2019/01/07/sami-works-graduates-of-job-training-program-at-neit-got-higher-quality-work-and-wages/6368484007/>.

⁴¹ Rhode Island Manufacturers Association. (n.d.). Retrieved December 13, 2023, <https://rimanufacturers.com/>.

collaborations, but public materials provide little insight into how RIMA has promoted collaborations among education providers and manufacturers.

Financial Sustainability

There is not enough data available about Rhode Island to make useful conclusions about the state of funding in its WLEs.

Our one interviewee mentioned that their operations depend in part on grant funding through the federal government. Likewise, SAMI was created with grant funding from non-profit organizations and federal and state governments.⁴² But whether SAMI is still sustained by grant funding is unclear.

Whether learning programs have enough learners to bring in sufficient income through tuition fees (paid for by the learner or a sponsor such as an employer) is also unclear, but there is no reason to think that learning programs are struggling to be funded. In fact, the relatively strong enrollment and graduation numbers of programs in Rhode Island—SAMI, for example, graduated more than 500 learners between 2016 and 2018 alone—suggests that learning programs could have dependable revenue. Still, with little data, such assessments are speculative.

⁴² New England Institute of Technology. (n.d.). Shipbuilding and Advanced Manufacturing Institute at NEIT. Retrieved August 11, 2023, <https://www.neit.edu/sami>.

Vermont

Demand

- Learner demand for learning programs is too low to meet industry needs.
- High cost of living may put employment and learning programs out of reach for many students.
- Workforce is aging, and younger populations may be leaving the state.
- There is a need for outreach and marketing to build awareness about manufacturing careers.
- Multiple stakeholders are currently engaged in marketing and outreach.
- Free tuition is available for eligible learners to take work-relevant courses at public institutions.

Learning programs

- Apprenticeships are underused.
- The Vermont Manufacturing Collaborative at Vermont Technical College has a record of successfully placing students in jobs.
- There is little available information about advanced manufacturing programs in the state.

Collaboration

- Stakeholders across all sectors are collaborating at a high level.
- Collaborations are yielding positive results, such as organizing collaborative outreach and identifying and communicating employers needs for curricula and credentials.

Sustainable Funding

- Collaborations in the ecosystem are made sustainable due to widespread institutional support across sectors.
- Due to their strength and centralization, stakeholder collaborations may be making the ecosystem more efficient by reducing redundancies.
- There is insufficient data on the efficiency, equitability, and sustainability of individual learning.

Like other New England states, VT manufacturing appears to be experiencing a shortage of labor. According to VT's most recent WIOA plan, the state's manufacturing industry had 2,400 job openings—or 7.4% of “all employment opportunities” in the industry—in Nov. 2021.⁴³ It's likely that job openings have remained elevated. With 20.6% of its population 65 or older, VT is the fourth oldest state in the U.S. according to that measure (i.e., percentage of population that is 65+).⁴⁴ Moreover, the Manufacturing Institute reports that, as of 2017, about a

⁴³ Vermont Department of Labor. (2022). *Workforce Innovation and Opportunity Act (WIOA) modified state plan*. <https://labor.vermont.gov/document/vdol-wioa-modified-state-plan-2022>.

⁴⁴ Kilduff, L. (2021, December 22). Which U.S. states have the oldest populations? Population Reference Bureau. <https://www.prb.org/resources/which-us-states-are-the-oldest/>.

quarter of employees in manufacturing across the U.S. were 55 or older. In an industry with an aging workforce and in a state with a large retirement-age population, Vermont manufacturers face the systematic problem of a shrinking workforce.

Vermont manufacturers may also be facing a dwindling workforce because housing costs are high and college-age populations are leaving the state. Like other New England states the cost of housing is too expensive for current worker's salaries, interviewees said. The state may also be struggling to retain younger populations that are most likely to have skills relevant in manufacturing. According to interviewees, younger populations may be leaving because the state has a "branding issue": high-school and college students may assume the state only offers "hiking and microbrews" and not know about job opportunities in high-tech fields in the state.

Whatever the cause for workforce shortages might be, VT manufacturers see workforce supply and development as perhaps the greatest challenge in the state. The Vermont Manufacturing Extension Center (VMEC), the state's MEP, reported that 76% of stakeholders surveyed in the state saw "employee recruitment and retention" as a challenge.⁴⁵ Recruitment and retention was identified as a challenge more often than all other challenges from which survey respondents could choose, including "continuous improvement and cost reduction" (70%).

Learner Demand

Since VT manufacturers have identified workforce recruitment and retention as their top challenge, demand for learning programs is likely low, and stakeholders will need to increase efforts to recruit learners. Low learner demand is unlikely to change rapidly in the short term. More positively, in the long term, demand for learning programs may be rising as stakeholders begin to collaborate on marketing and outreach.

Stakeholders throughout the state appear to be aware of the state's recruitment problem and are acting. Interviewees identified familiar causes for low interest in manufacturing careers: a stigma on manufacturing, low awareness and knowledge about modern manufacturing, and insufficient outreach and support for populations other than college-bound youth. Stakeholders in the state appear to be addressing some of these problems through marketing, outreach to youth, and tuition support for adult learners.

⁴⁵ Vermont Manufacturing Extension Center. (2022). *Impact Report*. <https://vmec.org/results/impact-reports/>.

Stakeholders in VT said that marketing and outreach need to improve, since awareness and desire to work in manufacturing are low, but addressing this problem may take a long time. The stigma on manufacturing is so strong that education programs will often leave out the word “manufacturing” when describing day-to-day work on the floor.

Vermont stakeholders have begun marketing and outreach. One stakeholder has incorporated a pre-manufacturing curriculum in K-12 schools, to help build pipelines for both manufacturers and post-secondary institutions. They are also marketing through “social media, TV, and events.” Similarly, Vermont Technical College (VTC), now part of Vermont State University, visits high schools and junior high schools to talk about manufacturing jobs and participates in awareness days.

Interviewees mentioned programs that offer incentives to attract learners to work-relevant post-secondary learning programs. Both Upskill Vermont (through University of Vermont, UVM) and 802 Opportunity Grants pay tuition for Vermont residents to take certain courses through the Vermont State Colleges System (VSCS). In addition to course limitations, only certain VT residents are eligible for funding. For example, 802 Opportunity Grants only fund students who meet income requirements and have not earned a prior bachelor’s degree.⁴⁶ Upskill Vermont requires that beneficiaries be unemployed or underemployed and are “seeking to transition to a job that provides better opportunities for career and economic advancement.”⁴⁷

As these latter two programs suggest, stakeholders in Vermont are aware that manufacturing programs need to increase efforts to recruit from diverse populations. Moreover, interviewees said stakeholders will need to help learners overcome many barriers to work—including childcare, transportation, and knowledge of English.

Learning programs

Interviews gave limited insight into the quality of learning programs in Vermont. While there was some evidence of experiential learning, namely internships, interviews suggested that apprenticeships were uncommon due to stringent state regulations. One interviewee provided insight suggesting that one post-secondary institution, VTC, has excellent advanced-manufacturing programs: programs that offer work-relevant curricula, hands-on learning, and high job-placement for students. Still, VTC is one school, and despite evidence that it is

⁴⁶ Vermont Student Assistance Corp. (n.d.) Free tuition at CCV. Retrieved December 13, 2023, <https://www.vsac.org/free-tuition-ccv-yes-really>.

⁴⁷ Upskill Vermont. (n.d.). Retrieved December 13, 2023. <https://upskillvermont.org/>.

performing well, there is not enough evidence to draw conclusions about learning programs across the state. Regardless, VTC deserves mention for its high-quality programming.

Apprenticeships may be underused in Vermont due to regulations that make it difficult for businesses to take advantage of them. As is common across New England, manufacturers in Vermont may find apprenticeships unappealing because of regulatory red tape.

Still, learners in Vermont may be able to access internships or earn-and-learn programs. The state has begun using CHIPS Act funding to pay employers for on-the-job training, but specifics were unavailable.

Aside from on-the-job learning across the state, one school, VTC, appears to offer high-quality curriculum and instruction in advanced manufacturing. The program also teaches non-technical skills, including holistic thinking, problem solving, ideation and design thinking. Learners in VTC programs also appear to receive ample time working with up-to-date equipment. However, it's unclear if VTC's education model can scale up with a current cohort size of 8 to 10 students.

Collaboration

There appears to be excellent high-level collaboration across Vermont. Collaboration is mainly organized around the Vermont Manufacturing Extension Center (VMEC), the state's MEP. VMEC works with at least three key partners in the WLE:

1. Vermont Technical College (VTC), which hosts VMEC and the Vermont Manufacturing Collaborative, a private-public partnership focused on workforce development and technology adoption.
2. The manufacturing arm of Vermont Talent Pipeline Management (VTPM), a collaborative economic-development initiative based on a model from the U.S. Chamber of Commerce Foundation and led by the Research and Education Foundation of the Vermont Business Roundtable.

3. The State Workforce Development Board (SWDB).^{48, 49, 50, 51}

Indicating the breadth of statewide collaborations, the Vermont Business Roundtable claims that VTPM has “organized more than 90 Vermont manufacturers” since 2018. VTPM also appears to have a two-phase plan for improving workforce development, a plan that includes organizing employers and setting and communicating competency and credential requirements.⁵²

The collaboration between VTPM and VMEC appears to be central to state-sponsored workforce development activities in manufacturing as well. In its most recent “Strategic Plan,” Vermont’s SWDB says that its Manufacturing Committee “must assist the work of the VMEC and VTPM to develop effective and accessible flow of competency to Vermont’s jobs and careers in manufacturing.”

The Manufacturing Committee of the SWDB also offers high-level collaborations to improve manufacturing education. According to interviewees, the committee meets often, includes educators and manufacturers, helps set credential standards, and helps map education pathways for manufacturing careers. Notably too, presidents of major education institutes must be present when the committee meets, interviewees said.

However, aside from the participation of college and university presidents on the Manufacturing Committee, we uncovered no evidence that educational institutions were involved in collaborations in the WLE. This does not mean that such collaborations are not occurring but that they may be inconspicuous.

Financial Sustainability

The strength of collaborations might be the best indicator of sustainability in the WLE. With the state’s MEP, workforce development board, and Vermont’s Business Roundtable involved in on-going collaborations, the WLE appears able to respond to future changes in advanced manufacturing. In short, there are

⁴⁸ Vermont Manufacturing Collaborative. (n.d.) Retrieved December 13, 2023, <https://vtmc.vtc.edu/>.

⁴⁹ Vermont Talent Pipeline Initiative. (n.d.) <https://www.vermonttpm.org/>.

⁵⁰ Vermont Business Roundtable. (2023, February 7). Vermont Talent Pipeline Initiative Partners with VMEC to address supply if [sic] manufacturing workforce skills. <https://vtroundtable.org/vermont-talent-pipeline-partners-with-vmec-to-address-supply-if-manufacturing-workforce-skills-2-6-23/>.

⁵¹ Vermont State Workforce Development Board. (2023). *Strategic Plan: 2023*. https://vwdb.vermont.gov/sites/vwdb/files/SWDB%20Strategic%20Plan_6.8.pdf.

⁵² State of Vermont, Agency of Commerce and Community Development. (n.d.). Retrieved December 13, 2023. <https://accd.vermont.gov/economic-development/programs/vtpm>.

strong and sustained feedback mechanisms in place to update the WLE about changes in industry needs for skills and credentials.

It's also notable that the collaborations appear to be well centralized, indicating at least an opportunity for reducing redundancies in the WLE. Rather than businesses and schools going it alone—forming individual partnerships that serve only individual organizations' needs—manufacturers and other stakeholders are collaborating to identify and communicate manufacturers' needs for learning programs.

A clear leader in the WLE, the state's MEP, VMEC, also appears to be thriving. According to its 2022 impact report, its clients earned an estimated return on investment of \$350 for every \$1 spent on VMEC services—a return that suggests VMEC will remain in demand among manufacturers for the foreseeable future.⁵³ In the same report, VMEC claims to have enabled Vermont manufacturers to create 96 jobs and retain 443 in 2022. Finally, the VMEC appears to be expanding its reach in the WLE, a potentially positive sign of sustainability: its partnership with VTPM was announced in Feb. 2023.⁵⁴

The state has begun using funds from the CHIPS Act to support employers who offer on-the-job training. The state also pays tuition for eligible learners to take courses in high-demand professions (see section on “Demand” above). Such support at state and federal levels bodes well for the sustainability of workforce learning programs.

With available data, we are unable to assess whether learning programs themselves are efficient—whether, for example, they use online learning materials to maximize in-person instructional time for hands-on learning.

⁵³ Vermont Manufacturing Extension Center. (2022). *Impact Report*.
<https://vmec.org/results/impact-reports/>.

⁵⁴ Vermont Business Roundtable. (2023, February 7). Vermont Talent Pipeline Initiative Partners with VMEC to address supply if [sic] manufacturing workforce skills.
<https://vtroundtable.org/vermont-talent-pipeline-partners-with-vmec-to-address-supply-if-manufacturing-workforce-skills-2-6-23/>.

Appendix B: Supplemental economic and workforce information for New England relevant to manufacturing and defense industries

The defense industry and manufacturing contribute greatly to regional economic output and employ hundreds of thousands of residents. Ensuring that regional workforce learning stays up to date with trends in manufacturing is critical to New England's economy.

According to SENEDIA (Southeastern New England Defense Industry Alliance), the regional defense industry provided 407,523 jobs or 5.5% of all regional employment in 2022. In the same year, the defense industry produced \$40.3 billion in income for individuals and \$119.1 billion in economic output, totaling 9.2 percent of the region's gross domestic product. SENEDIA also reports that New England received \$3,934 per capita from DoD and DHS contracts, nearly double the national average of \$2,003 per capita.

Manufacturing has a similarly large impact on the regional economy. According to the National Association of Manufacturers (NAM), the total economic output for manufacturing in New England was \$117.54 billion in 2021. Furthermore, manufacturing firms numbered 15,136 in 2019 and employed about 587,000 people in 2021 (see table 1).

Jobs in manufacturing also pay well on average, but as our research suggests, entry-level pay may lag. Across New England's states, the average annual compensation for jobs in manufacturing was higher than annual compensation in nonfarm businesses. Average annual compensation in regional manufacturing ranged from \$71,672.60 in Vermont to \$115,249.34 in Massachusetts.

Table 1. Economic output and employment of New England manufacturing.

	CT	MA	ME	NH	RI	VT	New England
Total Manufacturing Output (\$Billions, 2021)	34.9	56.1	7.8	10.0	5.3	3.5	117.5
Percent share of total gross state product (%)	10.9	9.7	10.0%	10.0	7.6	10.0	--
Mfg Firms (2019)	3,698	5,928	1,605	1,676	1,233	996	15,136
Mfg employment (Dec, 2021)	156K	240K	53K	67K	41K	30K	587K
Share of nonfarm employment (%)	9.6	6.7	8.7	10.0	8.5	10.1	--
Average Annual Compensation (\$, 2021)							
-- Manufacturing	106K	115K	75K	94K	81K	72K	
-- Nonfarm Businesses	68K	79K	53K	65K	60K	51K	--

Source: National Association of Manufacturers (NAM). NAM has drawn this data from the U.S. Bureau of Economic Analysis and the U.S. Census Bureau.

Despite manufacturing's large economic impact, New England manufacturers face current and future workforce shortages. Data suggests that unemployment remains stubbornly low in New England even as hiring cools from pandemic-related highs. Moreover, workforce shortages in New England could deepen due to retirements. The region has some of the oldest populations in the U.S. Yet, even as retirements accelerate, the manufacturing sector in all New England states, except Maine, is projected to add more jobs by 2030.

Nationally, manufacturers are struggling to fill open positions as unemployment remains at historical lows. According to a report from the Center for Manufacturing Research (CMR), there were 676,000 job openings in the national manufacturing sector in April of 2023 (the most recent month for which data is available). More broadly, the Center for Manufacturing Research reports, there were 100 job openings for every 56.0 unemployed workers in all industries across the U.S., indicating a broader workforce shortage.

Most recent data from the Bureau of Labor Statistics paints a similar picture of New England in June 2023 (Table 1). Across New England, for roughly every 47 unemployed workers, there were 100 job openings. New Hampshire had the lowest ratio, with roughly 30 unemployed workers for every 100 job openings.

Table 2. Employment data for all industries.

State	Job openings rate (%)	Total job openings (thousands)	Unemployment rate (%)	Total unemployed workers
Connecticut	5.1	91	3.7	70,173
Maine	5.4	37	2.4	16,014
Massachusetts	6.1	243	2.6	96,049
New Hampshire	6.1	45	1.8	13,466
Rhode Island	5.7	30	2.9	16,796
Vermont	5.9	19	1.9	6,726

Data source: Bureau of Labor Statistics for June 2023 as reported by the Society for Human Resources Management.

These workforce shortages may only worsen due to retirements. In 2020, populations in New England skewed older than in most states in the country. Among all states, Maine had the greatest percentage (21.8%) of total population that was 65 or older. Other New England states were not far behind (see table 3).

Table 3. Age data for New England's states.

Rank	State	Total Resident Population (Thousands)	Population Ages 65+ (Thousands)	Population Ages 65+ (%Population)
1	Maine	1,350	294	21.8
4	Vermont	623	129	20.6
8	New Hampshire	1,366	263	19.3
14	Rhode Island	1,057	192	18.2
14	Connecticut	3,557	646	18.2
25	Massachusetts	6,894	1,198	17.4

Data source: Kilduff, L. (2021, December 22). Which U.S. states have the oldest populations? Population Reference Bureau.

Despite aging populations, the number of jobs in manufacturing or production occupations is expected to increase across New England between 2020 and 2030. Massachusetts and Connecticut are projected to have the greatest increase in manufacturing jobs, while manufacturing jobs are expected to contract slightly in Maine.

Table 4. Projected manufacturing jobs in New England's states.

State	2020 mfg jobs	2030 projected mfg jobs	Jobs created by 2030	10-year Increase
Connecticut ⁵⁵	153,823	167,804	13,981	9.0 %
Maine ⁵⁶	50,400	50,280	-120	-0.2 %
Massachusetts ⁵⁷	229,913	253,069	23,156	10.1 %
New Hampshire ⁵⁸	67,284	69,113	1,829	2.7 %
Rhode Island ⁵⁹	37,414	38,905	1,491	4.0 %
Vermont ⁶⁰	27,993	28,828	835	3.0 %

Data source: See footnotes.

States may be facing widening workforce gaps as the number of manufacturing jobs increases. For example, in its "Workforce Strategic Plan" for 2020, an advisory group convened by the Governor of Connecticut, Ned Lamont, projected that there would be a demand for 6,000 new workers in manufacturing per year but only 3,000 new entrants per year. We expect that other states in New England face this same problem—that as manufacturing jobs open, new entrants could remain drastically low.

⁵⁵ Connecticut Department of Labor. (n.d.). State of Connecticut industry projections: 2020 – 2030. <https://www1.ctdol.state.ct.us/lmi/ctindustry2020.asp>.

⁵⁶ Center for Workforce Research and Information. (n.d.). Workforce outlook. <https://www.maine.gov/labor/cwri/outlook.html>.

⁵⁷ Department of Economic Research. (n.d.). Long-term industry projections. <https://lmi.dua.eol.mass.gov/LMI/LongTermIndustryProjections/>.

⁵⁸ New Hampshire Employment Security. (2022, January). New Hampshire employment projections by industry and occupation. <https://www.nhes.nh.gov/elmi/products/documents/2020-2030-longterm-projections.pdf>.

⁵⁹ Department of Labor and Training, State of Rhode Island. (n.d.). 2020 – 2030 industry & occupational projections. <https://dlt.ri.gov/labor-market-information/data-center/2030-industry-occupational-projections>.

⁶⁰ Governor's Workforce Council, Connecticut. (2020). *Workforce Strategic Plan 2020*. <https://portal.ct.gov/-/media/Office-of-the-Governor/News/20201028-Governors-Workforce-Council-Strategic-Plan.pdf>.

Appendix C: Research Interviews

In conducting this research, we interviewed leaders from organizations across the region. To preserve privacy, this list shows organization names only, but not the specific interviewees.

Organization	Category	State
CCAT	Education	CT
Asnuntuck	Education	CT
Essex Tech	Education	MA
QCC	Education	MA
MACC	Education	MA
ME DOE	Education	ME
Nashua CC	Education	NH
Manchester CC	Education	NH
VCT	Education	VT
VSCS	Education	VT
Electric Boat	Industry	CT
Innovent	Industry	MA
GE Aviation	Industry	MA
HarmonicDrive	Industry	MA
Bath Iron Works	Industry	ME

Organization	Category	State
CompoTech	Industry	ME
Auburn Manufacturing	Industry	ME
Xact Tech	Industry	NH
TurboCam	Industry	NH
BAE Systems	Industry	NH
ReadyCT	Workforce	CT
EWIB	Workforce	CT
MassHire	Workforce	MA
MassHire	Workforce	MA
MassHire	Workforce	MA
MACC	Workforce / Education	MA
CCS	Workforce	ME
NH Workforce	Workforce	NH
Polaris MEP	Workforce	RI
VT Workforce	Workforce	VT

References

- Altman et al. (2021, April). *Workforce ecosystems: A new strategic approach to the future of work*.
<https://www2.deloitte.com/content/dam/Deloitte/de/Documents/human-capital/Workforce-Ecosystems-Study2021.pdf>
- BIW Apprentice School. (n.d.). General Dynamics Bath Iron Works. Retrieved December 13, 2023.
<https://gdbiw.com/careers/apprenticeship-programs/>.
- Center for Workforce Research and Information. (n.d.). Workforce outlook.
<https://www.maine.gov/labor/cwri/outlook.html>.
- Connecticut Department of Labor. (n.d.). State of Connecticut industry projections: 2020 – 2030.
<https://www1.ctdol.state.ct.us/lmi/ctindustry2020.asp>.
- Clochard, A. and G. Westerman, *Understanding the Incumbent Worker's Decision to Train: The Challenges Facing Less-Educated Workers*. MIT Work of the Future Task Force Working paper WP09-2020 December 14, 2020. [MIT Work of the Future](#)
- Department of Economic Research. (n.d.). Long-term industry projections.
<https://lmi.dua.eol.mass.gov/LMI/LongTermIndustryProjections/>.
- Department of Labor and Training, State of Rhode Island. (n.d.). 2020 – 2030 industry & occupational projections. <https://dlt.ri.gov/labor-market-information/data-center/2030-industry-occupational-projections>.
- Deloitte Insights. (2018, November 13). *2018 Deloitte skills gap and future of work in manufacturing study*. <https://www.deloitte.com/global/en/our-thinking/insights/industry/manufacturing-industrial-products/manufacturing-skills-gap-study.html>
- Eastern CT manufacturing pipeline. (n.d.). Eastern Connecticut Workforce Investment Board. Retrieved December 13, 2023,
<https://www.ewib.org/pipeline>.

- Eastern CT's Youth Manufacturing Pipeline Initiative. (n.d.). Eastern Connecticut Workforce Investment Board. Retrieved December 13, 2023, from <https://www.ewib.org/ympi>.
- Future iQ. (2019, June 13). *New England Regional Defense Industry Collaboration think-tank workshop report*. <https://lab.future-iq.com/wp-content/uploads/2019/09/new-england-regional-defense-industry-collaboration-think-tank-report.pdf>
- Future Skills. (n.d.). Commonwealth of Massachusetts. Retrieved December 13, 2023. <https://www.mass.gov/futureskills>.
- Governor's Workforce Council, Connecticut. (2020). *Workforce Strategic Plan 2020*. <https://portal.ct.gov/-/media/Office-of-the-Governor/News/20201028-Governors-Workforce-Council-Strategic-Plan.pdf>.
- Hallenbeck, B. (2023, February 28). Electric Boat hopes to hire 5,750 employees this year. Connecticut State Office of Military Affairs. <https://portal.ct.gov/OMA/In-the-News/2023-News/Electric-Boat-hopes-to-hire-5750-employees-this-year>.
- Jane Addams Resource Corporation, Rhode Island. (n.d.). Documents & publications. Retrieved December 13, 2023, <https://jarcri.org/mission-impact/documents-publications/>.
- Kilduff, L. (2021, December 22). Which U.S. states have the oldest populations? Population Reference Bureau. <https://www.prb.org/resources/which-us-states-are-the-oldest/>.
- Killada, L.A. (2022, May). *Understanding the attitudes of incumbent manufacturing workers toward training opportunities*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/massbridge>.
- Maine's Community Colleges. (n.d.) Workforce Training. Retrieved December 13, 2023, <https://www.mccs.me.edu/workforce-training/maine-workforce-development-compact/>.
- MassBridge. (n.d.). Bridging the gap in manufacturing technician training in emerging technologies. <https://cam.masstech.org/massbridge>.

- MassHire State Workforce Board. (n.d.). Commonwealth of Massachusetts. Retrieved December 13, 2023. <https://www.mass.gov/masshire-state-workforce-board>
- Nelson, S., Bonvillian, W.B., and Westerman, G. (2022, June). *Community college's role in building apprenticeships*. Massachusetts Center for Advanced Manufacturing. <https://cam.masstech.org/massbridge>.
- New England Institute of Technology. (n.d.). Shipbuilding and Advanced Manufacturing Institute at NEIT. Retrieved August 11, 2023, <https://www.neit.edu/sami>.
- New Hampshire Employment Security. (2022, January). New Hampshire employment projections by industry and occupation. <https://www.nhes.nh.gov/elmi/products/documents/2020-2030-longterm-projections.pdf>.
- New Hampshire Fiscal Policy Institute. (2023, March 27). New Hampshire policy points: Education. <https://nhfpi.org/blog/new-hampshire-policy-points-education/>.
- Northeast Advanced Manufacturing Consortium. (n.d.). Retrieved December 13, 2023, <https://namcnetwork.com/>.
- The Ohio Manufacturers' Association. (n.d.). <https://www.ohiomfg.com/>.
- OhioTechNet. (n.d.). <https://ohiotech.net.org/>.
- Parker, P.E. (2019, January 6). Jobs training pays. *The Providence Journal*. <https://www.providencejournal.com/story/news/education/2019/01/07/sami-works-graduates-of-job-training-program-at-neit-got-higher-quality-work-and-wages/6368484007/>
- Polaris MEP. (2022). *State of manufacturing: Rhode Island*. <https://polarismep.org/state-of-ri-manufacturing-study/>.
- (n.d.). Getting Rhode Islanders on a fast track to a career in manufacturing. Retrieved December 13, 2023, <https://polarismep.org/videos/fast-track-to-cnc-manufacturing-extended-cut/>.

- Ready CT. (n.d.). Manufacturing Careers Roadshow. Retrieved December 13, 2023, <https://readyct.org/manufacturing-careers-roadshow/>.
- Rhode Island Manufacturers Association. (n.d.). Retrieved December 13, 2023, <https://rimanufacturers.com/>.
- SENEDIA. (2023, May). The economic impact of the defense cluster in New England. <https://senedia.org/economic-impact/>.
- Singer, Stephen. (2024, Mar. 1). Maine colleges, universities partner with defense industry to recruit and train thousands of workers. *Portland Press Herald*. Retrieved 1 Mar., 2024: <https://www.pressherald.com/2024/03/01/maine-colleges-universities-partner-with-defense-industry-to-recruit-and-train-thousands-of-workers/>.
- Sletten, P. (2023, March 23). A snapshot of New Hampshire's workforce and the impacts of the COVID-19 pandemic after three years. New Hampshire Fiscal Policy Institute. <https://nhfpi.org/blog/a-snapshot-of-new-hampshires-workforce-and-the-impacts-of-the-covid-19-pandemic-after-three-years/>.
- (2023, June 15). Labor force trends in New Hampshire. New Hampshire Fiscal Policy Institute. <https://nhfpi.org/assets/2023/06/NHFPI-Labor-Force-Trends-in-New-Hampshire-6.15.23.pdf>.
- State of Vermont, Agency of Commerce and Community Development. (n.d.). Retrieved December 13, 2023. <https://accd.vermont.gov/economic-development/programs/vtprm>
- Statista. (N.d.) Population density in the U.S. by federal states including the District of Columbia in 2021. Retrieved Dec. 13, 2023, <https://www.statista.com/statistics/183588/population-density-in-the-federal-states-of-the-us/>.
- Sullivan, Shawn P. (2024, Mar. 1). Maine colleges, leaders unveil \$6.5M plan to train thousands for defense workforce. *Foster's Daily Democrat*. Retrieved 1 Mar., 2024: <https://www.fosters.com/story/news/local/york-star/2024/03/01/maine-defense-workforce-portsmouth-nabal-shipyard-pratt-whitney-bath-iron-works/72791917007/>.

- Ton-Quinlivan, Van. (n.d.). Wicked challenges in the workforce: Van Ton-Quinlivan (CEO Future Health). Interview. Global Opportunity Forum. Retrieved Jan. 26, 2024, <https://gof.mit.edu/news-research/podcast/episode2/>.
- UMaine engineers are growing Maine's economy. (2017, August 14). The University of Maine. <https://mcec.umaine.edu/2017/08/14/comptech-inc-knows-get-engineers/>.
- Upskill Vermont. (n.d.). Retrieved December 13, 2023. <https://upskillvermont.org/>.
- Vermont Business Roundtable. (2023, February 7). Vermont Talent Pipeline Initiative Partners with VMEC to address supply if [sic] manufacturing workforce skills. <https://vtroundtable.org/vermont-talent-pipeline-partners-with-vmec-to-address-supply-if-manufacturing-workforce-skills-2-6-23/>.
- Vermont Department of Labor. (2022). *Workforce Innovation and Opportunity Act (WIOA) modified state plan*. <https://labor.vermont.gov/document/vdol-wioa-modified-state-plan-2022>.
- Vermont Manufacturing Collaborative. (n.d.) Retrieved December 13, 2023, <https://vtmc.vtc.edu/>.
- Vermont Manufacturing Extension Center. (2022). *Impact Report*. <https://vmec.org/results/impact-reports/>.
- Vermont State Workforce Development Board. (2023). *Strategic Plan: 2023*. https://vwdb.vermont.gov/sites/vwdb/files/SWDB%20Strategic%20Plan_6.8.pdf.
- Vermont Student Assistance Corp. (n.d.) Free tuition at CCV. Retrieved December 13, 2023, <https://www.vsac.org/free-tuition-ccv-yes-really>.
- Vermont Talent Pipeline Initiative. (n.d.) <https://www.vermonttpm.org/>.
- Westerman et al. (2021, September 24). *Benchmarking advanced manufacturing education: From the MassBridge workforce education program*. Massachusetts Center for Advanced Manufacturing.

<https://cam.masstech.org/sites/default/files/2022-06/Benchmarking-Phase1-Report-Sept2021.pdf>.

Workforce training. (n.d.). Maine's Community Colleges. Retrieved December 13, 2023, <https://gdbiw.com/careers/apprenticeship-programs/>.