Benchmarking Advanced Manufacturing Education:
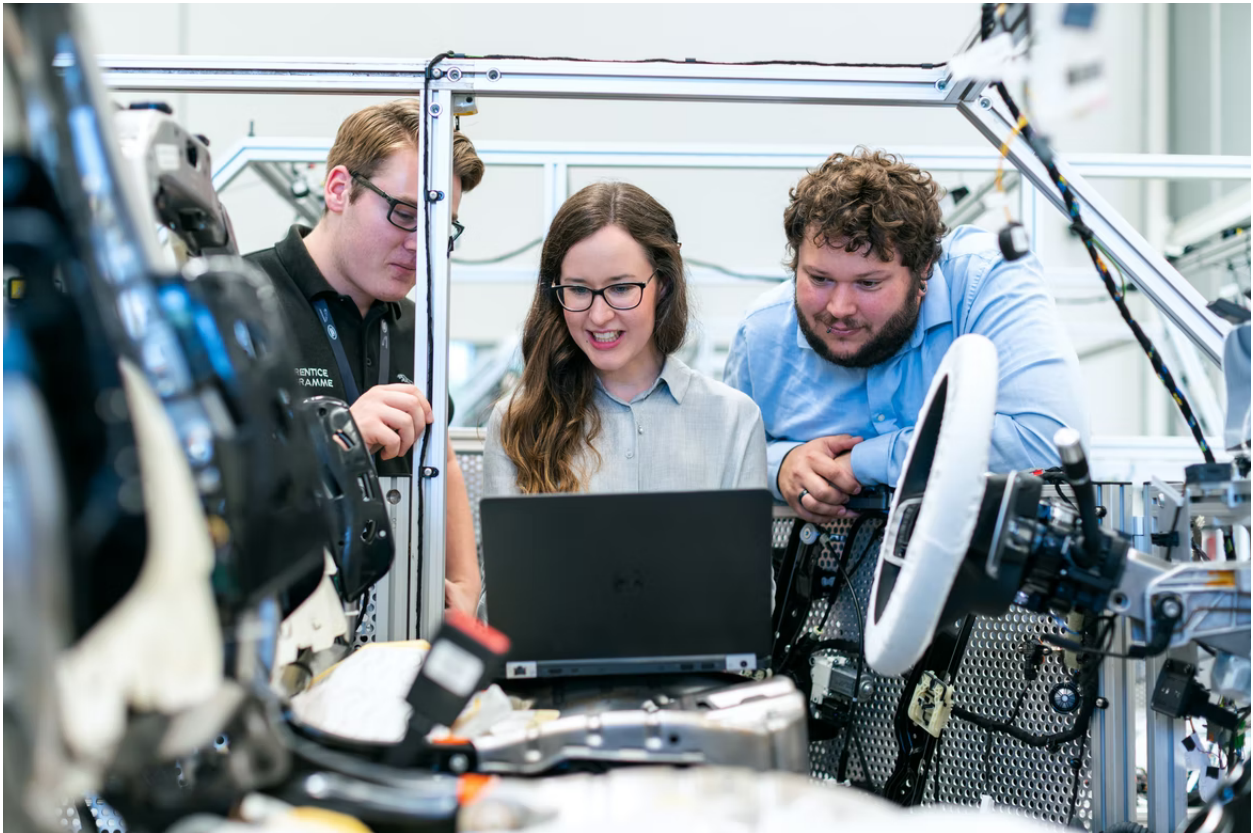
Perspectives from Community Colleges and Employers

We welcome your comments and suggestions.

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I. Introduction: Why Community College Advanced Manufacturing Training Matters

American manufacturing has been a troubled sector in recent decades. Between 2000-2010, the manufacturing sector lost close to six million jobs and closed 64,000 plants.[1] Between 2010 and 2020, the productivity of U.S. manufacturers declined both in absolute terms and compared to key foreign competitors.[2] The massive U.S. trade deficit in goods reached over $900 billion in 2020, including more than $190 billion in advanced technology goods.

Concerned about the strength of the U.S. industrial base, the DoD formed 9 of an eventual 16 advanced manufacturing institutes to help bring on new manufacturing technologies such as digital production, robotics, additive manufacturing, flexible electronics, photonics, and biofabrication. However, our workforce education system is not ready to provide the training we need in these new technologies.

The MassBridge project, funded by DoD ManTech, is an ambitious effort to plan and develop advanced manufacturing programs for community colleges and vocational-technical high schools in Massachusetts. It aims to extend traditional manufacturing training to include many common skills required for advanced manufacturing occupations, leaving only the "last mile" of technology-specific training for employers. In essence, MassBridge will be a bridge that helps to span the gap between education programs and employer needs in advanced manufacturing. The DoD hopes that MassBridge, once successful, can also be a model for efforts in other states.

In the initial phases of MassBridge, the MIT Office of Open Learning, collaborating with MassTech, NCATC, Massachusetts community colleges, and MassHire boards, conducted a deep and wide-ranging benchmarking study to understand what will be required for community colleges to deliver advanced manufacturing training effectively.[3] The study, based on extensive interviews with educators and industry executives, made recommendations in terms of content, curriculum structure, and collaboration with employers. In the current phase of the project, the project team surveyed 91 community colleges and 50 manufacturing employers from across U.S. regions to understand the extent to which some of these practices were being used across the United States.

The findings presented here present a promising picture with many challenges still to address. Our analysis shows that community colleges can play an important role in providing advanced manufacturing skills but that more is needed to do it well. While the survey shows employer satisfaction for their engagements with community colleges, their responses also suggest that community college education too often lacks the clear signals of competence that work experience or independent certifications can provide.

Meanwhile, community colleges are more split in their opinions about employer engagement. Half of the community college respondents indicated satisfaction, while another quarter expressed dissatisfaction with important aspects of engagement.

Furthermore, our findings indicate a potential difference in aspiration about what strong engagement can do for educators, employers, and the individuals they train.   Our findings suggest several areas that can enhance employer engagement and, ultimately, student outcomes:

1. Build longer-term relationships between community colleges and employers to address activities such as curriculum development and apprenticeships. Doing so can transform education and hiring from a transactional process to a partnership that benefits both sides.
2. Improve the ways in which community colleges deliver and show competencies. In particular, work with employers to identify the most valuable certifications and align curricula so that students can acquire these credentials in a stackable way as they complete their programs.
3. Bridge the education/workforce gap by incorporating work experiences such as internships and apprenticeships.
4. Embed independent, industry-approved certification opportunities into the curriculum design.
5. Improve the use of advisory boards to improve broader workforce learning alignment beyond the one-to-one partnerships on which many employers and community colleges rely.

II. Satisfaction with Employer and Community College Engagement

Table 1 shows that, in general, employers and community colleges express satisfaction with their engagement for advanced manufacturing training, but dissatisfaction is higher among educators than employers. 64% of employers and 71% of community colleges are satisfied with engaging in hiring graduates – arguably the most important outcome for manufacturing training programs. This is good news for educators and students. However, this enthusiasm is not reflected in responses to more intensive engagement activities. Although the high satisfaction for hiring graduates suggests that students are well-trained for entry-level manufacturing jobs, it may also reflect a seller's market in manufacturing hiring, where employers appreciate having a steady supply of workers with basic qualifications from community colleges to fill an ever-present need.

Looking further, both employers and community colleges are generally satisfied with community college engagement in training incumbent workers, with 50% or more respondents satisfied. More opportunity exists in this area, however. 29% of employers answered "Does Not Apply," meaning that they do not work with community colleges to train their incumbent workers. This represents an untapped opportunity to attract students and build strong relationships with employers. Educating incumbent workers helps community colleges stay current with what manufacturers need and builds ongoing relations that can translate into joint apprenticeship programs and cooperative curriculum development. In addition, while relatively few employers were dissatisfied, 25% of community colleges were dissatisfied. That suggests that a significant number of community colleges feel they need to build deeper relations with manufacturers. Conversely, employers that are satisfied may tend to continue the relationship, while those that are dissatisfied may simply choose not to engage.

The other three engagement questions show higher dissatisfaction for engagements that require collaboration on activities that are less structured than hiring workers or training incumbents. While 52% of community colleges were satisfied with employer engagement to develop new courses, only 38% of employers felt that way. Dissatisfaction among community colleges was 23% compared to 15% for employers. Furthermore, 32% of employers surveyed indicated that they do not engage with community colleges on course development. Engaging effectively on curriculum development can involve detailed discussions about what skills are needed and how well they are being taught. It can also involve putting words to tacit knowledge that can be difficult to discuss in concrete terms. This type of engagement benefits from sustained collaboration through which partners in the discussion can develop shared understanding. The ability to develop these long-term relationships may be one reason for the difference between the satisfied half and the dissatisfied fourth of the responding community colleges.

Table 1: Community College and Employer Satisfaction in Engaging for Advanced Manufacturing Education.

	Community Colleges			Employers		
	NA	Not Satisfied	Satisfied	NA	Not Satisfied	Satisfied
Partnering to hire graduates into manufacturing roles	7%	13%	71%	14%	12%	64%
Partnering to train incumbent employees.	3%	25%	58%	29%	8%	49%
Engaging to developing new courses	1%	23%	52%	32%	15%	38%
Partnering to hire students into internships or apprenticeships	4%	24%	56%	14%	12%	63%
Engaging with a state-wide or regional industry advisory board for advice on courses or curricula	5%	38%	36%	21%	17%	46%

Notes: Responses from a survey of leaders from 91 community colleges and 50 manufacturing employers. Questions presented here but were tailored to the type of respondent (see appendix for actual questions). Responses were from a 5-point Likert scale. For the table, Dissatisfied combines responses of Very Dissatisfied and Somewhat Dissatisfied, while Satisfied combines responses of Somewhat Satisfied and Very Satisfied. Respondents selecting Not Applicable (NA) were eliminated from the satisfaction percentage calculations.

Another type of engagement that requires deeper relationships is in the area of student internships and apprenticeships. Employers' high satisfaction rate (63%) with engaging for internships and apprenticeships aligns with the community colleges' satisfaction rate (56%). Interviews indicate that employers generally see internships as a good way to identify talented workers before going on the general job search, although not all have high expectations for the interns producing high value during their internships. Apprentices produced higher value, but apprenticeships also required much more formal planning and monitoring.

Nearly one-fourth (24%) of community colleges were dissatisfied with the process, double the dissatisfaction rate of employers. This difference could relate differing aspirations among employers and educators about the nature of the student experiences. Among community colleges, the difference between the half of satisfied educators and the quarter dissatisfied could reflect a presence (or lack) of strong relationships and processes through which employers regularly host students each year. It may also reflect a difference in aspiration, where less satisfied schools want a more systematic pipeline process than their local employers are willing to embrace.

Continuing the trend, the area of least satisfaction for both employers and community colleges is engaging in advisory groups. 79% of responding employers engage in these activities – higher than curriculum development or internships – but only 46% of those that participate say they are satisfied with the engagement. Community colleges have a different sense, with dissatisfied respondents outnumbering satisfied ones. Advisory boards are enticing ideas, but they can be difficult to manage well.

When they work, industry advisory groups can be very useful ways to build agreement on a standard set of requirements across diverse employers (for more on this, see [3]). For example, the Ohio Manufacturers Association (OMA) has a major workforce education emphasis, which has been ongoing and provides strong leadership for education programs from the industry. Reflecting the different manufacturing sectors in different parts of the state, it has chapters in different regions. However, OMA itself pulls together these strands to present a coordinated and uniform perspective in cooperation with community colleges to the state government and the governor on manufacturing workforce program needs. When community college curricula are developed, OMA is at the table with community colleges, providing industry input and perspectives on an ongoing basis. Building advisory boards that work is an opportunity for community colleges to improve engagement on all five topics we discussed while reducing the number of 1:1 discussions required with employers.

Overall, the picture is one of the employers generally happy with their community college engagements, though perhaps expecting less from these engagements than their community college parts do. Community college leaders are split among the half that are satisfied and the relatively large quarter that are not. The stark difference among educator respondents could partly be described by lower aspirations among the satisfied group but more likely reflect a differential ability to establish the strong relationships that are necessary for activities such as curriculum development and internships or apprenticeships. In the remainder of this report, we dig deeper into how well the community colleges and employers are aligned on curriculum topics and how they manage the alignment.

III. What They Teach

Are community colleges teaching the right topics? Figure 1 shows that community colleges and employers are remarkably aligned on the technologies they teach and use. When asked whether they teach or use 15 types of technologies, the prevalence rankings among community colleges or employers are remarkably similar. Looking at traditional manufacturing technologies (hand tools, manual metalworking), moderately advanced technologies (CAD/CAM, CNC metalworking), and advanced ones (PLCs, optics), the alignment is very strong.

Figure 1: Top Technologies Taught by Community Colleges and Used by Employers.
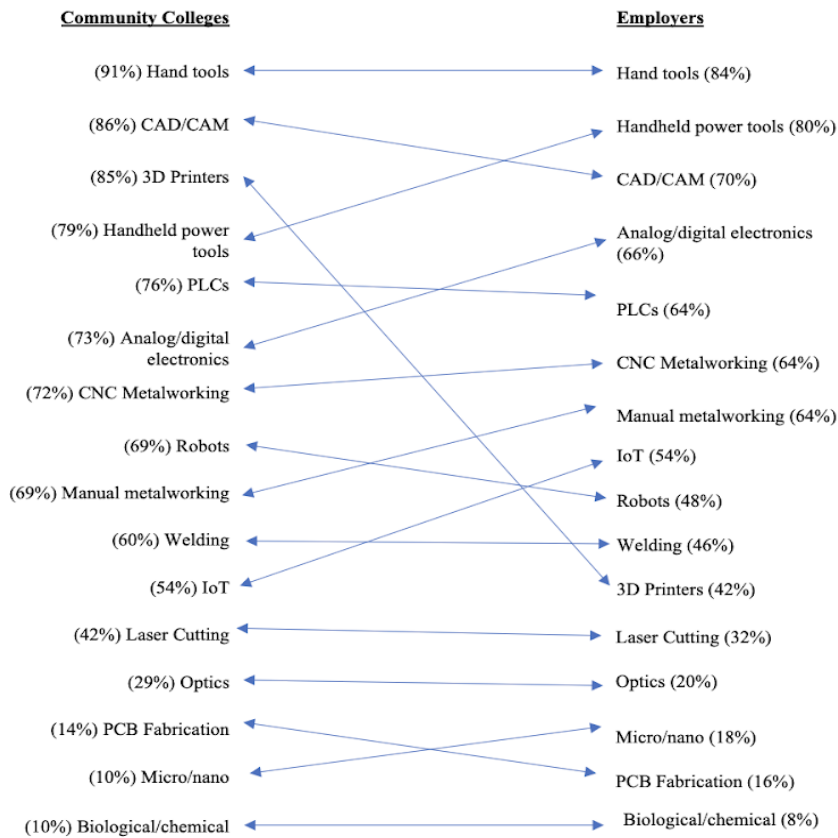
Note: The figure shows percentages of employers and community colleges using each type of equipment. For example, 84% of employers use hand tools in their manufacturing organization, and 91% of community colleges are teaching hand tools in their courses. Respondents could make multiple choices from the list of equipment provided.

Differences arise in some areas. For example, twice as many community colleges teach 3-D printing (85%) as employers who indicate they use it (42%). Similarly, robots are taught more commonly in community colleges (69%) than they are used by the responding employers (48%). Furthermore, the types of devices used in education and the workplace for these technologies can sometimes differ, especially for 3-D printing. Interviews with community colleges indicated that educators are aware of the difference but still see value in teaching the technologies. In addition to teaching the technology itself, the 3-D printers and robots are often used for project-based

learning that extends the lecture experience. They suggested that these two technologies provide students with a broader competence with system-level concepts such as data, programming, and troubleshooting that have value beyond the specific technologies being taught. 3-D printing and robotics are also more advanced technologies, and the employer reaction may reflect the relatively slow uptake of these among smaller manufacturing firms,

Non-technical skills

The analysis above focused on technical skills only. However, prior research showed that advanced manufacturing requires non-technical skills that enhance technical skills.[3] Skills such as troubleshooting, critical thinking, communication, professional skills, and comfort with data represent a subset of "human skills"[7] that differentiate order-followers from people who can be more collaborators in making the business work better. Furthermore, these skills are what employers are increasingly demanding.

Table 2 summarizes prior research on the core topics that were most prevalent across advanced manufacturing programs that prepare workers for careers in either the specialized branches of advanced manufacturing or in highly connected Industry 4.0-related manufacturing. Beyond technical skills expected in these programs, human skills such as communication, professional skills, critical thinking, and problem-solving are core topics.

Table 2: Core Skills for Advanced Manufacturing Education.

Technical Skills			
Instrumentation & Sensors	Troubleshooting	PLCs	Automated Systems
Systems Control	Data Management	Safety	Hydraulics
Process Control	Maintenance	Technical Blueprints & Drawings	Lower-Level Mathematics
Basic Mathematics	Scientific Communication	Pneumatics	Machine Tools
Manufacturing Materials	Manufacturing Processes	Introductory Physics	Robotics
Simulation	Basic Computer Skills	Basic Measurement	Hand Tools
Electronics	Data Management	Safety	Process Control
Probability & Statistics	Quality		
Non-technical Skills			
Professional Skills	Communication	Critical Thinking	Problem-Solving
Reading Comprehension			

Note: Abridged version of Table 6 from Westerman et al. (2021) Benchmarking Advanced Manufacturing Education: A Study from the MassBridge Workforce Education Program.[3]. Skills identified through analysis of curricula and certifications for advanced manufacturing.

We also surveyed educators about how they incorporate critical thinking skills into the curriculum. The survey queried five elements of critical thinking factors – problem discernment, hypothesis, framework creation, inference, and communication – based on the Paul-Elder

Critical Thinking Framework.[4] Levels of curriculum integration ranged from "not addressed" to "integrated throughout the program."

Figure 2 shows the most common approach through which educators integrate the five critical thinking skills into curriculum. The tiny yellow slices of each bar show that educators very rarely teach these skills in specialized courses. They prefer instead to teach them as elements of other courses. Interestingly, the number of programs that integrate thinking skills at the highest level of integration ("integrated throughout the program") monotonically decreases along with the progression of the thinking skills sequence. This could suggest the challenge in which educators include a complete framework of critical thinking in the curriculum. Additionally, across the board, roughly 50% of surveyed education programs teach these critical thinking skills in only *one course or less*. This absence of contact with learning thinking skills could help explain why manufacturing executives consistently rank critical thinking as a top-five skill.[5]

Figure 2: Modes of Curriculum Integration for Different Elements of Critical Thinking.
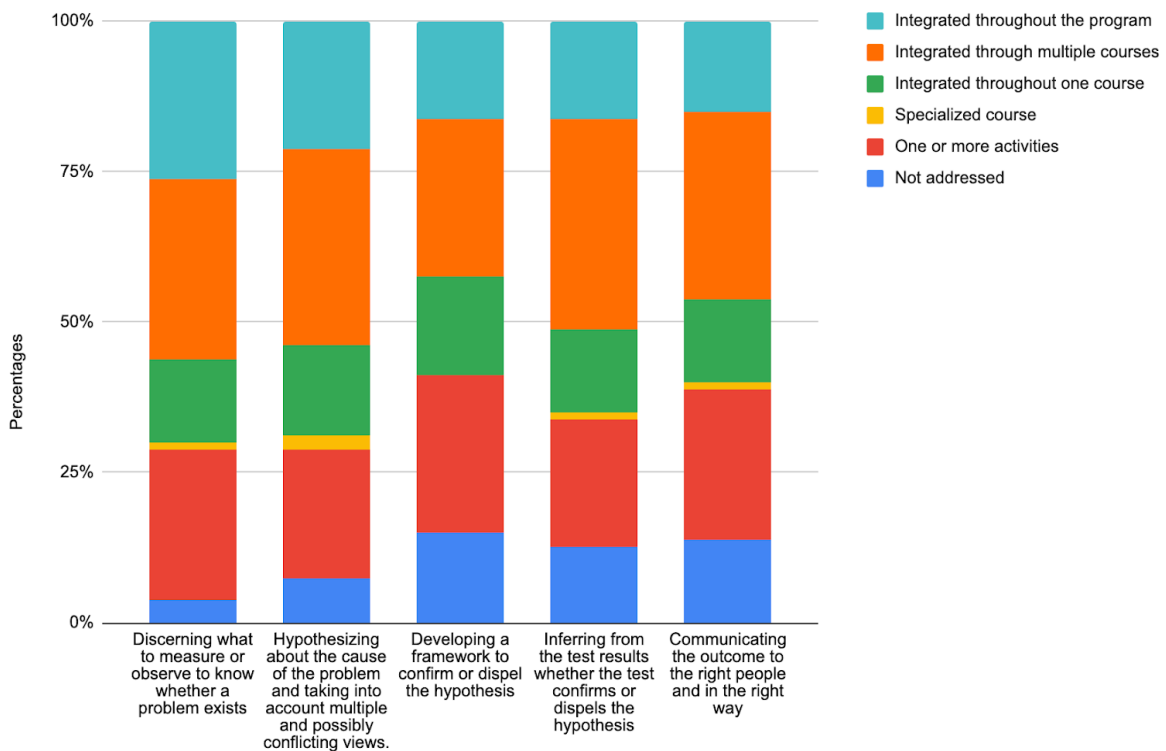
Note: Responses from 80 community college leaders are used to calculate the total number of responses for each option above for integration of critical thinking. The level of integration is a multiple choice question where the respondents are asked to select all the options that are applicable to a critical thinking concept taught from the range of Not addressed to Integrated throughout the program. We calculated the percentage of integration for each critical thinking skill to view how the topic is addressed. For example - We can see the critical thinking skill of 'Discerning what to measure or observe to know whether a problem exists' is addressed majorly as being Integrated throughout the program and least addressed as a Specialized course.

IV. Aligning the Curriculum with Employer Needs

Given the apparent strong alignment between topics taught and technologies used in industry, we examined the processes that community colleges use to create alignment. While educators may vary in how they define "significant revision," their responses indicate that they are paying attention to the need to keep the curriculum up to date. A majority of community colleges say they perform a significant curriculum review every 2-3 years (see Figure 3). Fully 92% say they update curriculum at least every five years.

**Figure 3: Rate of Performing Significant Curriculum Updates.**
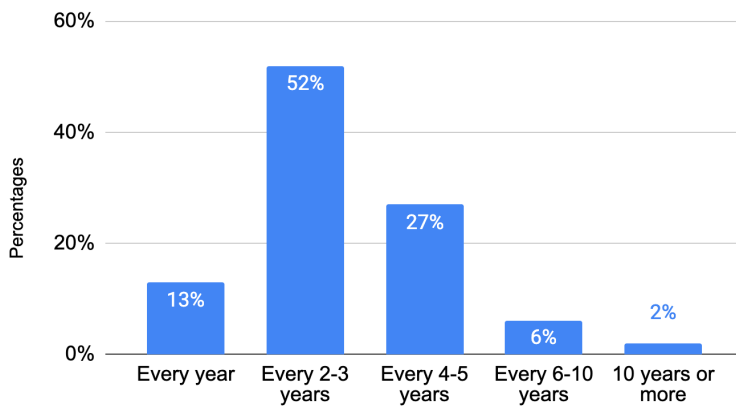
Note: Percentage of 91 community college respondents selecting each option for the question "how frequently do you perform a significant curriculum revision."

Community colleges showed a strong commitment to meeting industry needs when developing or revising curricula. Figure 4 shows the educators' ranking for the relative importance of various mechanisms community colleges might use. Three of the four most important mechanisms (alignment with industry, employer feedback on needs, employer feedback on student skills) represent employer feedback. These rank higher than student feedback or requirements of accreditation groups.

The strong alignment of technologies being taught is encouraging. However, in the fast-changing world of advanced manufacturing, a good process is needed to ensure that the curriculum stays aligned with employer needs. Recall from our earlier discussion of employer satisfaction that 32% of employers indicated they do not engage with community colleges about curriculum development. On the educator side, 23% are dissatisfied with their employer engagement around curriculum development, and they were more dissatisfied than satisfied with industry advisory boards. Although aligning can be difficult, there are good examples of doing it well, such as the Ohio Manufacturers' Association example described earlier.

Figure 4: Community College Usage of Various Curriculum Evaluation Methods.
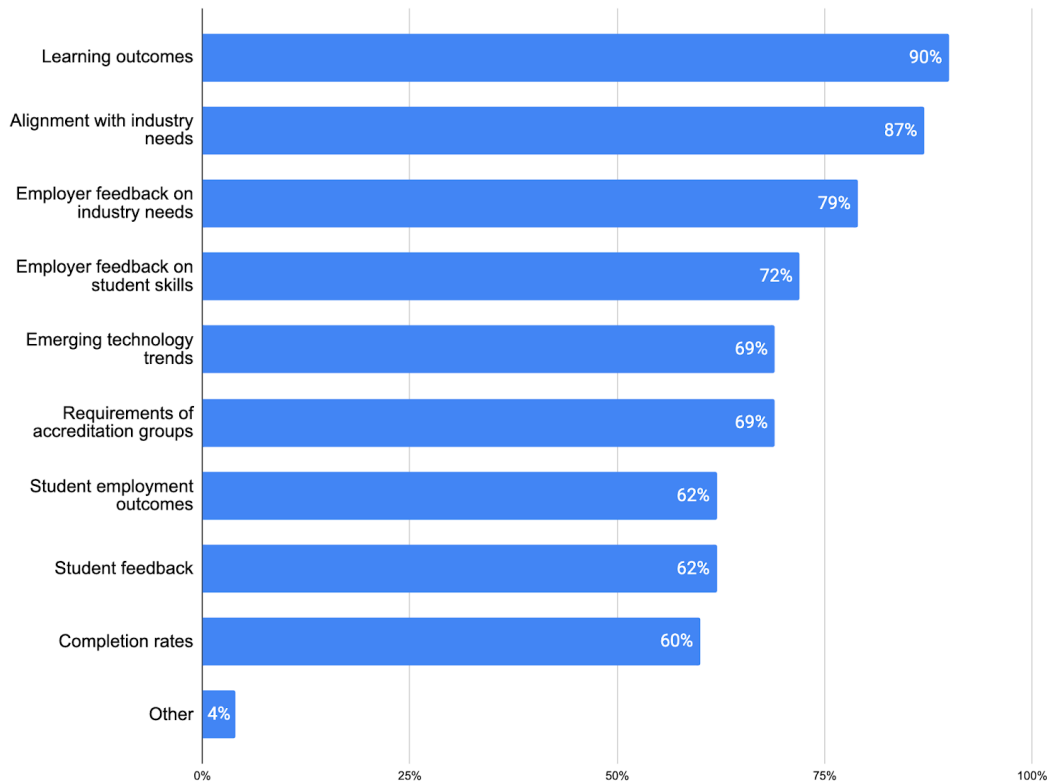
Note: Percentage of 91 community college leaders choosing each mechanism to assess the curriculum. Respondents could choose multiple mechanisms that apply, so percentages total to more than 100%

Alignment is, of course, less difficult for non-credit than credit programs. Non-credit programs need not meet a complete list of degree requirements and thus can focus specifically on the needs of a potential employer. The governance and approval process for these programs is also less intensive. Accordingly, community colleges say they are able to customize their non-credit programs more flexibly than their credit-based ones (Figure 5). Moreover, the type of flexibility is more constrained in credit than non-credit programs. For non-credit programs, 81% of educators indicated they are very flexible at the level of elements within courses. Meanwhile, credit-based programs more commonly restrict flexibility to swapping courses or a few elements within courses.

Figure 5: Community Colleges Are More Flexible with Non-Credit Programs.
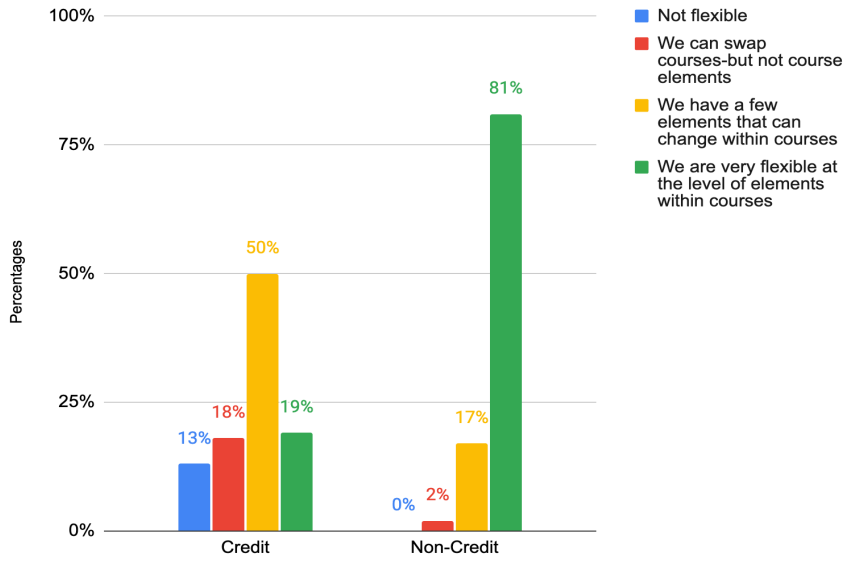
Note: Percentage of 91 community college respondents choosing each level of flexibility in credit and non-credit programs.

V. Improving Labor Market Transparency

Our survey and interviews suggest that the manufacturing labor market lacks clear indicators of Table 3 shows the average ranking of several hiring criteria when we asked employers to sort eight criteria from most to least important. Manufacturers rate work experience as the most important criterion in hiring a worker, usually ranking it first or second in importance. Next in line are industry-recognized certifications, which employers rank higher (3.1) than associate degrees (4.3).

Table 3: Average Rank of Employer Hiring Criteria for Advanced Manufacturing Workers.

Hiring Criterion	Average Rank (1=Highest)
Work experience	1.7
Industry certification	3.1
Associate degree	4.3
Number of apprenticeships	4.4
Number of internships	5.0
We hire for will, not for skill	5.4
Four year degree	5.8
Projects done within academic programs	6.3

Note: A total of 50 employers ranked each of eight criteria in the order of their preference when hiring candidates for advanced manufacturing roles. Lower numbers represent higher importance. For example, work experience is ranked most important.

Why would this be? Like all educational institutions, community colleges vary widely in quality and curriculum content. A degree simply says that a student met the criteria to graduate but does not indicate the actual level or content of any particular competence. Industry certifications, meanwhile, test specific competencies using standard well-recognized criteria. One reason that doctors, lawyers, and pharmacists must pass certification exams beyond graduating from school is to ensure that they have the basic competencies to serve in their professional roles. Apparently, manufacturing employers feel the same: while a degree is a useful signal of competence, a certification is better.

Three criteria ranked lowest among the choices provided. Four-year degrees ranked 5.8, slightly below "we hire for will, not for skill" (5.4). This can be understood if we consider that graduates of four-year programs may be a better fit for engineering roles rather than technicians. Projects

done within an academic program rank lowest of all. Although community colleges use classroom projects to simulate the real-world experience, employers give these projects less credence than other more work-related activities that better signal competence to them.

In the middle of the chart, two criteria offer important opportunities. Apprenticeships were ranked almost equally with associate degrees, and internships slightly lower. Incorporating these mechanisms into educational programs can create work experience, which is the attribute that employers value most. Given that 63% of employers who engaged in internships and apprenticeships said they were satisfied, these are levers community colleges can use to improve their employer relationships and the employability of their graduates.

Digging deeper, Figure 6 shows the extent that employers consider various degrees and certifications to be required for hiring. It is striking that very few employers require any specific certifications for employment. The most common ones (vendor-specific, associate degree in manufacturing, other associate degree, and other general manufacturing certification) are required by only about 10% of the respondents. One-third (33%) indicated that they require another credential beyond the list we provided in the survey.

Figure 6: Employer Requirements for Credentials.
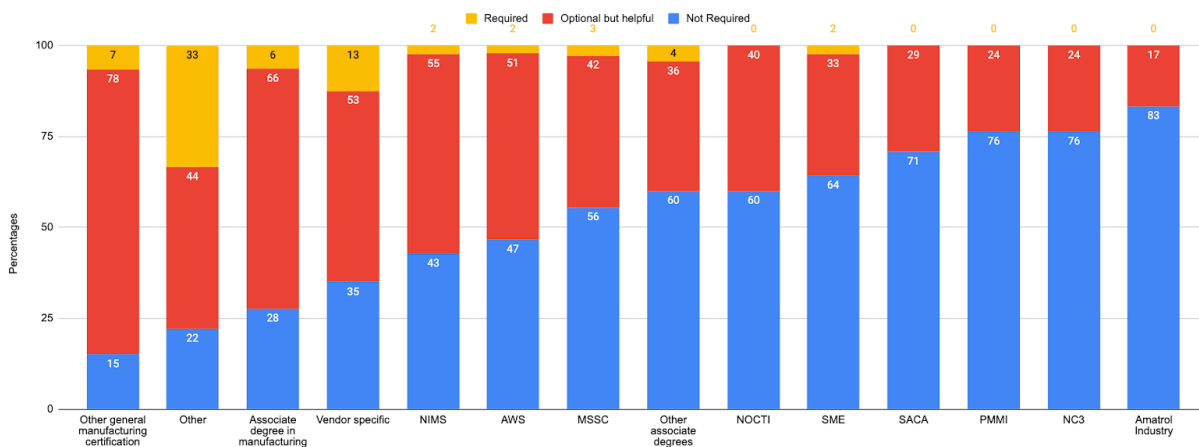
Note: Employers indicated the extent to which each credential is required for hiring manufacturing employees. For example, 13% of the 50 employer respondents said that vendor-specific credentials are required, while 53% said they were optional and 35% said they were not required. The percentages exclude "does not apply" responses.

Employers distinguish strongly between types of associate degrees. For hiring manufacturing technicians, 72% say that an associate degree in manufacturing is required or optional but helpful, compared with only 40% who say this for other associate degrees.

The situation for industry certifications is more complex. There are a large number of certifications in the industry, and few have broad market acceptance across employers. Employers we interviewed stated that they cannot require specific certifications because they are

not common enough in the labor pool. Instead, they recognize some as "optional but helpful," while listing others as "not required" in stronger numbers than certification groups would desire. The certifications that employers most commonly listed as helpful were the more commonly-known ones (vendor-specific, NIMS, American Welding Society). Newer or less common ones such as SACA and NC3 are less often listed as required or optional but helpful. Amatrol's certification preparation programs run counter to this trend. Amatrol's tools and programs are widely used in community colleges for training, but relatively few employers selected them as required or optional but helpful. This may align with the earlier finding that employers give less credence to classroom projects than they do to other forms of credentials.

VI. Funding Advanced Manufacturing Programs

Table 4 shows how community colleges engage with government programs that can help educate workers and improve technology in manufacturing. Only about a third of community colleges utilize the federal and state-supported manufacturing extension partnerships (MEP) in their areas. However, MEPs operate in every state and can provide a key link to the small and mid-sized manufacturers. Workforce education is also one task MEPs support. This lack of coordination with MEPs means most community colleges may be missing out on a potentially key way to help meet the workforce needs of small and medium manufacturers in their areas, which in turn could provide additional students for their programs.

Table 4: Working with Government-Sponsored Resources for Community College Manufacturing Curriculum.

	Not sure	No	Yes
Does your community college work with your state MEP?	34%	35%	31%
Does your community college work with any MIIs in the Manufacturing USA network?	43%	47%	10%
Does your community college provide training for WIOA programs?	20%	10%	70%
Can participants in WIOA programs get credit at your institution?	0%	11%	89%

Note: Responses from 91 community college leaders.

The sixteen federally-supported Manufacturing Innovation Institutes (MIIs) are another source for information and connections. MIIs, which are present in many manufacturing regions, work to develop advanced manufacturing technologies and workforce capabilities in areas such as additive manufacturing, flexible electronics, and photonics, However, only 10% of community colleges in the survey work with them. Therefore they may be missing out on materials that could enrich their programs and help their students learn about advanced manufacturing.

Also surprising is the large number of "Not Sure" responses to both questions. This indicates a substantial opportunity to make community colleges more aware of these and other resources.

A contrast is WIOA. Workforce development boards (under the federal WIOA law) provide training primarily to underemployed, unemployed, and displaced workers who need new skills to get better jobs. The many "Yes" responses positively signal that connections between WIOA programs and community colleges are working. This shows that the community colleges are helping with training programs for these workers, which expands community colleges' reach and assists their regional economies.

It is a good sign that the students participating in programs sponsored by area workforce development boards under the WIOA law can go on to earn credit for the skill courses community colleges offer, which can help them earn an associate degree and continue on a longer-term career path. Unfortunately, as Figure 7 shows, few students actually complete their programs.   This echoes the broader completion challenge facing many community colleges, where only 27% of students complete their programs within four years.[8] Notably, 38% of respondents did not know the answer to this question, suggesting limits in tracking these students.

**Figure 7: Percent of WIOA-Funded Students Who Complete their Degree or Certificate.**

Percentage of WIOA-funded students who complete their degree or certificate
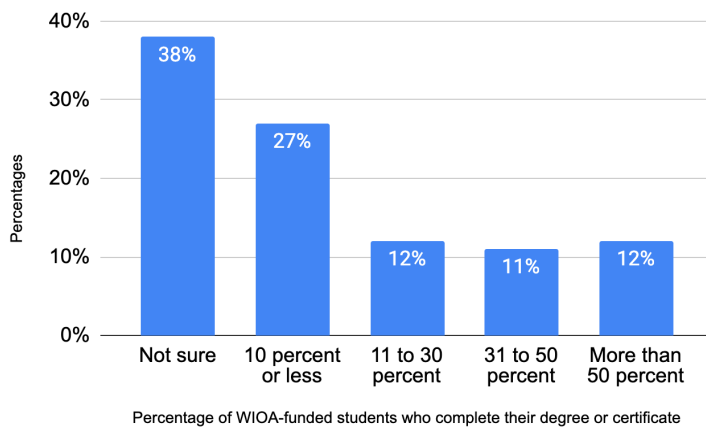
Note: Responses from 91 community college leaders.

VII. Manufacturing Equipment: A Critical Bottleneck in the Training Process

We see a pattern of underutilizing industry partners in funding community colleges' equipment. The majority of community colleges said that industry partners only fund 0-25% of the equipment they use, thus signaling underutilization. Some of this may be a reluctance to tie instruction to particular equipment vendors, but overall there seems to be an issue in collaboration with employers. However, when it comes to government grants, a consistently larger percent of community colleges said that they use these methods to fund their equipment in each percentage bucket, as seen in Figure 8.

The majority of community colleges themselves fund 0-25% of their equipment using their own resources. Nearly all respondents indicated that only 0-25% of equipment is funded by organizations they are sharing the equipment with. Building strong relationships to share the equipment with other organizations, especially employers as well as other schools, can give students experience with equipment they will use in their future jobs. This also allows community colleges to gain first-hand knowledge of emerging trends in manufacturing technologies and alter their curriculum to teach their students the necessary skills to have an advantage after graduation.

Figure 8: Sources of Funding for Community College Manufacturing Equipment.
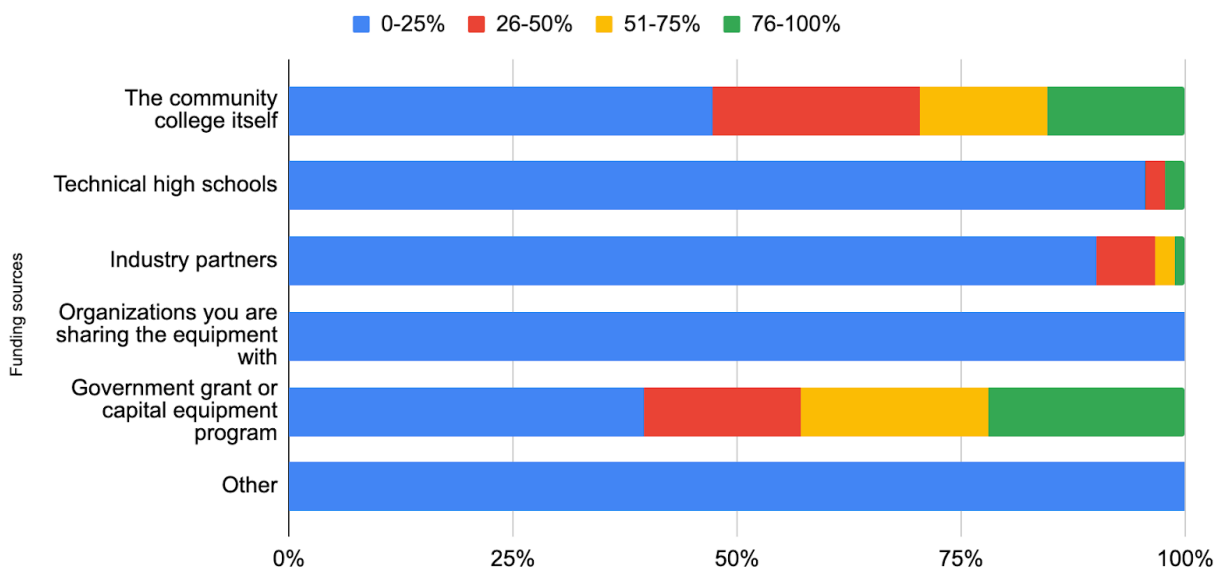
Note: 91 community college leaders indicated the percentage of manufacturing equipment used by their institution that was funded by each source. We then bucketed the responses into four percentage ranges for clarity of display. For example, on average, the majority of community colleges fund only 0-25% of their own equipment, whereas a very small percentage of community colleges fund 76-100% of their equipment.

Building on interviews that expressed concern over older and incompatible equipment, we asked about compatibility of course-related equipment. In Figure 9, educators indicated that current equipment at community colleges is very much compatible with each other; 36% of community colleges have 51 to 100 percent of their equipment mutually compatible or inter-related. This gives the advantage of sharing resources between different courses. The disadvantage of not upgrading the equipment will slow down the process of teaching new technologies to the students.

Figure 9: Percentage of Community Colleges Whose Equipment is Mutually Compatible or Inter-Related.
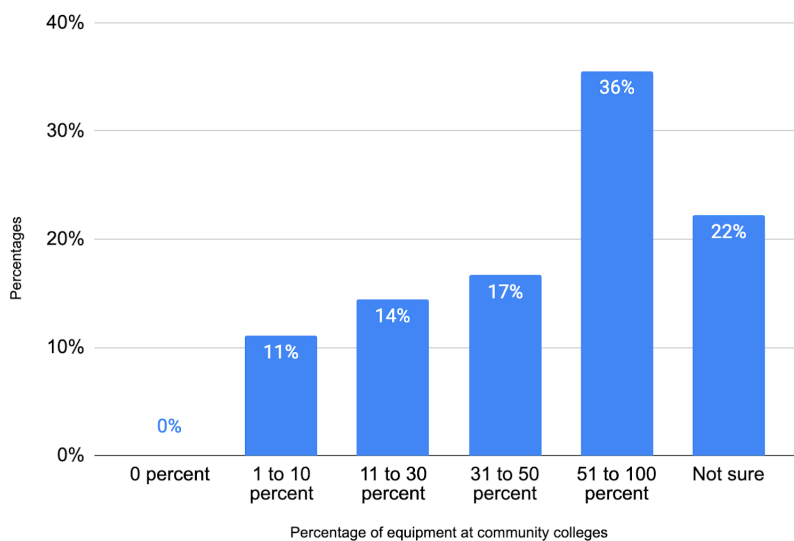
Note: Responses from 91 community college leaders.

To understand the situation more clearly, we asked about the relative importance of cost and compatibility when purchasing new equipment. responses indicated that cost is not the dominant factor in these decisions. 43% of community college respondents said they give approximately equal priority to cost and compatibility with existing equipment, while 42% of community colleges focused more on compatibility than cost.

VIII. Conclusion: The Engagement Opportunity for Community Colleges and Employers

This survey of community colleges and manufacturing employers paints a promising picture for advanced manufacturing training, among those that choose to engage. However, many challenges and untapped opportunities remain. Addressing these areas can provide benefits for students, employers, and the community colleges themselves.

Employers are generally satisfied with their engagement with community colleges; relatively few expressed dissatisfaction. However, there is a question of aspiration. Do employers consider it enough that community colleges supply some of their need for entry-level workers? Or should they aspire to something more – to work with community colleges to build a strong pipeline of workers who can do more at entry-level and regularly return for upskilling over time? The high numbers of employers who do not engage with community colleges for curriculum development (32%) or incumbent training (29%) represent lost opportunities for employers and community colleges to build a more strategic relationship.

Analyzing responses from community colleges reveals a more complex situation. Although most community colleges expressed satisfaction in their employer engagements, a sizable percentage were dissatisfied. This is especially true for the engagements that require close interaction, rather than just handing off graduates to the labor market. Nearly one-fourth of community colleges were dissatisfied with their employer engagements for curriculum development, internships, and apprenticeships, or training incumbent workers. Nearly 40% were dissatisfied with regional advisory boards. Once again, this could reflect a difference in aspiration. If employers consider community colleges to be a source of commodity products, in the form of workers trained for entry-level manufacturing jobs, then they may not engage deeply beyond the hiring process. However, just as strategic supply chain relationships can improve product design and availability, a strategic workforce learning approach can help community colleges to produce a larger supply of workers who are an even better fit for their employer partners.[3][6]

Partnership, while important, is a localized phenomenon. It works for the partners but not for companies that do not engage in those partnerships. It also cannot extend to geographic areas beyond the location of the community college. Therefore, community colleges should do more to improve transparency in the labor market for their graduates. Employers give high priority to work experience and industry certifications because they provide clearer indicators of an individual's competence. Associate degrees can signal this competence, but the strength of the signal depends on the extent to which employers know and trust the community college granting the degree.

Our survey data and interviews show two clear levers community colleges can use to improve labor market transparency for their graduates. First, since employers prefer work experience above all other credentials when hiring manufacturing technicians, community colleges should build more work experience into the curriculum. This could take the form of internships that clearly develop specific competencies through actual work experience or more formal apprenticeships that intersperse learning time and work time. Both require a strengthened partnership between educator and employer than a typical arms-length relationship can provide. Engaging in this way can also strengthen the partnership as employers and community colleges gain a common understanding about how to improve the training process. On the other hand, while "real world" classroom projects can help students build skills, our survey data suggests employers do not see them as a substitute for internships and apprenticeships. Employers ranked classroom projects lowest of the eight options provided – even lower than "we hire for will, not for skill," likely because they cannot readily translate them into work-related experience.

The second lever for labor market transparency is to link the community college curriculum to well-respected independent, industry-accepted certification processes. Embedding these certifications in the learning process enables students to graduate with both a degree and standardized signals of competence in specific skills. For example, Microsoft and Cisco offer widely-accepted information technology certifications that virtually assure employment in IT fields. Could community colleges embed comparable manufacturing certifications in their programs to help students and employers understand their job qualifications? Some areas have worked with employers to adopt systems for doing this, but many have not. So, credentialing presents an opportunity for community college and employer partnership. Such credentials – especially industry-recognized, externally-validated certifications – can help community colleges prepare their students and let them show clearly the skills that they are expected to have when they begin work.

When designed well, the process of creating certifications for particular skill areas can help students even before they graduate. Low completion rates are a fact of life for many community colleges. Building stackable certifications into the associate degree process creates an additional and parallel pathway to help students toward career advancement. A modular curriculum with stackable credentials can provide useful on-ramps and off-ramps that enable individuals to pursue learning on their own time and schedule. Incumbent workers can take specific courses as needed while building to degrees over time. Certifications can clearly show prior knowledge when entering educational programs. Degree programs that require two or more years will still be needed but can be based on a series of related, stackable credentials. This, in turn, can enable short programs that help workers get to required skills and employment earlier while providing a pathway toward additional skills or a degree, as desired.

In the world of advanced manufacturing training, the choice is clear for community colleges and employers. They can retain a relatively arms-length approach to the labor market – an approach that may still work in current manufacturing environments. Or they can engage much more closely to build partnerships that improve the training process and employment pipeline. This second approach may be increasingly required for advanced manufacturing. Our research suggests that this type of partnership can have benefits not only for students but also for employers and educators. Each engagement can improve shared understanding in a virtuous cycle that improves other areas of engagement over time.

However, building this more profound engagement with employers will require more than just asking for it to happen. It will require changes throughout the ecosystem. Community colleges must be more willing to customize their programs for groups of employers, an approach that is supported by shorter-term stackable certifications. They will need to design their curricula, especially on the credit-bearing side, to be more flexible, possibly through enhanced modularity and embedded micro-credentials. Community colleges and employer partnerships can also explore building industry-recognized certifications into academic programs.

Employers must be more willing to hire candidates with such recognized skills at good wages and advance them over time. They may also need to engage more closely during the training process through internships and apprenticeships. Creating industry associations can allow tighter engagement without one-to-one meetings between educators and large numbers of employers. Furthermore, all parts of the ecosystem need to be better at telling success stories so that potential employees see the value of entering the advanced manufacturing workforce.

Our research has identified a growing number of community college systems that are already doing these things. The MassBridge project, too, is investigating these options. If successful, it can become a model that other educational institutions can adopt in their areas.

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Appendix

Benchmarking Survey: Community Colleges

Introduction MassBridge Advanced Manufacturing Curriculum Benchmarking Survey

Thank you for taking this survey. Your participation will help us understand better how to bridge the education/employment gap for manufacturing. We expect this survey to take no more than 10 minutes. Participation in the survey is voluntary, and you may cease participation at any time. If you wish us to delete the information you provided, simply email us at the address below. Your privacy is important to us. Your information will be kept confidential. The detailed information collected through the survey will be seen only by our small MIT research team. All data will be kept secure and will be reported only in aggregated form. If you have any questions about the study or our confidentiality processes, please contact the project lead, Dr. George Westerman, at xxxxx.

Click ok to proceed

- OK

Q1 Please tell us about yourself

- First Name _____
- Last Name _____
- Title _____
- Institution _____

Q2 Would you like a copy of our survey findings?

- Yes, (Please specify your email below)
- No

Q3 Community Colleges often work with local Employers for various hiring and training activities. If you engage in any of the activities below, how satisfied or dissatisfied are you with their effectiveness?

	Does Not Apply	Very dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Very satisfied
Partnering with manufacturing companies to hire your graduates into manufacturing roles.	●	●	●	●	●	●
Partnering with manufacturing companies for student internships and apprenticeships.	●	●	●	●	●	●
Engaging with manufacturing companies to train their incumbent employees	●	●	●	●	●	●
Engaging with manufacturing companies in developing new courses.	●	●	●	●	●	●

Engaging with a state-wide or regional industry advisory group for advice on courses or curricula.	●	●	●	●	●	●

Q5 How much of the equipment for your advanced manufacturing courses are funded by the following sources?
    Please fill in with corresponding percentages.
        The community college itself : _____
        Technical high schools : _____
        Industry partners : _____
        Organizations you are sharing the equipment with : _____
        Government grant or capital equipment program : _____
        Other : _____
        Total : _____

Q6 What percentage of your course-related equipment ...

	Not sure	0 percent	1 to 10 percent	11 to 30 percent	31 to 50 percent	51 to 100 percent
... is mutually compatible or inter-connected	●	●	●	●	●	●
... has formal plans to be replaced	●	●	●	●	●	●

Q7 When buying new course-related equipment, how important are cost and compatibility? Please use the slider
    to indicate relative importance.

	Lowest cost	Equal priority	Compatibility with existing equipment

0   100

Q8 Please select all the types of equipment used in your courses.
- Hand tools
- Handheld power tools
- Manual metalworking (mill, lathe, bandsaw)
- CNC metalworking
- 3D printers
- CAD/CAM
- Welders
- Robots
- PLCs
- Analog/digital electronics
- PCB fabrication
- Laser cutting
- Advanced/IoT instrumentation and sensors
- Biological or chemical (synthesis, analysis)

- Optics (fiber optics, optical sensors, evaluation and testing)
- Micro/nano (fabrication, measurement, imaging)
- Other _____

Q9 Do you embed industry-recognized certificates into your academic degrees and certifications? Check all that apply.

- SACA (Smart Automation Certification Alliance)
- NIMS (National Institute of Metalworking Skills)
- NOCTI (National Occupational Competency Testing Institute)
- PMMI (Packaging Machinery Manufacturing Institute)
- NC3(e.g. TRANE, Lincoln Electric)
- AWS (American Welding Society)
- SME (Society of Manufacturing Engineers)
- MSSC (Manufacturing Skills Standards Council)
- Amatrol Industry 4.0
- Vendor-specific(e.g. Fanuc, Rockwell, Siemens)
- Other (6) _____

Q10 Does your community college work with your state MEP(Manufacturing Extension Partnership)?

- Yes
- No
- Not sure

Q11 Does your community college work with any Manufacturing Innovation Institutes (MIIs) in the Manufacturing USA network?

- Yes
- No
- Not sure

Q12 Does your community college provide training for area workforce development board WIOA programs?

- Yes
- No
- Not sure

Q12.1 Can the participants in WIOA programs get credit at your institution?

- Yes
- No

Q12.2 If you answered yes to the previous question, what percentage of the participants eventually earn an associate degree or certificate at your institution?

- 10 percent or less
- 11 to 30 percent
- 31 to 50 percent
- More than 50 percent
- Not sure

Q13 Do you customize credit-based programs for particular Employers?

- Yes
- No

Q14 Do you customize non-credit programs for particular Employers?

- Yes
- No

Q15 How flexibly can you reconfigure elements within your credit-based programs?

- Not flexible.
- We can swap courses, but not course elements.
- We have a few elements that can change within courses.
- We are very flexible at the level of elements within courses.

Q16 How flexibly can you reconfigure elements within your non-credit programs?

- Not flexible
- We can swap courses, but not course elements
- We have a few elements that can change within courses
- We are very flexible at the level of elements within courses

Q17 Does your community college offer stackable credentials?

- Yes
- No

Q18 How frequently do you perform a significant curriculum revision?

- every year
- every 2-3 years
- every 4-5 years
- every 6-10 years
- 10 years or more

Q19 Which of the following mechanisms does your institution use to assess the curriculum? Check all that apply.

- Learning outcomes
- Requirements of accreditation groups
- Alignment with industry needs
- Completion rates
- Student employment outcomes
- Student feedback
- Employer feedback on students skills
- Employer feedback on industry needs
- Emerging technology trends
- Other   _____

Q20 To what extent does your curriculum address the following technical topics?

	Not addressed	Part of a course	One or more courses	Certificate program	Degree program
Additive manufacturing	●	●	●	●	●

CNC machining	●	●	●	●	●
Electronics	●	●	●	●	●
Mechatronics	●	●	●	●	●
Artificial intelligence	●	●	●	●	●
Cybersecurity	●	●	●	●	●
Cloud computing	●	●	●	●	●
Computer programming	●	●	●	●	●
Data Analytics	●	●	●	●	●
Data management	●	●	●	●	●
Digital twins	●	●	●	●	●
AR/VR	●	●	●	●	●
Internet of Things (IoT)	●	●	●	●	●
Robotics and automation	●	●	●	●	●
Classical or statistical process/quality control	●	●	●	●	●
Design of experiments	●	●	●	●	●
Manufacturing system control and/or optimization	●	●	●	●	●
Lean manufacturing practices and/or 5S	●	●	●	●	●
Technical troubleshooting	●	●	●	●	●
Other	●	●	●	●	●

Q21 To what extent does your curriculum address the following non-technical topics?

	Not addressed	Part of a course	One or more courses	Certificate program	Degree program
Digital Literacy	●	●	●	●	●
Communication	●	●	●	●	●
Team Work	●	●	●	●	●
Critical thinking	●	●	●	●	●
Problem-solving	●	●	●	●	●
Professional skills	●	●	●	●	●
Reading comprehension	●	●	●	●	●
Research	●	●	●	●	●
Systems thinking	●	●	●	●	●
Scientific Communication	●	●	●	●	●
Other	●	●	●	●	●

Q22 To what extent do you teach the following types of activities in your programs?

	Not addressed	One or a few activities	Specialized course	Integrated throughout one course	Integrated throughout multiple courses	Integrated throughout the program
Discerning what to measure or observe to know whether a problem exists.	●	●	●	●	●	●
Hypothesizing about the cause of the problem and taking into account multiple and possibly conflicting views.	●	●	●	●	●	●
Developing a framework to confirm or dispel the hypothesis.	●	●	●	●	●	●
Inferring from the test results whether the test confirms or dispels the hypothesis.	●	●	●	●	●	●

Communicating the outcome to the right people and in the right way.	•	•	•	•	•	•

Optionally, if you have any suggestions on best practices for collaborating as community colleges with Employers for manufacturing workforce training please let us know below.

Thank you for participating in our survey. Your answers will be valuable as we examine community college approaches to designing curriculum for advanced manufacturing training. In addition, we hope to provide helpful advice for community colleges and Employers to improve their programs. If you provided your email earlier, we will send you our report. If you did not, but would still like the report, please email georgew@mit.edu.

Benchmarking Survey: Employers

MassBridge Advanced Manufacturing Curriculum Benchmarking Survey

Thank you for taking this survey. Your participation will help us understand better how to bridge the education/employment gap for manufacturing. We expect this survey to take no more than 10 minutes. Participation in the survey is voluntary, and you may cease participation at any time. If you wish us to delete the information you provided, simply email us at the address below. Your privacy is important to us. Your information will be kept confidential. The detailed information collected through the survey will be seen only by our small MIT research team. All data will be kept secure and will be reported only in aggregated form. If you have any questions about the study or our confidentiality processes, please contact the project lead, Dr. George Westerman, at xxxx.

Click ok to proceed

- OK

Q1 Please tell us about yourself

- First Name   _____
- Last Name   _____
- Title   _____
- Organization   _____

Q2 Which organizational level are you most comfortable answering questions about?

- The whole enterprise
- Part of the enterprise (Please specify below)
- _____

For the rest of the survey, where we talk about 'your organization', please refer to the organizational level you just answered.

Q3 How large is your organization?

- 1 - 9 employees
- 10 - 49 employees
- 50 - 249 employees
- 250 - 500 employees
- 500+ employees

Q4 Would you like a copy of our survey findings?

- Yes (Please provide your email address below)   _____
- No

The survey uses the term a*dvanced manufacturing technician* in some of the questions. When you answer these questions, please keep the following definition in mind; "*Advanced Manufacturing technicians run and maintain factory equipment and assembly processes, monitor and check the product quality and document results.*"

Q5 Do you have a category of workers with the title of advanced manufacturing technicians?

- Yes
- No

If no, please consider the most advanced level of non-supervisory manufacturing technician at your organization while completing the survey.

Q6 When hiring advanced manufacturing technicians, which of the following criteria are weighted the most? Please rearrange them so that the first item in the list is the most important and the last item is the least important option. You can click and drag the options.
_____ Associate degree
_____ Four-year degree
_____ Industry certification
_____ Work experience
_____ The number of apprenticeships in a similar topical area
_____ The number of internships in similar topical areas
_____ Projects done within an academic program.
_____ We hire for will, not for skill

Q7 When hiring advanced manufacturing technicians, what credentials do you look for in a new hire? For each, select either not required, optional but helpful, or required.

	Don't know (6)	Not required (1)	Optional but helpful (3)	Required (2)
Associate degree in manufacturing	●	●	●	●
Other associate degrees	●	●	●	●
Other general manufacturing certification	●	●	●	●
SACA (Smart Automation Certification Alliance)	●	●	●	●
NIMS (National Institute of Metalworking Skills)	●	●	●	●
NOCTI (National Occupational Competency Testing Institute)	●	●	●	●
SME (Society of Manufacturing Engineers)	●	●	●	●
NC3(e.g. TRANE, Lincoln Electric)	●	●	●	●
PMMI (Packaging Machinery Manufacturing Institute)	●	●	●	●

AWS (American Welding Society)	●	●	●	●
MSSC (Manufacturing Skills Standards Council)	●	●	●	●
Amatrol Industry 4.0	●	●	●	●
Vendor-specific(e.g. Fanuc, Rockwell, Siemens)	●	●	●	●
Other	●	●	●	●

Q8 Employers often work with local community colleges for various hiring and training activities. If you engage in any of these activities below, how satisfied or dissatisfied are you with the effectiveness?

	Does Not Apply	Very dissatisfied	Somewhat dissatisfied	Neither satisfied nor dissatisfied	Somewhat satisfied	Very satisfied
Partnering with community colleges or technical high schools to hire their graduates into manufacturing roles	●	●	●	●	●	●
Partnering with community colleges or technical high schools to hire their students for internships or apprenticeships	●	●	●	●	●	●
Partnering with community colleges or technical high schools to train our incumbent employees	●	●	●	●	●	●
Engaging with a state-wide or regional industry advisory board to give advice on courses or curricula	●	●	●	●	●	●
Engaging with community colleges on developing new manufacturing courses	●	●	●	●	●	●

Q9 How many times a year does your organization meet with a community college?

● 0 times
● 1 - 2 times
● 3 - 6 times
● 7 or more times

Q10 How frequently do you give input on the revision or development of a community college manufacturing curriculum?

● once a month
● once a term
● once a year
● once every two years
● once every four years
● Never

Q11 Please select all the types of equipment used in your organization's manufacturing processes

● Hand tools
● Handheld power tools
● Manual metalworking (mill, lathe, bandsaw)
● CNC metalworking
● 3D printers
● CAD/CAM
● Welders
● Robots
● PLCs
● Analog/digital electronics
● PCB fabrication
● Laser cutting
● Advanced/IoT instrumentation and sensors
● Biological or chemical (synthesis, analysis)
● Optics (fiber optics, optical sensors, evaluation and testing)
● Micro/nano (fabrication, measurement, imaging)
● Other _____

Q12 Please select all the technologies and skills that are used at your manufacturing organization

● Additive manufacturing
● CNC machining
● Electronics
● Mechatronics
● Artificial intelligence
● Cybersecurity
● Cloud computing
● Computer programming (Basic computer skills)
● Data analytics
● Data management
● Digital twins
● AR/VR
● Internet of Things (IoT)
● Robotics and automation
● Classical or statistical process/quality control

- Design of experiments
- Manufacturing system control and/or optimization
- Lean manufacturing practices and/or 5S
- Technical troubleshooting
- Other _____

Optionally, if you have any suggestions on best practices for collaborating as Employers with community colleges for manufacturing workforce training please let us know below.

Thank you for participating in our survey. Your answers will be valuable as we examine manufacturing organizations' approaches to collaborating with community colleges for advanced manufacturing training. We hope to provide useful advice for community colleges and Employers to improve their programs. If you provided your email earlier, we will send you our report. If you did not, but would still like the report, please email xxx.