RESEARCH BRIEF

How Can the United States Prepare a Workforce for Advanced Manufacturing Using Robotics?

Photo credit: B4LLs/Getty Images

There is much information and misinformation about the future of work as it relates to robots and jobs in manufacturing. The Advanced Robotics for Manufacturing Institute (ARM) engaged the RAND Corporation to review and assimilate publicly available information on this topic with a goal of coalescing data and trends. This research should inform ARM's membership, others in the robotics industry, and the wider policymaking community in their approaches to managing workforce issues.

This research was sponsored by the Advanced Robotics for Manufacturing Institute.

Manufacturing in the United States has experienced a bit of a renaissance of late, with a notable increase in the number of individuals employed in manufacturing since 2010. Many experts expect additional job opportunities in manufacturing as large numbers of existing workers retire and advancing technologies, such as robotics, create new positions not previously seen on the typical manufacturing floor. Importantly, these manufacturing jobs will likely pay wages higher than the national average for equivalent positions in other industries, according to a 2017 report by the National Academies of Sciences, Engineering, and Medicine, *Building America's Skilled Technical Workforce*. But experts also warn that workers will likely need more-specialized skills to engage with advancing robotics and other technologies in manufacturing.

To assist workers and employers in preparing for this shift, RAND researchers addressed the following questions related to preparing a robotics-ready manufacturing workforce: What is the economic context of manufacturing using robotics? How are current education and training programs preparing people to work with robots in manufacturing? And finally, what practices might improve these programs and their desirable outcomes, such as a job-ready workforce?

KEY FINDINGS

- There is a critical need for better and more-integrated workforce data systems that support data-driven policies for building a better AM workforce. This need can only be addressed by all stakeholders, including employers.
- A weak or absent policy response in the short to medium term might aggravate negative impacts for less educated and vulnerable workers or fail to draw the large, skilled workforce needed by employers.
- The number of AM-related education and training programs is growing, but, based on newly available data, many programs do not offer field-based experience, industry-based credentials, or emphasis on nontechnical "21st-century" skills (e.g., problem-solving and dependability and reliability).
- Based on the available research evidence and federal guidelines for determining quality research evidence, the most-promising practices in education and training programs in AM using robotics include industry-based credentials, apprenticeships, and student support services. Program providers should continue to experiment with the exact format of these practices, while conducting rigorous evaluations of them.

Methodology

RAND researchers addressed the three questions above with analyses related to *advanced manufacturing* (AM). A June 2011 report by the President's Council of Advisors on Science and Technology broadly defines AM as "activities that . . . depend on the use and coordination of information, automation, computation, software, sensing, and networking." To understand the nation's AM workforce development needs, particularly in the case of AM using robotics, the researchers first examined the economic context in which education and training programs in AM using robotics now operate. Then, they researched the number of related programs across the country and analyzed the curricular content and instructional practices of programs located in the Midwest and Pennsylvania, which are traditional hubs of manufacturing in the United States. The researchers' original data on program content and practices and their analysis of these data provided unique insights into how well current programs may address the potential skills gap in AM. Finally, researchers reviewed evidence on the efficacy of educational practices related to AM workforce and robotics training—some of which are currently in use by AM training programs. In combination, answers to these three research questions provide critical information for employers, educators, and policymakers to consider as they seek to enhance U.S. manufacturing competitiveness.

Findings

What Is the Economic Context of Manufacturing Using Advanced Technologies?

U.S. manufacturing is currently growing jobs and becoming even more productive, but the United States is not adopting robots for AM as quickly as some other countries

The trend in industrial production has dipped and spiked over the past 45 years (for example, during the Great Recession), but industrial production has generally increased. Though the trend in the number of manufacturing jobs has not always matched the trend in industrial production, the demand for technicians and other manufacturing workers has grown since 2010 and the demand for skilled workers is expected to continue to grow as the current manufacturing workforce ages and as technological innovations in manufacturing (such as more-advanced industrial robots) continue apace. Still, the lower rate of adoption of advanced industrial robots in the United States, compared with rates in China and Japan in recent years, suggests that U.S. manufacturing might not benefit as much from likely productivity gains associated with advanced industrial robotics.

The U.S. workforce needs to be ready to benefit from further adoption of robotics for AM

Firms, consumers, workers, and the broader economy all likely will be affected in positive and negative ways as AM continues to adopt advanced industrial robots. For example, some workers might reap rewards for their technical skills and higher educational levels, while others with less education might not be able to find or keep manufacturing jobs. This is because automating portions of the manufacturing process generally reduces the number of workers needed to complete a job, even as new technologies create new types of jobs and raise manufacturing productivity over time. All stakeholders have a vital role to play in responding to such a transition. A weak or absent response in the short to medium term might aggravate negative impacts for less educated and vulnerable workers or fail to draw the large, skilled workforce needed by employers.

How Are Current Education and Training Programs Preparing People to Work with Robots in Manufacturing?

In higher education, a small but growing share of programs offer technician training for AM

The researchers' assessment of 2,407 four-year universities and colleges and 1,476 two-year colleges in the United States demonstrates that about 0.27 percent of the 271,497 unique available higher education programs are directly related to technician training in manufacturing at the sub-baccalaureate level ($N = 743$). About 0.1 percent of all postsecondary programs serving undergraduate students in the United States are directly related to manufacturing *and* culminate in a bachelor's degree ($N = 251$). But it remains unclear whether the current supply of sub-baccalaureate program can train a sufficient number of manufacturing technicians given projected shortages in skilled technical workers in manufacturing and projected increases in the use of robotics in AM. As many as 2.4 million jobs in manufacturing could go unfilled because of an insufficient supply of manufacturing workers, according to a 2018 analysis for Deloitte Insights and the Manufacturing Institute.

Programs for AM using robotics vary with respect to flexibility in program duration, combination of certificates and degrees, and emphasis on industry

Three key ways to potentially address the expected gap between available manufacturing jobs and the supply of manufacturing workers are to (1) introduce greater flexibility in the time it takes to train a manufacturing technician, (2) combine various certifications to build technical manufacturing careers and address emerging workforce needs in the face of technological innovation, and (3) provide industry-recognized credentials or leverage specific industry partnerships that also address emerging workforce needs. About 50 percent of programs analyzed in the Midwest and western Pennsylvania (111 of 222 programs total) offer certificates that take less than a year to complete; 50 percent allow students to combine or "stack" certificates to a higher credential, such as an associate's degree. A rather small share of programs promote specific industry partnerships or industry-recognized credentials in their program materials (2.4 and 1.4 percent, respectively).

Most programs for AM using robotics emphasize technical and academic skills; nontechnical workplace and personal effectiveness skills are less emphasized

Since the 1960s, the importance of nonroutine analytic and interpersonal tasks has increased in U.S. jobs—including manufacturing jobs.[1] However, programs for AM technicians working with robotics do not appear to emphasize nonroutine analytic and interpersonal skills. Figure 1 shows skills emphasized in program materials in the Midwest region and Pennsylvania. Skill categories were taken from the U.S. Department of Labor's AM competency model (updated April 2010) and are mutually exclusive. The skill categories shown in the figure are "Technical skills, general"; "Technical, workplace"; "Nontechnical, workplace"; and "Personal effectiveness." The figure shows that most programs emphasize technical skills (such as working with tools and technologies) over nontechnical workplace skills (such as teamwork) and personal effectiveness skills (such as dependability and reliability).

Many programs do not emphasize some of the technical skills that an AM technician will need

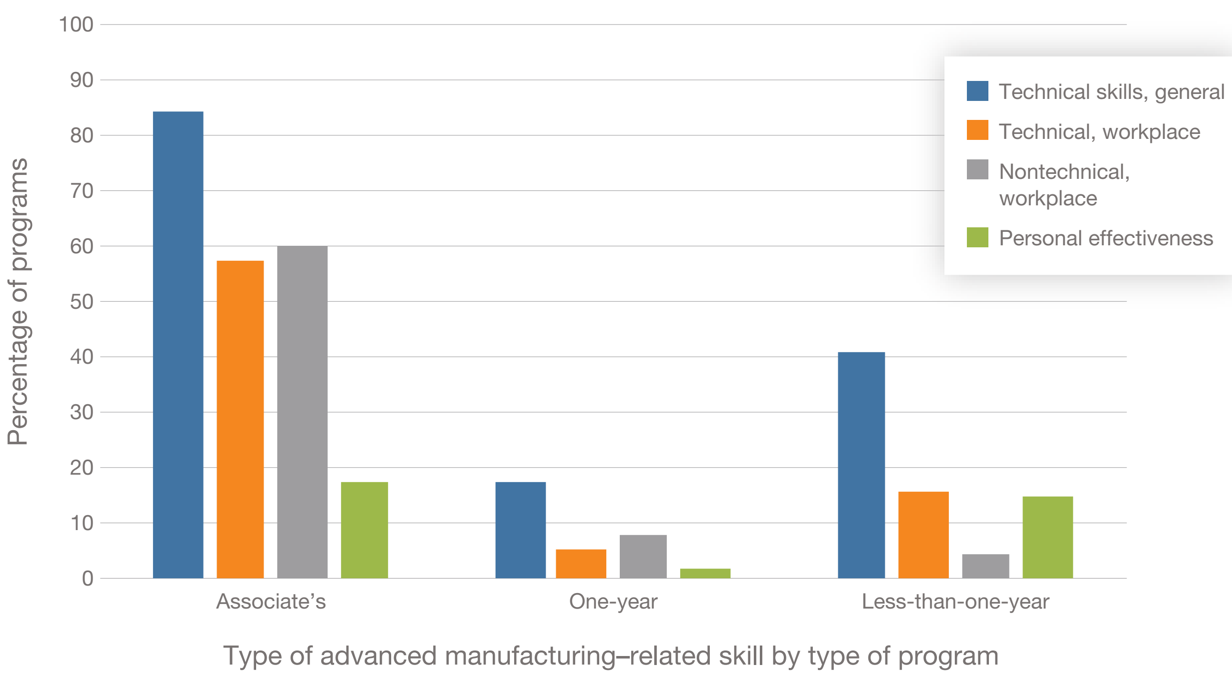
The Department of Labor's O*NET system suggests that AM technicians must understand computer-assisted design, programmable logic controllers, computer numerical controls, and supervisory control and data acquisition. RAND researchers found that 45 percent of the sample programs emphasize technical skills related to computer-assisted design, while only 31 percent teach skills related to programmable logic controllers. Only 30 percent teach skills related to computer numerical controls. Few programs (12 percent) publicly emphasize supervisory control and data acquisition.

Work-based learning has not taken root in AM education and training programs

Of the programs examined, most training occurs in a relatively traditional classroom setting with an expert instructor. Only 24 and 15 percent of associate's and one-year programs in the sample, respectively, promoted work-based learning in program materials. Shorter-term, and therefore potentially more-flexible,

FIGURE 1

Percentage of Programs Emphasizing Various Advanced Manufacturing–Related Skills, Midwest and Pennsylvania, 2019



SOURCE: CareerOneStop data.

programs lasting less than a year did not offer field experiences at all. Perhaps individuals are able to combine work and higher education programs (especially less-than-one-year programs) on their own. But the overall lack of work-based learning in these programs is surprising, considering that the Manufacturing Institute recently recommended apprenticeships and other field experiences as integral to effective training in AM.[2]

What Practices Might Improve Education and Training Programs in Advanced Manufacturing Using Robotics?

Manufacturing experts suggest that a variety of educational practices can help address worker shortages and skills gaps, but the efficacy of many of these practices is uncertain

The federal government and various experts have flagged numerous practices for addressing education and training needs in manufacturing, including industry-based credentials, stackable credentials, online instruction, bootcamp courses, and apprenticeships. Academic research further underscores the general importance of other practices, such as additional non-academic or "wraparound" student support services for some students. Based on 2020 guidelines from the U.S. Department of Education's What Works Clearinghouse, very little of the research on the effects of these educational practices is rigorous enough to draw succinct conclusions as to whether they improve education and training outcomes. A smaller share of this research addresses students attending community colleges specifically; almost none of it addresses students attending manufacturing technician programs.

The available evidence indicates that industry-based credentials, apprenticeships and perhaps other forms of work-based learning, and student wraparound support services are the most-promising education practices for AM technician programs to date

According to the available research and Department of Education guidelines for determining the rigor of research evidence, research on these three educational practices will likely benefit AM students by preparing them for work in AM factories, increasing their wages, and/or helping ensure that they complete their training program of choice.

The analysis indicates that not-so-promising practices include traditional online and bootcamp courses and stackable credentials

Studies have found that large online courses generally have negative effects on students, especially those who are academically weak. Similarly, bootcamp courses that aim to develop student competency in key technical skills in a few days to a few months also might not benefit students and, thus, U.S. manufacturing. This is not to say that these educational practices should be abandoned entirely. Some research suggests that online instruction combined with in-person instruction and/or social and cooperative work with students' peers might unlock benefits of online learning. And some manufacturing education programs are experimenting with bootcamps in combination with other, more-intensive training. Overall, AM stakeholders should continue to experiment with these educational practices while keeping a close, evaluative eye on whether they improve AM training, using appropriate data and rigorous evaluation methods.

Recommendations

Although several recommendations are made in the full report, key recommendations related to education and training programs in AM include the following.

Emphasize nontechnical, "21st-century" skills

Many AM sub-baccalaureate programs do not emphasize critical nontechnical skills, even though these skills are of increasing importance under present and likely future waves of roboticization and automation in AM. Training and education programs related to AM using robotics are typically short, but instruction in such skills can be woven throughout program curricula. These skills should be based on standardized and detailed competencies that clearly emphasize 21st-century skills that are uniquely human.

Bring more employers to the table via intermediary organizations and services

A number of recent federal initiatives (for example, the Workforce Innovation and Opportunity Act of

2014) aim to increase employers' direct participation in workforce development. Some 90 percent of AM employers are small to medium-sized firms that might face particular resource constraints to participation. Thus, intermediary organizations, such as the U.S. Chamber of Commerce, manufacturing institutes, and unions, can play a critical role in providing effective training services with employers. For example, Manufacturing Extension Partnership network members might be able to provide trained coaches to small to medium-sized firms to provide direct, as-needed support to onboard and reskill workers. Ideally, coaches would complement ongoing employee training, including employer-provided training and external training at area education and training providers, such as community colleges.

Conduct rigorous research on what works in education and training in AM and other critical industries

Despite increasing interest in the topic, there remains a lack of rigorous research on career and technical training across the educational and labor market careers. However, the Departments of Education and Labor have begun to respond, so reliable answers to questions about what works in career and technical education, when, and for whom (e.g., nontraditional or low-income students) might be available in the near future. It will be important to ensure that some of this research directly addresses career and technical education in AM.

Notes

[1] Yujia Liu and David B. Grusky, "The Payoff to Skill in the Third Industrial Revolution," *American Journal of Sociology*, Vol. 118, No. 5, March 2013, pp. 1330–1374; and David J. Deming, "The Growing Importance of Social Skills in the Labor Market," *Quarterly Journal of Economics*, Vol. 132, No. 4, 2017, pp. 1593–1640.

[2] Manufacturing Institute, "Advanced Manufacturing Competency Model," undated. As of February 10, 2020: http://www.themanufacturinginstitute.org/~/media/92432E603CFE4C51849734DF3B5CB08B/Manufacturing_Pathways.pdf

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This brief describes work done in RAND Education and Labor and documented in *An Analysis of Education and Training Programs in Advanced Manufacturing Using Robotics*, by Megan Andrew, Timothy Marler, Jesse Lastunen, Hannah Acheson-Field, and Steven W. Popper, RR-4244-ARMIP, 2020 (available at www.rand.org/t/RR4244).

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