Open Learning

Preliminary report —

THE WORKFORCE EDUCATION PROJECT

April 2020

SUBMITTED IN FULFILLMENT OF A RESEARCH GRANT FROM SCHMIDT FUTURES

THE RESEARCH GROUP

William B. Bonvillian
Sanjay Sarma
Meghan Perdue
Jenna Myers

CONTENTS

EXECUTIVE SUMMARY 2

ACKNOWLEDGEMENTS 4

SECTION 1: INTRODUCTION 6

SECTION 2: BREAKDOWNS IN TODAY'S WORKFORCE EDUCATION 11

SECTION 3: THE BROKEN LABOR MARKET INFORMATION SYSTEM 19

SECTION 4: THE UNIVERSITY ROLE IN WORKFORCE EDUCATION 22

SECTION 5: THE NEW EDUCATIONAL TECHNOLOGIES 32

SECTION 6: THE APPRENTICESHIP MODEL 42

SECTION 7: THE NEW CONTENT DELIVERY METHODS 55

SECTION 8: POLICY RECOMMENDATIONS 77

ENDNOTES 80

ABOUT THE RESEARCH GROUP 92

EXECUTIVE SUMMARY

The nation faces a series of major societal challenges. While the upper middle class is thriving, the middle class is thinning out. Too many in the working class are shifting from the middle class to an expanding, lower-end, lower-paid services sector. At the same time, the overall workforce is up-skilling as new technologies incrementally enter the economy, with good jobs increasingly going to those with a college education. Those without it face a quality job challenge. Could a reformed workforce education system, building on institutions now in place, help us reverse growing income inequality and help put the middle class back on a growth track?

This is a difficult task because the country lacks a sound and readily accessible workforce education system. There are too many gaps in the current system, with disconnects between school and work, between federal labor and education programs, between employers that need to collaborate, and between education institutions. We do not have enough advanced skills programs, involved institutions are generally underfunded, and colleges and universities are largely disengaged. Behind this problematic labor market is a broken information system. Poor information systems make for poorly functioning markets; U.S. labor markets have a weak information system, with limited information available to participants and employers. A new navigation system is needed.

Colleges and universities have been key to the success of the nation's technological advance and growing its middle class. But higher education is an established and complex legacy sector that is resistant to change. Despite the need for new education technologies and workforce delivery models, it has not been educating for the workplace; it has largely focused on foundational skills as opposed to career skills. Given the accelerating pace of technology introduction and economic inequality

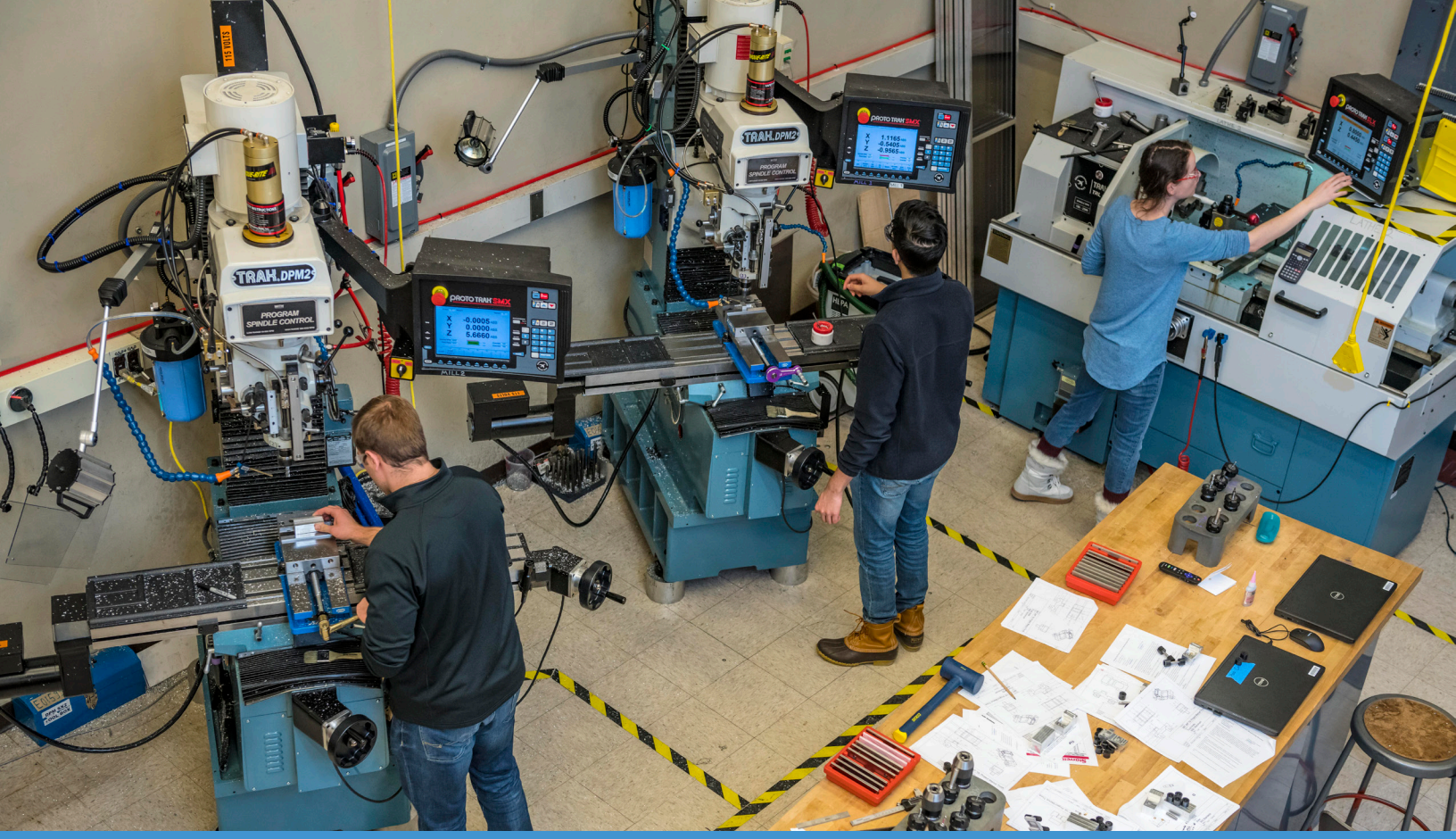
problems, our higher education sector may well need to give greater focus to teaching career skills in addition to foundational skills.

New education technologies – online education, virtual reality, augmented reality, artificial intelligence, digital tutors and computer gaming - present new education opportunities. They could make significant contributions to workforce education, with its need for "learning by doing." Supplementing existing workforce education, the new technologies could help it to scale.

In addition to new technologies, new models to connect school and work are evolving. Behind this study project is a policy goal: to identify replicable models that can be scaled up to achieve a societal impact. This is typically how U.S. social policy proceeds, and a number of models are identified. Apprenticeships are one possibility. Except in the construction trades, the U.S. has had a limited history with apprenticeships. In contrast, Germany and other European nations have intricate collaborative apprentice systems between employers, educators and government which have cut youth unemployment and enabled a solid transition to work. New approaches in the U.S. to apprenticeship and what could be called "apprenticeship light" are starting to show promise.

Behind all this is a deep workforce delivery challenge where additional models are emerging. These include new programs at community colleges with short programs that reach underemployed workers, programs that simultaneously reach community college, high school and incumbent workers, and new apprenticeship programs. The new models include technical colleges that have found ways to triple the completion rate compared to area community colleges, technical and comprehensive high schools that link students to both jobs and follow-on community colleges, and efforts by employers to offer apprenticeships and to collaborate on workforce training. They also include state efforts to unify the delivery of disconnected federal labor and education programs, development of new labor market information navigators, and adoption of promising new education technologies.

Of course, new models require policy implementation. There are a range of complementary implementing roles for government (by state, federal and local governments), for employers and for education institutions, from high schools through universities. Change will require cooperation across all three kinds of institutions. This will mean integrating classroom education with hands-on training linked with area employers and their needs; forming groups of area employers to work together and with education providers to support efforts to train and employ graduates; orienting education and training not just to a particular job but to more lasting career development; building a lifelong education and training system between employers and schools that can continue to upgrade skills across the workforce; and introducing new education technologies that can scale up to meet the size of this workforce challenge.



ACKNOWLEDGEMENTS

This is the preliminary report of the Workforce Education Project, a research effort begun in 2018 at MIT Open Learning. As MIT's implementation of online courses and programs has developed over the past several years there has been a growing focus on meeting workforce needs, through our MOOC courses, MicroMasters certificates, bootcamps and professional education. Given this growth, we felt a need to understand the landscape of workforce education in much more depth. We also felt a strong need, in light of the social disruption of recent years, to try to contribute to understanding and meeting the nation's growing workforce needs. This initial report deals with problems in the current U.S. workforce education system and in our accompanying labor market information system, the role universities could play in workforce education, new education technologies that could help us reach the scale required to meet workforce needs, new apprenticeship programs, and a range of new models that could help in delivering workforce content. A subsequent final report will add perspectives on such issues as the workforce education challenges faced by the working class, new technologies requiring new levels of education and training, workforce developments in three major economic sectors (manufacturing, retail and healthcare), workforce education content questions, and a detailed series of policy recommendations.

There are many to thank for assisting in the project's progress to date.

First, we thank Schmidt Futures for the foundation grant that has made this study possible; we have benefitted from their deep concern about these workforce issues.

Critical to the project have been Meghan Perdue, Digital Learning Fellow at MIT's Office of Open Learning, and Jenna Myers, MIT Sloan School doctoral candidate, who have ably served as our research advisors. Each has tackled major parts of the workforce puzzle and four of their

detailed case studies are posted and available along with this report. We have also been assisted by an early travel grant from MIT's International Policy Lab led by Chap Lawson and Dan Pomeroy that got the project started; we thank Dan for his important assistance on a series of early meetings and briefings that helped shape the overall project. MIT's Jameel World Education Lab (J-WEL) supports ongoing research on education and workforce issues and has contributed important insights to this report.

Our MIT colleagues have played an important role advising us. Tom Kochan and Paul Osterman, MIT's Sloan School able experts and leaders on workforce issues, have helped us in many ways, from their writings to reviewing their ideas with us. We particularly appreciate Tom's close read of this report in draft form and his suggestions for it. David Autor, David Mindell, Elizabeth Reynolds and members of MIT's interdisciplinary task force on Work of the Future, have helped us better understand an important context for our study, the effects on the workforce of evolving new technology advances. Political Scientist Suzanne Berger has contributed insights at many stages, helped review the draft, and has been a great sounding board, as has George Westerman of the Office of Open Learning's J-WEL workforce project. Zenep Ton of the Sloan School has advised on retail sector developments. Kim Kimmerling and Julie Diop, leaders of the AIM Photonics Academy located at MIT have helped us see the practical demands of developing workforce education in an advanced technology sector. At MIT Open Learning we have appreciated the help of Lana Cook, Tom Smith, Patricia Gao and Yvonne Ng, who supported the project and helped prepare the report.

We have also been greatly helped by many experts and leaders who have shown us first hand new models for workforce education. Particular thanks go to Sandy Shugart, Kathleen Plinske and Joe Baptista at Valencia College in Orlando and Oceola, Florida; Captains Wes Naylor and Erik Etz at the Naval Air Warfare Training Systems Division in Orlando; Marilyn Barger of Florida Advanced Technology Education and Kevin Carr of FloridaMakes; Mitchell Harp and Melissa Stowasser of Trident Technical College in Charleston; Vince Lombardy of VTL in Charleston; Mark Johnson, Josh Summers and Kapil Chalil Madathil of Clemson University; Ira Moskowitz of the Mass Tech Collaborative; Frank Gulluni. James Lombella and Jose Marcelino of Asnuntuck Community College in Enfield, Connecticut; David Cruise of MassHires in Springfield, Massachusetts; Michael Valario, Anne Marie Zenni and Elvio Ferreira of Diman Regional Vocational Technical High School in Fall River, Massachusetts; Ned McCullough of IBM; Brad Markell of the AFL-CIO; Tom Kriger of NABTU; and Amy Firestone formerly of the Department of Labor Office of Apprenticeship and now with Apprenticeship Carolina. Other practitioners that contributed to our thinking include Judith Glassgold of Rutgers University; Wilma Liebman, former chair of the National Labor Relations Board; Paul Lewis of Kings College London; Andrew Reamer of George Washington University; Celeste Carter of NSF's Advanced Technology Education Program; Michael Britt-Crane, David Heckman and Emily DeRocco of Mantech in the Office of the Secretary of Defense; and Phillip Singerman of NIST.

We have relied on studies from a series of experts from many schools and organizations and specifically cite their contributions in endnotes. Here we must note, in addition to those cited above, some we are particularly indebted to, David Autor; Anthony Carnevale and colleagues at the Georgetown Center on Education and Workforce; Claudia Goldin; Kenneth Gray; Edwin Herr; Harry Holzer; Lawrence Katz; Robert Lerman; Frank Levy; Mark Muro, Jonathan Rothwell and colleagues from the Brookings Institution; Merrilea Mayo; William Symonds, Amy Loyd and Robert Schwartz from Pathways to Prosperity and Kathleen Thelen.

— Sanjay E. Sarma and William B. Bonvillian

SECTION 1: INTRODUCTION

Our society faces growing income inequality and too many deadend jobs. Technological advances are placing quality jobs out of reach for too many because they are not trained for them. Our democracy was built around an ever-expanding middle class, but is starting fray as that middle class declines.

What are we going to do about it? A much better educated and prepared workforce is not the only answer but it is a central one.

THE PROBLEM

The nation lost one third of its manufacturing jobs – 5.8 million - between 2000 and 2010; only about 18% of these jobs came back by 2018.[1] It paid a price in social disruption: manufacturing had been a critical route to the middle class for those with high school educations or less.[2] Because manufacturing is the largest job multiplier – manufacturing jobs create many more jobs throughout the economy than service jobs – these effects rolled through other sectors of the economy. The effects were not geographically uniform – some communities suffered far more than others. Nationwide, median income of men without high school diplomas dropped 20% between 1990 and 2013; for men with high school diplomas or some college it fell 13%.[3] Women without a high school degree fared only marginally better: their median earnings fell by 12% and women with a high school degree experienced only a slight 3% gain. For the same period, the numbers that have dropped out of the workforce is at historic highs. Full-year employment of men in prime working age (35 to 45) with a high school diploma but without a college degree dropped from 76% in 1990 to 68% in 2013; the share of these men who did not work at all rose from 11% to 18%.[4] Just 55% of such prime working age men without high school diplomas worked in full year, full time jobs.[5] Women's wage levels remain significantly below those of men, although the gap has been narrowing. In part, this is due to growing educational attainment for women, although that trend has been in place for some time. The remaining gap is related more to still being paid less and promoted less than men. Both men and women, then, face significant wage and employment problems.

Our workforce is increasingly polarized, income inequality is growing and the middle class has been in decline. With unemployment in 2019 below 4%, the workforce is working, but those on the lower tiers face a job quality problem – they tend to be stuck with lower end services work without benefits. Manufacturing and retail are examples of industries that have been in decline. The largest causes of manufacturing job loss, appear to be sectors lost to international trade,[6] coupled with a general hollowing-out – some 60,000 factories were closed from 2000 to 2010.[7] Automation hasn't been the major factor thus far.[8] In retail, the underlying problem is that the nation has overbuilt retail space, but online commerce is also starting to reshape the flow of goods, replacing store jobs with warehouse jobs. In warehouses, meanwhile, robots and automation are taking on significant roles. In sum, a significant part of the workforce is being left behind. Health care services are a growing sector offsetting declines in other sectors, but the need for more technical skills to field new medical technologies at scale is hindered by various barriers to entry. Each of these sectors will be examined in detail in the upcoming final report.

Upskilling: Manufacturing is a particularly good marker for what is going on because of its historic role in leading productivity gains. It is no longer dark and dirty; many factories will more and more look like clean labs. New production jobs are upskilling. Data from the Bureau of Labor Statistics (BLS) helps us to understand the elements within the term "manufacturing workers."[9] We can consider essentially three categories for U.S. manufacturing workers: production level workers (lower skilled), machinists, technicians, welders and other skilled workers (high skilled), and engineers, researchers and scientists (very high skilled).[10] These categories are changing: the first category of employees – assemblers and basic production workers – was once more dominant but the second category of skill level – high skilled (often called "middle skilled") - is now the growing category, with 20 years of significant growth. Production level workers now make up only some 40% of manufacturing jobs; workers with college or some college education in manufacturing made up 54.8% of the workforce in 2011, compared to 48.6% in 2001.[11] Middle skill jobs are generally defined by educational level required, i.e., some post-secondary education, including associate degree, certificate, or significant certified training, using this as a proxy for actual skill.[12] It is a workable but still imperfect measure.

The above data illustrates part of a general trend in U.S. labor markets: required skills are moving steadily upscale in the overall economy. If high skill jobs are defined to include some college education, BLS found these jobs now include 37.7 million workers, rising from 28.7% of the workforce population in 2006 to 33.4% in 2012; in the same period, lower skill workers declined 7.5%.[13] This is a remarkable shift in a relatively short period of time.

The Education Divide: When there is advancing technology and corresponding rising demand for skills, those that have them can command a wage premium. U.S. real median family income was $32,101 in 1954, and by the end of 2015 it had grown to $70,697 (in 2015 dollars). However, according to Census Bureau data, in 2000 median income was $69,822, indicating nearly a decade and a half of income stagnation. During this same period, the share of income going to the top 1% and 10% increased from 9.39% and 32.12% to 18.39% and 47.81%, respectively.[14] This corresponds to an increase in the average income for the bottom 90% of the population from $21,852 to $33,218, while the top 10% saw their average income increase from $93,095 to $273,843.[15] The share of wealth owned by the bottom 80% fell from 18.7 percent in 1983 to 11.1 percent in 2010. Upper and upper middle classes are thriving; the rest are not.

Economists Claudia Goldin and Lawrence Katz, as will be discussed below, have shown the clearest sorting mechanism between these boundaries is a college education – the thriving upper middle class has it and captures the increasingly sophisticated tech jobs, while the rest doesn't.[16] The lifetime earning differential between those with college educations and those

without is dramatic.[17] In parallel, is an increase in lower-end, lower-pay service jobs that many with lower skills who lost middle income jobs are being moved into.[18] Some suggest that the advent of this workforce polarization, with the growth of lower education, often manual, service work, means that the link that Goldin and Katz make between higher education and technological change has come to a halt. Not so; it means the opposite. Those without the education and higher skills will fall far further behind the advancing technological curve. Our society is breaking up its historical political consensus around this divide.

The Training Problem: A strong workforce skills training system could make up for this college education divide. However, economist Gary Becker in a noted work on human capital argued that U.S. labor markets generally supply suboptimal levels of skills training.[19] This is because labor market competition between firms tends to create an underinvestment in skill training because the gains from such training can't be adequately appropriated by the firm providing the training. This is a clear market failure. In other words, companies aren't willing to invest in worker skills because competitor companies frequently acquire these trained employees, avoiding their own workforce training investment and preventing the first company from recapturing its training investment. Employers, then, to the extent they provide training, have tended to build their programs around skills needed only by their firms and are more valuable for their firm than for others. In other words, they lean toward firm-specific skills and away from broader skills training. Reflecting this, some studies of corporate investment in workforce training indicate it has declined significantly in the past twenty years,[20] and this presents a significant problem for American workers. In turn, government investment in workforce education has also been in decline.[21] So the American working class is increasingly polarized and adrift and neither employers nor government are not throwing them a lifeline. They are increasingly stuck in place.

Automation: Is automation and the productivity gains it enables a cause of these problems? Predictions are growing of the imminent end of work and corresponding societal dystopia because of a suite of information technology (IT) advances – robotics, artificial intelligence, machine learning, internet-of-things, etc.[22] However, these conclusions seem premature.[23]

Our current productivity increase and investment rates are at very low levels – productivity is in the 1% range.[24] Even if we reached quite high productivity rates signaling major new oncoming automation, a 3% productivity rate (which we haven't seen since the information technology innovation wave in the 1990s) would take three decades to realize a 75% improvement in productivity.[25] An OECD study indicates that the suite of new IT technologies noted above would likely disrupt the jobs of 6 to 12 percent of the workforces in OECD nations, varying between nations, over an extended period.[26] A McKinsey study suggests up to 14% by 2030.[27] These are large but not overwhelming numbers and will materialize over time. Past innovation waves have taken several decades to work their way from initial introduction to full implementation. Work will not end tomorrow – we have some time to adjust our workforce. A 2019 report from MIT's Work of the Future task force buttresses this conclusion.[28] Workplaces will shift, make no mistake about it, requiring, for example, higher levels of digital technology - and too many workers lack these skills. The sky is not failing - but change is coming. The current reality is more that key parts of the workforce have already been disrupted largely by trade displacement, and an upskilling is now underway. The new technologies will over time eliminate jobs, but more jobs will likely change and new jobs will be created, as well. In other words, upcoming technology challenges don't make improved workforce education hopeless, they make it more of a necessity.

Taking Up the Workforce Challenge: With deep societal challenges around quality job creation, with the entry of new digital technologies and with a general upskilling already underway, there

is already a growing consensus on the need for improved workforce education. We're not going to send displaced steel workers or incumbent retail workers to four-year colleges, but could we build alternative systems to give them the skills they need to move toward quality jobs and back onto middle class pathways? Labor markets are already tight and the baby boom demographics suggest this is not a short-term issue. Could we move more into quality jobs? Some have proposed solving the country's growing income inequality by tax measures to guarantee higher incomes, but politically this kind of income redistribution seems highly unlikely. Workforce education efforts appear to be a leading alternative.[29]

The signs are apparent. Congress in 2018 passed on a bipartisan basis a major reauthorization of the Perkins Act, which supports federal work training programs.[30] The President in 2018 issued a new executive order to promote apprenticeships.[31] The Chamber of Commerce has launched a new workforce education program built around regional consortia of employers.[32] Community colleges are developing new certificate programs, new online training programs are evolving, and the Secretary of Labor's Workforce Information Advisory Council has proposed a major revamping of the information systems behind our problematic labor markets.[33] In a period of profound political divide driven by the economic inequality discussed above, it is very difficult to reach a political consensus around any issue; an exception is workforce education. The public, the private sector and even the political system appear ready for change.

The focus of this work is on the American working class. This is a term many stopped using in the decades from the 1960s through the 1990s – we began to pretend that we were all middle class. The American rule was that each generation got better, each was more economically successful than the last. The middle class was the bulwark of our democracy, the basis for a consensus-based political system. In the decade of the 2000s, however, the middle class began to erode, paralleling in significant part the decline of manufacturing. We now find we have growing economic inequality not economic convergence, with the upper middle class thriving and a lower middle class falling economically behind. Who is in the working class? A Strada Institute report adopts a practical definition based on Census Bureau data: the 44 million adults who lack an associate degree level of education and earn less than $35,000.[34] The definition could be more complex but this gives us a rough sorting mechanism for those who lack the education, skills and credentials to earn adequate income to support themselves and their families. As noted in that report, of those with high school education or less, 50% are more likely to live in poverty.[35] Only 11% of these working class Americans earned a bachelor's degree by age 24;[36] only two out of every 25 children born in lower income households reach the top quintile of the economic ladder.[37] They are of all races and ethnic groups. They are at risk of being left behind and a new workforce education system needs to be aimed to assist them. Without action, their lot will not get better because the jobs of the future will require significantly more education and training. This process is already underway.

THE STORY AHEAD

Section 1, above, has served as an **introduction** to what happened and what's ahead; it has been a short overview of the issues the report will review. These include quality job growth and workforce education challenges. It has noted manufacturing decline (including trade and productivity issues) and retail change.

Section 2 takes up the **breakdowns in today's workforce education.** It examines the major actors in the current problematic system, from employers, to the Departments of Education and Labor, to community colleges and universities, to efforts to educate for advanced skills, to the problematic labor information system. It reviews the disconnects and gaps between the actors and the problems they have in scaling up their efforts to make an overall impact.

Section 3 finds that lurking behind problematic labor markets is a **broken labor market**

information system. Section 3 notes that poor information systems make for poorly functioning markets; U.S. labor markets have a weak information system, with limited information available to participants and employers. A new navigation system is needed.

Section 4 looks at **colleges and universities and their role in workforce education.** These institutions have been key to the success of the nation's technological advance and growing its middle class. But higher education is facing a decline in its historic business and political support. It is an established and complex legacy sector that tends to resist disruptive change, such as from new education technologies and new delivery models. It has not been educating for the workplace, it has focused on foundational skills as opposed to career skills. But given the accelerating pace of technology introduction and economic inequality problems it may now need to do both.

Section 5 turns to the **new education technologies** – online education, virtual reality, augmented reality, artificial intelligence, digital tutors and computer gaming all represent new education delivery systems. These present dramatic new learning opportunities. How could they contribute to workforce education, with its requirement for learning by doing? How do they fit into new learning models and into established education and training institutions?

Section 6 sets out the possibility of a **new apprenticeship model.** It examines the limited apprenticeship history in the U.S., which has focused primarily on the construction trades. It then compares this to Germany's well-known system and the intricate collaborative system between employers, educators and government behind it, and its advantages in cutting youth unemployment and ensuring a solid transition to work. It considers ways in which aspects of the German apprenticeships could be adopted in the U.S. then turns a series of interesting new apprentice models emerging in the U.S. and their policy and organizational prerequisites.

Section 7 confronts the **content delivery challenge:** what are the emerging models? What would be the new mechanisms for meeting the challenge? Categories of workers to be reached include:

- Displaced or underemployed workers who are out of work or in lower end services jobs,
- Existing workers wanting to upskill, and
- New job entrants seeking work, out of high school or community colleges.

Each presents different quite different challenges and requires different approaches. What partnerships between community colleges, universities, employers, apprenticeship offerings, manufacturing institutes could reach each community? The section reviews a series of new models that could be adopted by stakeholders to create what can amount to a new workforce education system.

The goal of this study project is to identify demonstrated, replicable models that can be scaled up to achieve a societal impact. This has been the way most of U.S. social policy proceeds, and a number of models are identified. Many have been well-tested, others require further evaluation but show significant promise for solving system challenges and filling gaps.

This model identification process is followed by a brief list of **policy recommendations** in **Section 8** summarizing implementing steps that can be taken by governments (state, local and federal), educational institutions, and employers.

SECTION 2: BREAKDOWNS IN TODAY'S WORKFORCE EDUCATION

Ask Americans and they will be able to describe what junior high and high school look like. They will be able to describe a four-year college and have a good idea of what community colleges are like. But ask about what the workforce education system looks like and you will draw a blank stare. There is no real system and the elements that we have are not well understood or connected.

While residents of many European nations have systems that effectively prepare and transition the young from school to workplace, with the skills for well-paid careers, there is a disconnect between the worlds of school and work in the U.S. Incumbent workers also need access to workforce development options to keep up with technology advances, including lifelong learning. This nation has the most decentralized labor markets in the developed world and limited active labor market policies from government.

It is important to note that many dedicated people are trying very hard to make this system work and there are many examples of successes and new ideas. Paul Osterman has argued that there are some advantages in the complexity of the system – there are many entry points and workers can change their minds about careers and restart.[38] A European system where career paths lock in at very early ages would not work well here. It's not that there aren't high-functioning parts to our system – there are outstanding efforts in numerous community colleges, among numerous employers and in creative, new programs – but there is still a system problem. The actors and programs are often not well connected, funding can be problematic and too many fall into the gaps.

Let's look at the breakdown points among the numerous institutional actors in the workforce field.

UNDERINVESTMENT BY GOVERNMENT AND EMPLOYERS

Justified by economic theory on interventions in labor markets, **governments** in developed nations often make significant investments

in "active labor market policies" – they invest in job training, identifying job opportunities, and employment services. The average OECD developed country invests .5% of GDP in these policies, the U.S. invests .1%, the 29th lowest of all 31 OECD nations.[39] And it invests at a level of less than half of what it did three decades ago. Harry Holzer sees this as a basic breakdown in workforce development policy: in a period in which skills are more important than ever in setting earnings in labor markets we are spending ever-declining amounts.[40]

Paul Osterman has called out the significant role of **labor market intermediary organizations** that can help connect the actors and programs, better linking workers and jobs.[41] The intermediaries can range from workforce development boards to internet job services. While there are problem actors in this group, studies show that overall, high quality intermediaries can play a significant role in supporting job placement and related training. But with the decline in federal support, many of these institutions have trouble playing their roles.[42]

On the **employer** side, a Council of Economic Advisors study based on Census Bureau data indicates that between 1996 and 2008 (prior to the disruption of the Great Recession) workers who reported they received employer-provided training declined from close to 20% to approximately 11%.[43]Jeffrey Waddoups has noted that Census surveys indicate a troubling 28% decline in employer training between 2001 and 2009, finding that the decline was widespread, occurring across industries, occupations, ages, education levels, job-tenure and demographic groups.[44] He has also found that the decline most affected workers in the middle of the education spectrum;[45] workers with higher levels of education tend to be the focus of more employer training attention. Unfortunately, we lack recent studies. Robert Lerman, however, has noted the wide variation among U.S. employers;[46] some employers historically adopting what Thomas Kochan and others have called "high road" and others "low road" worker training approaches reflecting different attitudes to the role of employees.[47]

While government and firms appear to be disinvesting – and we need better data on employer training support - the workforce needs to upgrade their skills. Quality jobs are going to the better educated; those with high school educations or less face stagnating or declining incomes while those with a college education are receiving a significant wage premium. The falling demand for less-skilled workers seeking middle income wages means a substantial percentage are no longer in the workforce.[48] Clearly, the need for training is out of sync with the investment levels.

What is the employer role? There is a long and varied history. Skilled workers are a key driver of productivity gains for their employers and the economy; overall, improving workforce learning is a key driver of growth.[49] The division of labor of the 19th century paralleled the industrial revolution, enabling low skilled employees in an assembly system to replace skilled artisans to scale up production. Replacing labor with capital equipment developed then and remains a long-standing tradition in American production. Larger employers had the revenue base to train employees, smaller employers less so. But as global competition soared in the 1970s, a financial model drove employers to cut costs to go "asset light"[50] and training too often fell by the wayside. There was a further development. As larger firms, driven by the financial sector and global competition, thinned-out to pursue their core competencies, they also often outsourced non-core activities. If the outsourcing went to U.S.-based contractors (not abroad), these were often low margin firms. There simply haven't been incentives to encourage larger firms to switch strategies and go labor-intensive, which means many have less workers and less incentive to train. In turn, the low-margin outsourcing firms have limited resources and therefore limited interest in training.

While employers still needed skilled workers, they may well have hoped public programs and institutions could provide them. Public institutions, then, would have to be the providers,

which meant employees would be acting more on their own, disconnected from employer needs, responsible for their own education and bearing the costs. With tighter labor markets of recent years, some employers, particularly larger ones in more economically stable sectors, are having to rethink their training roles. Workforce education has become a priority for business organizations, including the Business Roundtable,[51] the Chamber of Commerce[52] and the National Association of Manufacturers.[53] However, there is a labyrinth of different employer approaches to workforce education, and an era of cutbacks and disengaged employers to overcome.

Employers typically act in isolation, trying to make their own arrangements with training providers and education institutions, rarely acting in concert with other area employers to pool resources and make a significant dent on mutual training problems. Individual firms acting alone simply cannot operate at the scale needed to solve the workforce development challenge. There are few incentives to collaborate, and this gap in collective activity amounts to a market failure. The obvious solution to this type of market failure is for groups of employers in a regional labor market to coordinate. This may require other coordination or intermediary institutions—government, employer association, labor, or education - to serve as the connecting force. Meanwhile, however, there is typically no system here across employers, only a lack of a system.

ROLE OF LABOR UNIONS

Historically, labor organizations have played an important role in American training and workforce development. Yet the percentage of workers belonging to a union went from 20.1 percent in 1983 to 10.3 percent in 2019, with union members making up only 6.2 percent of private sector workers.[54] However, unions still play a significant role in the workforce in some key sectors, including construction, aerospace, automotive, utility, and healthcare fields.

Their training role reflects the historic division of the labor movement into craft and industrial unions.[55] The construction trades – craft unions - have dominated apprenticeships in U.S. Because data is gathered by both federal and state governments the number of apprentices in construction trades registered with the Labor Department (DOL) cannot be exactly estimated but is between 180,000 to well over 200,000. Construction registered apprenticeships have amounted to a significant majority of all the apprentices registered with DOL, and three-quarters of all construction apprentices have been trained in joint labor-management training programs. Joint labor management training funds maintained by unions and construction contractors provide $1.5 billion annually for the apprentice programs at1600 training centers with over 20,000 instructors. Because the training is funded through collective bargaining agreements by employer contributions, the training is free to the apprentices, who attend classes at a training center and work on the job under mentors, paid an average of $60,000 a year. A typical program takes four years and requires 8000 hours of work experience. Completion rates are between 50 and 60 percent; because a set number of working hours is required, completion rates go down during recessions when working hours are limited. The program amounts to one of the nation's larger education systems. We rely for construction skills on this system because non-union contractors have never developed a training program at all comparable. And construction skills are no longer about wrenches and screwdrivers; areas like steel framing, electrical systems, piping, modular roofing and energy systems are built on computer-based modeling, for example.

The industrial unions have a much smaller apprentice system, with some 15,000 to 20,000 in manufacturing areas, including automotive, aerospace and food processing. The service employees union, for example, is supporting apprenticeship programs in 30 to 40 different medical care fields. Like the construction side, this is mentor-based on-the-job training coupled with classroom instruction but is organized around particular large employers.

Both craft and industrial programs to build the skills of their members and want to expand the reach of their apprenticeship efforts. The Industrial Manufacturing Technician (IMT) program was first developed by the AFL-CIO and the Wisconsin Regional Training Partnership and trains workers in basic manufacturing skills such as production systems, safety, quality production and logistics that are foundational for going onto the next level of skills. These trainees – who can be apprentices or in workforce development programs - take four basic courses and complete 3000 hours on the job. The IMT program is now being offered by many community colleges, with 3000 to 4000 thousand a year now coming through the program.

On the craft side, the Multi-Craft Core Curriculum offers a standardized 120-hour course in such areas as construction tools and materials, math, safety, use of construction plans and green construction. It is an apprenticeship-readiness bootcamp program to supply foundation skills in part to help open up more skilled construction jobs to more minorities, women and young people. In 2018, 2600 successfully completed this program and it is growing quickly. A number of union-supported programs are also now developing college-level credit systems with community colleges or through their own state accredited systems so their programs programs allow apprentices and trainees to translate skill training into college-level credentials that can transfer into state higher education systems. Working with employers, online and virtual reality efforts are underway. While union membership in the private sector has been in decline, unions remain an asset for potential workforce collaborations in key sectors. They have resources, organizing reach and new workforce programs they want to build.

BACKGROUND ON WORKFORCE LAWS

The Labor Department's training and employment programs arose in significant part out of Lyndon Johnson's 1964 War on Poverty. The concept of a "demand driven" system developed with the passage of the Workforce Investment Act (WIA) in 1999. Under this law, locally-based "workforce investment boards" (WIBs) were named with a voting majority from local industry, to implement training for the labor needs of local businesses. WIA created "One Stop" offices where workers could access all Labor Department services including Unemployment Insurance and "labor exchange" services for job openings posted by private employers. The concept behind WIA was empowering local employers and workers to cooperate in the job search process. To end any "welfare" stigma, assistance for adults was no longer for the disadvantaged only. Holzer has noted the three key services provided.[56] The "core" services included use of the employment search system including staff assistance. "Intensive" services included job skill assessments and job counseling. Training was the third category of services, and included essentially any kind of education that qualified workers for specific jobs. Workers acquired more control over how their training funds were spent through "Individual Training Account" vouchers. There was an emphasis in WIA on "work first" – getting adults into jobs as soon as possible, with or without specific training.

THE WORKFORCE INVESTMENT AND OPPORTUNITY ACT, TRADE ADJUSTMENT ASSISTANCE AND THE LABOR DEPARTMENT'S LIMITED FOCUS ON HIGHER SKILLS AND INCUMBENT WORKERS

The successor law to the Workforce Investment Act was the **Workforce Investment and Opportunity Act (WIOA)** which went into effect in 2015 and is one of the Department of Labor's two major programs with training features. WIOA continues to authorize the core federal programs for workforce development. These include employment and training services for unemployed and underemployed adults and dislocated workers. Most of the funding is distributed through formula grants made to the states.[57] Under the act, state and regional Workforce Development Boards, with a majority of their members drawn from area employers, set regional employment strategies and funding priorities for worker training, registered apprenticeships, transition jobs, on-the-job training, and customized training. They also support one-stop career centers for job search and counseling assistance.

WIOA continues the "demand driven" focus of WIA, emphasizing serving needs of local labor markets and responsiveness to local employers. However, the annual formula funds to the fifty states for a range of the WIOA programs declined by 40%, from $4.6 billion in 2001 to $2.7 in 2018.[58] This level is simply not approaching the scale of the problem. While low income and unemployed workers, who continue to be the basic focus under WIOA, deserve more help, a new, additional focus is required on raising skills, given the decline of routine jobs and the need to upskill workers for the technology challenges ahead. There is limited flexibility under WIOA available to states and the Workforce Development Boards to undertake this shift.

Overall, the local nature of the Workforce Boards can be a strength because it puts them in touch with local employers and job needs. But if the nation is to train the workforce for a new generation of advanced technologies, the local Boards are not in a position to be the first to see the technologies and get ahead of the curve to implement them. Nor are the small and mid-sized employers they work with.

In addition to WIOA, the other major Labor Department program is **Trade Adjustment Assistance (TAA)**, originally proposed by President Kennedy in 1962, which assists workers, firms and farmers damaged by import competition from trade. Workers can receive a trade readjustment allowance that supplements state unemployment insurance if they participate in training programs. There is also job search assistance and income subsidies for workers over age 50 with limited incomes. The funding available in 2018 for both training and employment assistance was only $387 million.[59]

The Labor Department also leads the country's registered **apprenticeship programs.** However, this program has been largely tied, as noted above, to the construction trades reflecting craft unions that dominated the unionized part of this sector. The program is only starting to branch out in significant ways into other sectors. An organizing tool that many nations, particularly in Europe, use to better connect learning to work, apprenticeships have simply not scaled up in the U.S. Although growing in the last few years, there are still only 585,000 apprentices in programs registered with the Department, up from 420,000 a decade before.[60] And there has been only limited focus on youth apprenticeships in the past, so young, new entrant workers coming out of secondary school are not reached.

EDUCATION DEPARTMENT PROGRAMS FACE GAPS IN FILLING WORKFORCE NEEDS

An initial issue is that programs at the Departments of Labor and Education are not connected or complementary. They are separately administered in Washington then carried out in regions and states by different organizational stovepipes tied to the federal programs, so the limited federal resources from the two Departments have difficulty leveraging each other.

The Education Department's most significant workforce program is through its **Pell Grant** program for some 7 million students, a $28 billion program that dwarfs the others.[61] These grants go to students in undergraduate degree programs at colleges or community colleges who show clear financial need and are enrolled full-time. Stand-alone, short-term certificate programs can qualify, but have required detailed data demonstrating the student's subsequent "gainful employment."[62] Unlike student loans, Pell grants do not need to be repaid; for the 2019-20 school year the maximum grant was $6195.[63] Of Pell Grant recipients in 2015 in two- and four-year college and related programs, 2.4 million attended community colleges and 1.3 million went to for-profits; the remainder went to public and private colleges.[64] Community colleges and the for-profits alike offer what is largely workforce education, but they are often shaped as college programs so their students can qualify for the Pell Grants. Nevertheless, the Pell program is not well matched with actual workforce education needs and labor market demands. Undergraduate degree education may not overlap directly with workforce training, and the grants are not available to students seeking shorter-term certificates in workforce skills unless the sponsoring educational institution collects additional subsequent employment data. This barrier excludes many who cannot make the time commitments required for undergraduate degree programs or extended certificate programs, or who need particular job skills. Opening up Pell Grants for workforce education programs more generally outside of degree programs has been a major topic of discussion, but there's a problem. For-profit schools that are funded largely by Pell tuition money—so-called "Pell Mills"—have low college student completion rates.[65] Efforts by the Education Department to crackdown on poor performers have had limited results.

So Pell amounts to the largest workforce education program but it isn't really aimed at workforce education.

Paralleling Pell is the **student loan** system for loans, another very large program, available either directly from the Department of Education or indirectly through private lenders. These go to students in accredited two- or four-year programs.[66] However, student debt has as of 2018 climbed to $1.46 trillion, reflecting rising college costs, with $166 billion of these loans in "serious delinquency" status, reflecting the often stagnant wage growth of recent years outside of the top income tiers that limits the ability to repay.[67]

The other major Department of Education program is the **Perkins Act** for career technical education (CTE is the term that has replaced "vocational education." A bipartisan reauthorization of the program was passed in 2018.[68] It funds states for high school and community college career and technical education for a wide range of "middle skill" occupations. Both certificate programs and non-certificate programs are eligible. Funding is allocated by formula grant to states, with some two-thirds of funding going to secondary institutions and one-third to post-secondary. States can shift a portion of this funding to meet state priorities. However, funding has been stagnant for many years. In 2004 funding was $1.3 billion and it fell to $1.1 billion in 2017 and was $1.2 billion in 2018.[69]

Data on the overall CTE education system highlights some of the problems. In the 2017-18 academic year there were some 2.6 million postsecondary learners in career and technical education (CTE) certificate and degree programs.[70] Forty percent of these learners, according to Higher Learning Advocates, came from low income backgrounds, and forty percent were minorities. However, within three years of starting their postsecondary education, only 23% had completed either a degree or a certificate. What happened to the rest? Thirty-two percent dropped out, 16% were still enrolled in their program at their first institution, 13% were still at the first institution but changed fields, and 17% transferred to another institution. Clearly there is a completion problem.

To summarize, overall, there are important gaps in federal programs. While Labor Department programs emphasize displaced and underemployed workers, there is limited focus on incumbent workers and on young, new entrant workers entering labor markets. While Education Department programs provide extensive student aid for college education, they are not focused on non-degree programs. The completion rate for CTE programs backed by these programs is a significant problem. While advanced new technologies, particularly in information technologies, will be entering the marketplace in coming years, there is no system in place to educate workers in applying these technologies. Overall, the Education Department's programs don't connect or mesh with the Labor Department's programs, If the federal programs are disconnected at the federal level, could they be better connected at the state level? This work will cite some specific examples. in addition, there was an interesting option created through the 2018 reauthorization of the Perkins Act to allow states for the first time to develop joint plans for both their Labor Department-backed WIOA and Education Department-backed Perkins Act programs.[71] Some sixteen states are pursuing this, with new plans due in 2020.

VOCATIONAL EDUCATION IN SECONDARY SCHOOLS WENT INTO STEEP DECLINE

In the 1950s and accelerated by Sputnik crisis, systematic tracking of students increased, separating out the college-bound from the rest who often were in vocational "shop" classes.[72] With the subsequent rise of the civil rights movement, concern arose that tracking was based on class and racial lines, so the emphasis shifted to preparing all students for college. It should be noted that some of these vocational programs were weak and lacked quality instruction particularly in emerging technical fields so some students were being tracked into dead ends. Many vocational schools and "voc ed" tracks were dropped in many states. However, many still did not go to college. So over 30 percent of the population were left with limited employment skills. While strong CTE continues in some states like Massachusetts, which strengthened rather than dropped its programs and its schools often now have long student waiting lists,[73] economic pressures continue against vocational education in some states in regions because, with the equipment it requires, it is expensive education.

FOR-PROFIT HIGHER EDUCATION HAS BEEN A PROBLEMATIC MODEL

There are some 1,300 for-profit institutions engaged in post-secondary education in the U.S. They offer a wide range of programs, from associate, undergraduate and graduate degrees to certificates in skill areas. The for-profits have a majority of the enrollment in non-degree-granting programs.[74] They are heavy users of federal Pell Grant and student loan programs.

Their enrollment jumped from 18,000 students in 1970, to 400,000 in 2000, to 2 million in 2010, but has since slipped to 1.3 million in 2015.[75] The overall completion rate for students in for-profit certificate, associate and bachelor programs was only 17% in 2008.[76] The most problematic completion problem since then has been with bachelor-level programs where completion in six years was only 23% in 2017, far lower than in their non-profit public and private counterparts.[77]These schools generally depend on the federal government student aid programs for the great bulk of their revenue, default rates greatly exceed those at other institutions of higher education, a number of major chains have gone bankrupt leaving numerous students stranded,[78] and in some cases there has been significant evidence of fraud.[79] While there certainly are quality programs, too many of the for-profits are problems not solutions.

PUBLIC HIGHER EDUCATION INSTITUTIONS ARE UNDERFUNDED AND DISCONNECTED

The over 1100 community colleges are predominantly state institutions and 74 percent of four-year college enrollment is at state universities.[80] However, state support for higher

education has been in decline for decades. Since 1980, state and local appropriations to higher education went from 50 percent of the revenue for public higher education to 37 percent by 2000. From 2008 to 2016, all but four states faced reductions in state per student higher education spending. The largest cuts occurred in five states and were dramatic: they ranged from 55 percent to 33 percent.[81]

Within this pattern of declining support, **community colleges** have a particularly difficult time. Community colleges are where much of the country's lower income and working class students go but state universities generally dominate state higher education funding. While 81 percent of first time community college students say they want to earn a bachelor degree, only 12 percent go on to do so, and two-thirds fail to attain an associate's degree.[82] This poor completion rate is a major system problem.

Even though the **four-year college** degree is increasingly replacing the high school degree as the prerequisite for workforce success, four-year higher education institutions are largely disengaged from workforce education. They are also disconnected from community colleges as suggested by the small number of community college students, noted above, who complete four-year degrees. Transferability of community college credits and associate degrees to four-year state universities is not assured in over a third of the states.[83]

What about education in **new technologies**? Although computer science skills are increasingly necessary in many careers, neither two-year nor four-year institutions are providing education at adequate scale in it for their students. A signal of the problem is that of the 1.8 million first-time college students who entered a community college in fall 2007, only 3,290, or less than 2%, went on by 2014 to earn a bachelor's degree in computer science, and an industry projection indicates that current college graduation rates in computer science will only meet one-third of job demand.[84]

In addition, **lifelong education** will likely be important to keep improving the workforce skills as new technologies are introduced in these and other sectors. While community colleges reach older students, they have limited funding to keep up with new advances such as the suites of new equipment to teach advanced manufacturing. Colleges and universities are still largely focused on students of traditional college age and only starting to think about lifelong learning.

In addition, neither community colleges or universities have yet adequately embarked on applying new **online education** capabilities and offerings to workforce education courses and modules. Community colleges, although major users of online, generally lack the high-quality online production facilities to undertake this effectively and colleges and universities are focused on starting to launch their own college-level online programming; workforce education is not yet on their agenda. While some online companies are starting to fill the gap, outside information technology and certain manufacturing skills most offerings are thin.

THE ADVANCED TECHNICAL EDUCATION PROGRAMS AND MANUFACTURING INSTITUTES ARE STILL SMALL SCALE

There are two institutions leading in advanced technical education: the National Science Foundation's **Advanced Technology Education (ATE)** program and the Advanced Manufacturing Institute program begun in 2012. ATE focuses on community colleges to promote the education of technicians for high-technology fields, with 31 centers and 278 active projects.[85] It has been a critical resource for community colleges, providing resources to develop innovative new curricula and online materials for emerging technical fields. Despite its output, ATE's FY2020 budget was only $75 million[86] to provide course materials and programs for the 5.8 million students enrolled in community college programs.[87]

The **Advanced Manufacturing Institutes**, which

participate in a network called Manufacturing USA, began in 2012 and number fourteen institutes, each with a specific new technology focus with programs that reach nearly every state. The role of the institutes and its network is to boost the robustness and innovative capacity of the U.S. manufacturing sector and improve its global economic competitiveness.[88] Federal seed funding for each competitively-selected institute from the Departments of Defense, Energy and Commerce leverages larger amounts of industry and state funding for each institute; overall the federal share is matched 2 to 1 by industry and state governments.

While technology development is the central task of each institute, workforce development in the institute's advanced technology field is also a critical task. Along with ATE, the manufacturing institutes could fill a major gap in workforce education: educating for next generation skills. Each institute has its own workforce education programs, some larger than others. Manufacturing USA reported that institute programs in 2017 touched 185,425 students through internships, training or development projects (although one institute's programs alone were responsible for most of this total), 4302 incumbent workers completed a certificate or training program, and 1299 teachers and trainers were reached by institute-led training efforts.[89] Innovative programs have been evolving. For example, DOD's Mantech, which supports the DOD-funded institutes, is supporting a group of institutes to develop advanced manufacturing technology course modules to be placed within a foundational manufacturing skill online training program. It is also creating an online platform to be the home for advanced skill online courses. The AIM Photonics institute's workforce program, for example, has developed new online MOOC courses for optics and photonics, is introducing VR and AR into its courses and has created collaborative programs for photonics education with state, private and community colleges. However, in a $2.2 trillion manufacturing sector in 2017,[90] total expenditures in 2017 for the fourteen institutes were $298 million ($120 million in federal funds and $177 million in industry and state matching funds). These cover all institute activities from technology development to capital equipment for demonstration centers; workforce education was only a modest portion of that total.[91]

Despite creative program elements that could help fill the major gap of educating for oncoming advanced skills, neither ATE nor Manufacturing USA were operating at the scale that will be required for a workforce transformation.

SUMMARY

The problem points in current workforce education are myriad. They include disinvestment in recent decades by both government and employers in workforce education; federal Labor Department training programs that have limited focus on higher technical skills and incumbent and young, new entrant workers; federal Education Department programs that have large gaps in filling workforce needs and are not linked or complementary to the Labor Department's programs; a vocational education/ CTE system in secondary schools that has largely been dismantled; publicly-supported community colleges that are underfunded and lack the resources to provide advanced training in emerging fields; colleges and universities that are disconnected from workforce education and the other participants in the system particularly community colleges; a general disconnect between the still-separate worlds of work and learning; a missing lifelong learning link; and creative but modest technical education programs in advanced technologies that are still of too small a scale. Overall, we are missing consistent criteria for funding different programs and there is a general lack of coordination across the system. Yet there are some promising paths forward, set out in upcoming sections.

SECTION 3: THE BROKEN LABOR MARKET INFORMATION SYSTEM

Adam Smith explained that market economies operate through an "invisible hand" but what was that hand? In 1945 Friedrich Hayek argued a market is an information system.[92] The problem facing economies was to efficiently allocate resources and goods through societies with millions of participants, both people and firms, where each held only partial information – there was a "problem of the utilization of knowledge which is not given to anyone in its totality." The market with its pricing is, "a mechanism for communicating information." Markets work, then, through the aggregation and transmission of information among the participants, and the better the underlying information the sounder the market. Markets with good information systems could be far more efficient than, for example, groups of central planners who inevitably have only partial information.

The U.S. has the most decentralized workforce management of any developed nation. Its labor market is highly individualized and localized, so is fragmented with relatively few information connections between participants. The information disconnects are now affecting managers, as well. Labor market expert Andrew Reamer argues we have "dysfunctional" information systems behind our labor and education markets.[93] Efficient labor markets, like all markets, require good information flow and widespread participation, and we lack that. On the supply side, younger workers face difficult education decisions, especially at ages 17 or 18, that will largely determine their work futures; they must act with limited understanding about their options and therefore on limited information. Displaced workers are in a worse box – they don't have the tools to understand job opening, education and training options. And managers are increasingly frustrated in their ability to hire and retain the talent they need in an ever more complex technological society.

The highly complex array of vast numbers of disconnected employer and education actors exacerbates the information problem. Overall, on the skill supply side, education institutions

offer over 300,000 different certificates and degrees[94] but lack the data to match them to actual job qualifications. Therefore, employers lack information about the relevance of education and of actual qualifications. On the other side of the mirror is the demand side – for a job seeker, what are the employment options, where are they, what skills do they require and how could they best be acquired? Our labor market information system is broken – both workers and employers are largely flying blind. The complex array of participants in the overall system is complicated by the complex array of agencies that collect relevant data.

A JOB NAVIGATOR

But suppose we had a work navigation system. There could be online-delivered interventions to help workers facing job dead ends find work opportunities requiring skills adjacent to their own that they could master. The navigator could be an online guardian that collects and scans occupation shifts and alerts employees, finds relevant job openings, and identifies the skills needed on new jobs – from soft teamwork skills, to basic education skills, to technical skills. It could be finely grained and nuanced around jobs, skills and openings. Government job displacement data and training support information could also be delivered. The navigator could also link workers to training interventions, including training opportunities from colleges and community colleges.

THE NAVIGATOR'S ROLE

What would a navigator look like? Think about how Netflix sends you movie recommendations based on the kinds of movies you have been viewing, or the way Amazon makes book recommendations. LinkedIn (now owned by Microsoft) in 2010 created a job recommendation engine that uses what are called content and collaborative filtering systems to compare job profiles with job applicant profiles.[95]

The Education and Training Administration within the Department of Labor already provides valuable data through its O*Net system.[96] O*Net can provide building blocks for more expansive systems. Noting the problems of increased job polarization and declines in income mobility, an MIT Media Lab team has been pursuing, for example, more closely defined skill categories, relying on detailed Department of Labor O*Net occupational skill surveys. Their system can identify sets of skills, from machine control to spatial orientation, that are highly complementary to produce a larger network of jobs that workers in a specific region could pursue, from pump operator to claims examiner. Their network is called Skillscape;[97] overall, it shows that workers with social and cognitive skills verses physical and sensory skills are doing better, and that regions with higher portions of these skills are thriving. The network can identify bottlenecks that limit career mobility, and help locate pathways through them. Burning Glass Technologies tracks numerous sources for labor market data from government data to want ads, applies data analytics and skill mapping, and presents businesses with a strategic view on skills they will need and where to get them. For government officials, its data can show evolving labor market skill supply and needs to guide workforce training programs and economic development efforts.

Head AI, a Finnish company, has been developing a "microcompetencies" system that maps regions, cities and organizations showing in real time which skills are most in demand and where they are needed.[98] It is working on a system to map online an individual's skills, that identifies employment fields that fit this personal map, and to identify additional skill areas that would help the individual meet job demands in particular new fields. The online map will show individual skill strengths, and have empty or gray areas where complementary skills are missing and could be added – clicking on each box in the map shows the nature of the skills the individual has or is missing.[99] It shows the occupations the individual would match to, with an overlay for different employment fields that visually shows missing skill areas. It then links the individual to programs to acquire missing skills. These are only a few examples of the many projects evolving.

Another example comes from the Strada Institute for the Future of Work.[100] Recognizing a new imperative that workers must adapt and advance their skills throughout their careers because jobs and tasks are changing with new skills required, it has attempted to build a new way of collecting job market and skill data in close to real time. It seeks to understand better just what skills employers are seeking and how these match the skills held by the regional workforce. Its "skill shapes" approach aims to help not only employers and employees but also educators and policy makers to pursue education and economic development strategies that fit their region's skills.

The Workforce Investment and Opportunity Act (WIOA), passed on a bipartisan basis in 2014, called on the Secretary of Labor to create a new and much larger workforce and labor market information system, and, as Andrew Reamer has noted, provided a full framework for organizing this system.[101] The Secretary of Labor's advisory council on the legislation developed detailed implementation recommendations in 2018 to form this system.[102] The Secretary accepted the report and there are plans for a follow-on advisory group. The rich lode of government data could provide a base for an operating information system, which potentially could be complemented by employer and educator data.

We can summarize the critical elements that are evolving: a system that links in real time workers along with an appraisal of their skillsets, to employers with jobs, and the actual skills required. The navigator must help workers not just move laterally to other jobs for their existing skill sets but upward to new and better opportunities; to do this it must suggest additional competencies within range of the worker's capabilities that the worker could acquire, then directly link the worker to education programs, including online and blended, to acquire the actual skills required. As part of this, it must be predictive and assess spaces where promising employment opportunities lie – it can't shunt workers into dead ends. And it must guide educational institutions toward offering better programs more realistically tuned to actual skills that will be needed that carry accepted credentials – likely these programs will be shorter and more modular, where workers can stack credentials that demonstrate their capabilities. Overall, to be an efficient information system – for the invisible hand to work – it must operate at large scale.

SECTION 4: THE UNIVERSITY ROLE IN WORKFORCE EDUCATION

HIGHER EDUCATION AS AN ENGINE OF ECONOMIC MOBILITY

Higher education has become increasingly tied to societal economic wellbeing. In particular, mass higher education was a critical step in ensuring that the skill base of the U.S. workforce stayed ahead of the curve of American society's implementation of new technology. Let's unpack that sentence. Harvard economists Claudia Goldin and Lawrence Katz have portrayed the societal advantages – indeed, the necessity of - continually raising the college graduation rate. As briefly noted earlier, their book **The Race between Education and Technology**[103] argues that the continuing technological advances in industry since the industrial revolution require an ever-increasing level of technological skill in the workforce. In effect, there are two curves: an ever-growing curve of the technological advance implemented by industry, and a corresponding curve of the technological skill base in the workforce needed to support this technological advance. In a successful, technologically advanced economy, the societal skill base curve must stay parallel to and ahead of the technology implementation curve because the two curves interact and are mutually interdependent.

For a hundred years, the U.S. kept the education curve ahead of the technology implementation curve, but starting in the late 1970s, it allowed the higher education graduation rate to stagnate. Goldin and Katz, using college graduation rates to tell this story,[104] argue that this stagnation is a major cause of the growing income disparity in the U.S., noted in section 1. While the U.S. upper middle class kept ahead of the technological skill curve, increasing its graduation rate, the lower middle and lower classes did not. While the college graduation rate has grown in more recent years, there is still much room for progress, as illustrated in Figure 4-1.

THE CRITICAL ROLE OF HIGHER EDUCATION IN WORKFORCE CREDENTIALING

A 2017 report from the Georgetown Center for Education and the Workforce cites a new

Level of Attainment	Percentage Reaching Attainment
Graduate or Professional Degree	12.2%
Bachelor's Degree	21.1%
Associate Degree	9.2%
Post-Secondary Certificate	5.2%
Total, Post-Secondary Degree / Credential Attainment	**47.6%**
Some college (No Credential)	15.4%
High School Graduate (or GED)	26.0%
9th-12th Grade — No Diploma	6.7%
Less than 9th Grade	4.3%
Total, Non Post-Secondary Attainment (Some College, High School or Less)	**52.4%**

Figure 4-1: US College Attainment (2018)
Source: Lumina Foundation, A Stronger Nation (2018)[108]

economic reality: a high school education, as previously noted, is no longer enough for a good job future; entering the middle class requires some post-high school education.[105] Another Georgetown Center study,[106] to reiterate a point made above, showed that workers with a college degree during the slow economic recovery between 2010-2016 added 8.4 million jobs while those with Associate's degrees or some college gained 3.1 million jobs. Workers with a high school diploma added only 80,000 jobs in the same period; these workers, in effect, experienced no job recovery. To state it another way, nearly all the jobs created during the recovery between 2010 and 2016 - 11.5 of 11.6 million jobs - went to workers with at least some post-secondary education, with those with college degrees taking 73% of these jobs. According to data collected by the Association of Public and Land Grant Universities, college-educated workers enjoy a substantial earnings premium.[107] On an annual basis, as of 2016, bachelor's degree holders earn about $32,000 more than those whose highest degree is a high school diploma.

HIGHER EDUCATION AS A LEGACY SECTOR

But even if universities wanted to adapt, change at universities is difficult. Higher education fits the characteristics of a complex, established "legacy" economic sector that resists change.[109] It is subject to a cost structure and hence a **price structure** that has continued to increase its published tuition and fees at a rate higher than any other significant economic sector including health care, which has created a mismatch with the broader social goal of a highly-educated public. Its demand structure could be characterized as "perverse" because the system tends to equate higher tuition with education quality. Higher education also has an **established infrastructure and institutional architecture** based on a "prestige" factor for long-established schools that disadvantages new entrants to the system. It also contains **powerful vested interests** – particularly faculties and the academic departments they

control - that defend the existing paradigm, are reluctant to adopt education reforms and resist innovations that threaten their existing business models. Higher education has been **averse to innovation**, as a system that conducted almost no R&D on educational reforms and technologies that could improve learning. Higher education is also characterized by the market imperfection of an inability to muster **collective action**. It is very difficult to organize collective efforts around reform of learning or curriculum because the system is highly decentralized, scattered among thousands of institutions. The decentralized nature of higher education institutions means that reforms adopted in one or even some are hard to spread to the others at scale. Bringing change to an established legacy economic sector with these kinds of legacy characteristics is an enormous challenge.

HIGHER EDUCATION CREDENTIALS ARE NOT A SUBSTITUTE FOR ACTUAL SKILLS

A study led by Burning Glass developed data indicating that,

> For many employers, the solution to the shortage of soft skills among their middle-skills applicant pool is to "upskill" the position or to add credential requirements, such as a Bachelor's degree or more work experience. In other words, companies use credentials like advanced degrees as proxies for soft skills.... [E]mployers have increasingly come to rely on a Bachelor's degree as an employment screen, even if it may not be related to actual job duties. This 'short-cut' to ensuring soft skills in employees very often comes back to haunt employers. By using overly restrictive screening procedures, employers effectively choke off viable talent from applying to their organization— and lengthen the hiring process.[110]

Higher education credentials, then, although largely disconnected from actual job skills, have come to be a critical employment signal in significant part because there is no alternative set of accepted actual skill credentials.

EROSION OF BIPARTISAN POLITICAL AND BUSINESS SUPPORT

Likely because of its historic roles in furthering economic and social opportunity, higher education long enjoyed strong support from both political parties. However, this support system now seems to be breaking down, which may partially reflect these credentialing challenges.[111] For higher education support to became a partisan issue creates a significant problem because federal student aid and research support is critical to these institutions, and state support is vital to public universities.

Some of this concern about public support for higher education may be related to concerns in the business community. A 2018 study by Association of American Colleges and Universities found solid overall support for college education from business executives and hiring managers, but there were some significant gaps in the support.[112] While both groups valued applied experiences and real-world skills, only 33 percent of executives and 39 percent of hiring managers thought that recent graduates were very well prepared to apply knowledge and skills to real-world settings. The survey found that among the college learning outcomes tested, both executives and hiring managers placed the highest importance on the ability to communicate orally, but only 40% of executives and 47% of hiring managers rate recent college graduates as well prepared in this area.

WHAT THIS ALL MEANS FOR UNIVERSITIES

Where does this all leave us? Higher education, particularly four-year colleges and universities, are now finding themselves in a predicament. Clear trends in the workforce show that it is upskilling, that ever-higher credentials are being required to be successful in the workforce. Achievement of some higher education is now critical to finding good jobs, and the jobs for those with lesser skills are in decline. Within higher education, the four-year college degree is increasingly the critical achievement; the

two-year associate degree is now required and the pressure, as the employment data shows, is increasingly toward the four-year degree.

Universities have long thought they were far up above the beach of workforce credentials, maintaining their own separate traditions of what they have taught. This was not their problem, this was an issue for high school or community colleges. But now the workforce credentialing tide has moved far up the beach and is starting to reach colleges and universities. As legacy institutions, they are not prone to change and largely have been ignoring it. Their education generally does not reflect career needs, and the capabilities they teach are not particularly well-tied to competencies needed in workplaces. Yet their credentials – their degrees – are now the determinant, de facto, of workforce success; they have become the career differentiating credential. But this degree credential is not well-linked to workforce realities. The result is a growing sense of frustration – for students, employers, and the public.

COMPLETION

If the workforce is upskilling, and the critical credential is increasingly the college degree, a fundamental requirement of colleges and universities is to raise their graduation rates. To follow degree completion in our institutions data tracking current students are required, not simply historic data covering an extended period, which don't give a full picture of what is happening now. The National Student Clearinghouse has tracked students entering college in fall 2012 academic year.[113] Four- year public and private non-profit colleges and universities have the best completion rates: private non-profits have a 76% rate and publics a 65% rate.[114] These rates cover completion within six years and include students who complete their degrees at other institutions. These rates have been inching up, but significantly more progress is needed. At two-year public community colleges, 46% of students did not complete two year degrees within six years and are no longer enrolled. This is a much more problematic number. The overall completion rate for all higher education institutions within 6 years, including completion at other institutions, is only 58.3%. Of the total enrollment of 2,259,497 students in these institutions, four year publics have approximately 45%, four year private non-profits have 20%, two year publics have 33% and four year for-profits the remainder (although they have a much larger enrollment in certificate programs).

Completion rates for African Americans and Hispanics are even more problematic. For African Americans, the six year completion rate at all of the four kinds of institutions listed above is only 41%. For Hispanics, it is 49.6%. Although these numbers have been improving, a major completion gap remains between white and Asian students on one hand and African American and Hispanic students on the other.[115]

THE APLU "READY FOR JOBS" REPORT

A higher education group that has started to see the workforce education dilemma more clearly is the Association of Public and Land Grant Universities (APLU).[116] Its "Ready for Jobs" report of 2017 acknowledged that policymakers and the public are increasingly skeptical about the value of a degree in terms of preparation of graduates for jobs and careers. It noted that "some employers point to a widening skills gap, a disconnect between the degrees graduates earned, the competencies they developed, and the knowledge, skills, and abilities demanded by the innovation economy for a 21st century workforce."[117] It noted the debate over skills shortages, but found that there is an "engagement gap:" much better coordination between labor market actors, including community colleges, research universities, employers, trade associations, government agencies and workforce development and training organizations has become "critical."[118]

The APLU report found that universities need to do a better job in enabling the pathway from degree to job to career, not only in the short term but lifelong. And they need to do a better job supporting not only traditional students but the rising number of adult learners, altering

career services and curriculum to accommodate these shifts. The report acknowledged university reluctance to incorporate new aims of job and longer term career preparation in addition to traditional and important goals of foundational knowledge and preparing educated citizens. Although there was tension between the two, it found that these aims were not mutually exclusive. Liberal arts and foundational education remain important to the society and culture, and the skills that can be acquired through these studies – close analysis, thought organization, advocacy, written and oral communication – are valued by business.[119] A 2020 study notes that over the course of a career the income levels of liberal arts graduates catch up to those with technical and science educations whose income initially spurted ahead.[120] However, the need for better career preparation remains. Credentials that clarify foundational capabilities **and** more career-oriented skills that matter for individuals could be offered by universities that connect to both personal economic and societal needs.

In addition, a rise in digital content skills and a wide range of other skills in a host of increasingly complex areas sends a message to higher education. Territories that colleges thought were the domain of modest numbers of professionals or of technicians will increasingly be the working domain of many industry and employment sectors. Since higher education plays an important role in providing education for many of these kinds of higher-end skills – particularly where design, systems and implementation are involved - it is going to need to find a way to scale its education offerings in these kinds of areas.

WHAT CAN RESEARCH UNIVERSITIES DO?

If technical skills required in the workplace are increasing, and this tide of increasing skills is now at the door of colleges and universities, what is their role? As we build a new workforce education system, one size will not fit all. There are a series of roles and tasks, and some will fit best with universities, some with colleges, some with community colleges, some with industry, and some with individuals. Most will require a mix of these actors.

For example, **development of education content for higher-end technical and engineering skills** will likely best fit universities, while technician level content development will likely continue to be the role of community colleges. The actual delivery of technician content will similarly fall more to community colleges while higher end technical skills will be a college or university role. However, universities can play an organizing role between institutions and employers, in setting up new content development and delivery. And in new, advanced fields, the line between higher and middle skills often overlaps and universities will need to be involved in both. Universities and community colleges will both increasingly be offering certificates to supplement their degree programs to scale up to meet growing needs, in part through online materials.

Colleges and universities are already deeply involved in **developing online offerings**. While community colleges often offer online courses, they generally lack resources to develop them or to ensure they optimize learning science in their delivery. Here again, universities could play a supporting role as coordinator and supplier for workforce needs.

With ongoing technical change in the workplace, **lifelong learning** will increasingly be required; organizing this into a system could also be largely a university task, as discussed below. Researching and testing optimal teaching models and applying lessons from learning science, particularly as online education grows, and creates blended learning opportunities, could also be a university task.

In Figure 4.2 is a **notional** chart that illustrates where universities could play a constructive role and areas that will be more outside their capacities. The chart is simply illustrative; the lines on the chart don't mean, for example, the percent of a task universities should dominate, they indicate only where a university could

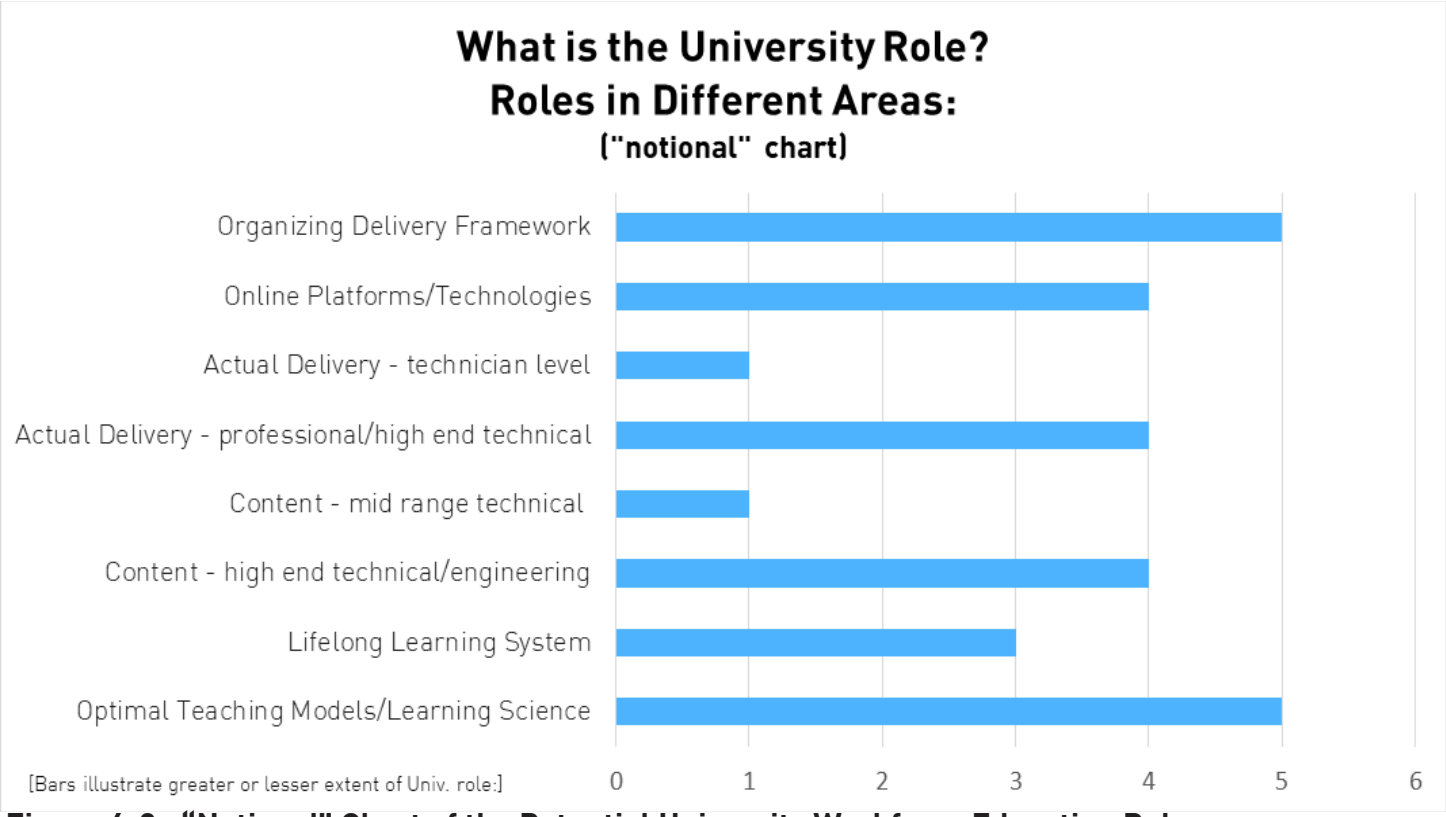


Figure 4-2: "Notional" Chart of the Potential University Workforce Education Role

generally play a greater or lesser lead role.

What would some of these university roles actually look like? The case study below and the two following sections flesh out the details of these possible roles.

CASE STUDY OF UNIVERSITY ROLE IN WORKFORCE EDUCATION – CLEMSON'S CENTER FOR WORKFORCE DEVELOPMENT

Clemson University's Center for Workforce Development has a mission to be "a new national model that engages universities, 2-year colleges, K-12 institutions, statewide industry and federal agencies to deliver workforce education tools that have the power to transform the economy of our state and region."[121] It works particularly to connect Clemson with the 2-year technical colleges in the area.

Supported by an NSF Advanced Technology Education (ATE) award, the Center has been developing VR/AR training modules to support the certifications for manufacturing skills developed by the Manufacturing Skill Standards Council (MSSC), which has become the nation's leading certifying body for the nation's front-line manufacturing production and supply chain logistics workers, offering certificates at the technician level in these areas. Thus, the Center is preparing VR/AR based online course materials that can support MSSC certifications. These simulations were developed to be used by technical colleges in South Carolina for insertion in their courses for education in manufacturing skills. They are also available to community colleges nationwide. The Center doesn't displace the technical or community college as the provider, it provides material that can be integrated into their existing courses. Also, as part of this NSF ATE program, the Center and Greenville Technical College co-developed aviation maintenance technician training materials.

By developing VR/AR modules tied to MSSC skills, the Center is performing a potentially major service for manufacturing, for students and for technical and community colleges. It is an important step, and the kind of step that probably

only a university could tackle.

The Center has also developed a portal called "Educateworkforce.com", for disseminating its simulations and modules;[122] technical colleges can easily access them through the portal and readily insert them into their own learning management systems (such as Blackboard or Canvas) for their own courses. The Center has found the portal works well as a widely and easily accessible site for this purpose. Thus, materials the Center develops and provides can be used by technical and community college instructors, who scaffold the VR and AR content with face-to-face instruction and lectures and with their own online courses into their own learning management systems. Some 6000 technical college students are now using these Center modules through the ATE program for automotive and aerospace technical tasks, for example for safety or maintenance. The modules are currently offered on flat screens that do not require additional expensive equipment. The Center recently undertaken an extensive evaluation of how students perform using VR/AR simulations.

In addition to developing digital learning content with VR/AR for ATE, tied to the recognized MSSC certification system, the Center is working on career pathways, providing certificates of completion when students complete its modules. A manufacturing safety simulation provides another example of the Center's work, according to the Center's Faculty Director, Kapil Chalil Madathil, an assistant professor of civil and industrial engineering, who is a leader on the Center's tech development side using VR/AR. Programs on robotics for technicians, Madathil notes, were "developed in three months, which included extensive meetings with manufacturers to better understand the areas and issues to cover. NSF funded this course through the ATE program. The course focused on enabling trainees to recognize a series of manufacturing safety issues throughout a plant and how to act on them."[123] Textbooks that the Center prepares always accompany the simulations, whether in safety, composites, electrical, or other skills. "Community colleges, technical colleges and high schools in 45 states are now using the Center's materials developed through NSF's ATE, so their effect is becoming widespread," according to Madathil. The Center is also preparing technician level course materials on robotics working with advanced manufacturing institutes.

Clemson's Center for Workforce Development provides an interesting and significant model for how a research university can become deeply involved in workforce education across technical and community colleges, secondary, and K-12 schools, using support from NSF's Advanced Technology Education program and state government. It is a good example of what an engaged university can do.

CONNECTING COLLEGE-LEVEL STUDENTS TO THE WORKFORCE

Colleges and universities need to develop systems to help students, families and employers unpack credentials and access job markets. A Georgetown Center on Education and the Workforce study[124] advocates integrating education and workforce data to help students navigate complex college and career paths. This would also benefit employers by helping them better identify talented workers. Without better information on results, colleges and universities cannot effectively restructure programs to improve student outcomes, and policymakers cannot adequately allocate resources to improve their regional talent bases and economies.

More specifically, the report promoted development by regional colleges and universities of **better data on education and skill supply and demand projections**, on business expansion and on overall workforce quality and needs. Data alone is not enough. **Education program alignment** to **match identified labor market demands** must follow from the data. Colleges and universities will need to make academic program decisions that address labor market needs, enabling college and system administrators to show the return on higher education investments to state leaders.

It is vital that this curriculum alignment with workforce requirements be undertaken. That certainly doesn't mean scrapping the classics, but it does mean opening education options for students so they can see and understand fields with career opportunities. There will be a need to help colleges and universities create curricula that match applied skills and abilities that learners will need to succeed in careers

Counseling about career pathways at the college and university level will need significant improvement. This means a more sophisticated approach than holding job fairs to serve out-of-town employers; the data identified above will need to be applied to help students understand career path options. Students now choose academic programs based on little knowledge of the career effects of these choices – they need career advice to better understand the implications of their choices. Career counseling should support students in their education and career decisions, and help identify those who need additional support.

To summarize, the report argued that the U.S has a maze of pathways through college education and training and they require **a better information system showing common, measurable outcomes that will help students find and meet workplace demands**. As part of this effort, students need a better guidance and counseling system to get them information to make better decisions in college and about career paths, through smart data, publically available tools, and new outreach systems.

The Association for Public and Land Grant Colleges reached complementary conclusions about what colleges and universities need to undertake, as briefly summarized above.[125] It recommended a shift from an approach where career services are focused at the end of a students' college experience to what it termed a "career exploration" approach with **career services embedded within students' entire undergraduate pathway**. It proposed better linkages between career services and faculty, and better academic advising to improve support for students. It called for **improved use of data and analysis by career services** and other student support professionals to help them better connect student interests with promising career and skills development opportunities. And it found that faculty and other student advisors need help in understanding "career pathways" approaches, including **alternative credentialing to assist in aligning student goals with opportunities**.

HIGHER EDUCATION AND LIFELONG LEARNING

There is one more piece in the higher education puzzle worth noting here: lifelong learning. The continuing pace of technological change demands better and ongoing ties between education and employment. In the U.S., the connection between education and economic wellbeing has been simple: pile up as much formal education as you can early on, then cash in on the rewards for the rest of your life. An **Economist** "Special Report on Lifelong Learning" noted that the literature suggests that each additional year of schooling leads to an 8-13% rise in hourly earnings.[126] The period since the Great Recession, as suggested above, made the costs of not completing at least some higher education even clearer; the unemployment rate keeps dropping as you go higher up the educational ladder.

The study's findings of shifting job content suggest that a college degree acquired in the beginning of a career cannot answer the need for the continuous acquisition of new skills of the course of a career. While vocational education/ CTE can provide job-specific skills, these tend to be frozen in time while the technology keeps evolving. The report notes that these, too, will increasingly need to be updated often during a career lasting decades. The report concludes that for workers to remain competitive, and to give workers, whatever their particular of skills, the best chance for economic success, economies – including their higher education components – will need to offer career-focused education throughout working careers.

There are significant implications for higher education here. First, **lifelong learning is going to require better connections and hand-offs between the actors in the system** because each will be a playing role. Traditionally, most colleges and universities behave like independent and disconnected actors from community colleges. However, many states are moving to better connect them. Over thirty states have required some level of transferability between their community colleges and state universities.[127]

Second, APLU has identified steps that universities will need to take to better serve their students that will be critical for lifelong learning. These include more **varied delivery mechanisms**, including courses on evenings, on weekends, online, in **hybrid formats**, and of varying lengths to meet needs of non-traditional students. This also means a great deal of attention will be required on development of **alternative credentialing programs**, including certificates, badges, and competency-based programs. **Adaptive learning** approaches will also be needed, including assessments for prior learning and allowing students to learn on their own pathways that meet their career needs yet satisfy needed competencies.

Third, **online education**, which most universities and colleges are now pursing at increasing scale, offers a unique opportunity space for lifelong learning. It is a highly flexible new toolset, so students can study at the levels and on the timelines they choose. They can pace themselves with online to accommodate outside pressures of work or family, and to meet their own individualized learning speeds.

Fourth, lifelong learning offers a **major new economic opportunity for colleges and universities** if they seize it. The demographics of higher education are changing: there will be significantly fewer students of traditional college age. This means a declining tuition base. If they stay the same, many schools will simply have to close, and we can already see these trends evolving.[128] Overall, enrollment throughout the system will decline unless something changes, and lifelong learning, which is increasingly required by the economy, could be that opportunity.

SUMMARY

Let's try to summarize what all this means for the role of colleges and universities in workforce education. As shown above, clear and stark trends in labor markets show that the American workforce is upskilling, and that ever-higher credentials are being required for economic wellbeing. Achievement of some higher education is now vital to securing good jobs, while jobs for those without these credentials are in decline. Within higher education, the four-year college degree is increasingly the critical credential; the two-year associate degree is now required and the pressure, as the employment data shows, is increasingly toward the four-year degree.

Four-year colleges and universities, are now finding themselves in a predicament. Through education system reforms in the late 19th and early 20th century, a high school education by the mid-20th century was adequate for most job skills, and professional or graduate education was required for professional skills. Although there was variation across institutions, a college education in most four-year schools was not well-linked to the workplace; it provided foundational skills and a liberal arts background for a modest although growing portion of the population. As described above, four-year colleges and universities were largely divorced from the workplace fray, maintaining their own separate traditions of what they taught. Scaling-up largely in the 1960s, community colleges emerged to help fill a gap for technical skills. But, as noted, now the workforce credentialing tide has moved far up the beach and is starting to flood into the unprepared four-year colleges and universities. As legacy institutions, they resist change, are decentralized so lack the ability to move collectively and collect little data on learning, education or work. The education they provide

generally does not reflect career needs, and the capabilities they teach are not particularly well-tied to competencies needed in workplaces. So far, they have been largely ignoring their increasingly critical role in workforce credentialing. Yet their credentials – their degrees – are now the critical determinant of workforce success. But the completion rates for their credentials need improvement, particularly for minorities and those from lower income background. And, in turn, their degree credentials are not well-connected to workforce realities. They face a growing sense of frustration from students, employers, and the public.

There is also a workforce reality compelling change. The nature of the jobs themselves in a growing number of areas requires more and more technical knowledge and skill. Although higher education degrees largely do not connect to these technical skill competencies, the college degree has become the accepted default because our workforce credentialing system is so problematic.

What are higher education institutions to do? A report from APLU argues that colleges and universities don't have to give up their significant traditions of the liberal arts and foundational skills and knowledge. The report, however, argues that these institutions can also do, without sacrificing their other traditions, a much better job of helping students become career-ready. The problem is not either/or, foundations or career; schools can do both.

Within the large societal task of better preparing the broad workforce, college and non-college, for solid working careers there are tasks that appear particularly suited to universities and their capabilities. As discussed, universities could play a significant role in helping to organize new kinds of delivery frameworks across secondary schools, community colleges, colleges and universities, particularly in connecting the latter to the former and in providing new capabilities. These new capabilities would include provision of and work on online platforms and new education technologies, from VR/AR to computer gaming, that the other elements in the system are unlikely or unable to take the lead on. While actual education delivery of high-end technical skills will be a college and university role, the actual education delivery of technician-level skills will likely remain a domain for linkages between secondary schools and community colleges. Correspondingly, education content development for high-end technical skills will likely belong to colleges and universities, while content for "middle" or technical skills will fall to the other institutions. However, colleges and universities can play an organizing role for both content and delivery across institutions. Concerning R&D on learning science and optimal teaching approaches, for example for blended online and classroom education, these will need to be taken up by universities and colleges. Lifelong learning systems will also require universities and college leadership in their development. These are massive new tasks for higher education that it will need to organize for. But there is an opportunity here. The demographics are narrowing for students of traditional college age; lifelong education offers a new market that could be important to the future economics of higher education.

SECTION 5: THE NEW EDUCATIONAL TECHNOLOGIES

A requirement for an agile workforce is placing new demands on our existing systems for workforce training and education in general. Education is a complex field, but for the purposes of this discussion, we will view it in terms of three pieces: the content, the pedagogical approach and the modality by which it is delivered. Each of these has undergone changes due to advances in technology. And this has caused a new interest in educational technology, also called EdTech.

While the partitioning is convenient, content, pedagogy and modality are connected to each other. Different content forms require different pedagogies, and often different delivery modalities. Consider how machine learning might be taught, for example, and compare it with teaching a nurse to use a new ultrasound machine: one involves algorithms and data, the other hands-on equipment. Yet a central aspect of the opportunity in mainstream education is the fact that good pedagogical practice – applying what we know about how people learn, and how to be effective in education -- has often taken a back seat to convenience, scale, tradition, and regulation in the development of our education systems. This is true not just in the U.S., but worldwide. Much has been written about the evolution of the school and college systems that we will not repeat here.[129] But the summary is that the need for better learning points towards a significant redesign of existing education systems; and happily, we posit, the optimal system would in fact be more agile, and therefore more in tune with today's labor market, than the systems in place today. So, with this view of the importance pedagogy, we begin our exploration of EdTech with a discussion of pedagogy.

BETTER PEDAGOGICAL PRACTICES

Insights about how the human brain gathers and stores information, and develops facility with new material, have been accumulating for over a hundred years, beginning with the seminal work of Hermann Ebbinghaus.[130] Unfortunately, our systems were well in place by that time, and the runaway train could not be rerouted. However, we continue to learn a great deal more.[131] For example, it appears that we are more likely to learn when we are curious,

because curiosity triggers a dopaminergic circuit. Socrates presciently said "wonder is the beginning of wisdom."[132]

So, material that inspires a student to become curious about a topic is well worth the effort. Unfortunately, this is hard to achieve in a standard classroom setting without exceptional educators – the ones many of us remember from our own experiences. But not every teacher can be inspiring -- many may have a better grasp of the material without the same level of charisma. And yet today, our one-size fits all model limits our efficacy at a time of great need for a revolution in learning. This is where technology can, and is, playing a part. We explain more below.

BITE-SIZED CHUNKS:

We learn in about 10-minute chunks. This appears to be related to the way we form short term memories in the brain. If learning exceeds that time, the mind seems to enter a state of mind-wandering. Therefore, lectures need to be extremely short to be effective – a lesson a parent probably recognizes instantly, though the insight applies equally to adults. Courses, then, should use 10 minutes of lecture segment, switch to another learning mode (for example, an interactive group discussion, a demonstration or an assessment), then return to a 10 minute lecture segment, and so on.

Impact of educational technology on the lecture:
Distance education, be it by correspondence, radio or cassette has been around for decades. But it should not be confused with modern online education. **Online, on-demand video** has unquestionably made a massive impact on learning by enabling students to access content on an on-demand basis. Content creators such as Khan Academy, Minute Physics and MIT OpenCourseWare have millions of subscribers on platforms such as YouTube. Content creators and learners have naturally gravitated towards shorter videos perhaps without explicit knowledge of the cognitive benefits. Furthermore, the ability to pause, rewind and speed-up video has made for a very adaptable and vibrant approach to the distribution and consumption of content. Transcripts can be generated automatically or manually to make the videos accessible, and also to give viewers search options. We tend not to think of YouTube as educational technology, but we argue it is probably the most important EdTech product out there.

In the 2010 decade, a new technology format became prevalent: **Massive Open Online Courses (MOOC's)**. Combining the short video format with computer grading, which we will discuss later, and forums where students can help each other as well as get help from teaching assistants, MOOC's have become a major force in education. The three largest MOOC providers are Coursera, edX[133] and Udacity. edX and Coursera offer certificates, micro-credentials and full master's degrees at the time of this writing. Udacity offers certificates and "nanodegrees." Today the three MOOC platforms collectively count some 100 million enrollees.

Finally, it is worth mentioning that **automatic lecture capture** of the traditional lecture is an interesting technology. By tracking the lecturer, these cameras can generate video with very little operator effort. A lapel mike can be used for sound. These systems make traditional lectures available for asynchronous viewing, where the viewer can pause or rewind the lecture, and for edited distribution internally and externally.

These online, on demand technologies hold great promise for education and for workforce education in particular. Unlike a classroom, they can both operate at great scale and offer new education opportunities. Because it will often involve operating equipment and physical activity, workforce education is inherently more "learning by doing," so online, with its capability for repetitive and visual engagement, can fit better than a classroom. Online is already reaching the workforce side, for example through commercial firms such as Thors, Tooling U, 180 Skills and others, although universities and community colleges, as discussed in section 4, have been slower in applying online to meet workforce

needs.

DESIRABLE DIFFICULTIES:

Students often re-read material, thinking it helps learning. Unfortunately, it is not effortful, and causes the illusion of learning. In fact, a surprisingly consistent result from learning research is learners' overconfidence about their own learning, and the importance of a realistic sense of one's personal competence.[134] A series of findings listed below show that **effortful** approaches – i.e., in which the learner struggles with the material a little -- unintuitively lead to better, more durable learning. Elizabeth and Robert Bjork call these techniques "desirable difficulties" – difficulties that lead to better learning by increasing processing of the material rather than being distracting.[135]

First, when a learner is tested frequently about the material that she or he has just learned, learning is better.[136] This is called the **"testing effect"** and the use of it as a learning technique is referred to as "retrieval practice." Together, they are much documented in the literature. An interesting aspect of retrieval practice is the positive effect of effortful retrieval. So, for example, a learner who is given weaker cues for the test, and therefore struggles more will learn better than one given stronger cues.

Second, **testing should be spaced**.[137] Also called, "spaced practice", this concept is related to the findings of Hermann Ebbinghaus himself. Spaced practice flies in the face of a prevalent and expedient approach in education today, mass practice, in which a student might address a number of problems at the end of a chapter in a short span of time (rather than spacing them out over days, weeks, and months). Spaced practice applies not just to academic learning but also to sports and motor learning. Ironically, learners themselves feel they have learned better with blocked practice although they may have learned less effectively – recalling the theme of illusory learning.[138] Spaced practice has even been replicated beyond humans, in animals such as insects, and now has been explained to some extent down to the levels of the proteins needed for long-term memory.[139] In fact, a key aspect of spaced learning is that relearning material is most effective just before the learner forgets the material. This requires sensing when a learner is getting rusty about the material – a level of attention that a teacher in a classroom cannot achieve at any scale.

Third, **content is best interleaved**.[140] A common, and understandable, practice in education is to practice topics in blocks: multiplication, say, followed by division. The evidence from extensive research points to the benefits of interleaving practice: multiplication problems alternated with division. This is, again, inconvenient in a large classroom in which students are on a march along a complex curriculum. However, the benefits have been replicated in a range of subject areas including mathematics and art. The neuroscientific mechanisms of this desirable difficulty, which results in so-called cognitive interference while learning, has also begun to be understood.[141]

Fourth, the act of assessing a student's performance in any interaction with a view to giving feedback, and the **when and how to give feedback** are obviously essential in learning. Many have studied the impacts of the amount of feedback, the time delay of the feedback, and the detail of feedback. Depending on context, for example, delayed feedback is a desirable difficulty. But feedback takes time, and pithy feedback may be generally (but not always) more efficient in terms of the allocation of total time in a learning task.[142]

All of these four lessons – spacing, testing, interleaved content and assessment/feedback loops - have direct application to workforce education. All can be fitted into a backdrop of "desirable difficulty" to keep students engaged and challenged. Unlike established classroom approaches, each can be directly incorporated into the way online education instruction is organized. Online education's potential for interactive learning can make it much more

sensitive than a classroom setting to the best timing for introducing spacing and feedback features, for example, to attain the right level of desirable difficulty.

Educational technology and cognitive science: Traditional lectures with large classrooms are hard-pressed to leverage cognitive science. Technologies such as clickers can engage students, make learning more active, and mimic the testing effect, but the full use of the cognitive science described here requires personalization. For example, since spaced practice would ideally detect when the learner is becoming rusty in the material, ideally a few "probing" assessments are necessary to fine tune the spacing for each student.

The software application SuperMemo is truly a pioneer in the use of spaced repetition.[143] Language learning apps such as Duo Lingo also appear to use cognitive science principles.[144] Flashcard software such as Quizlet leverage the testing effect, and can be used to apply spaced repetition and interleaving. MOOC platforms already leverage the testing effect, and have a significant opportunity to incorporate spacing and interleaving. Research is on-going.[145]

MOOCs really changed the state of the art in assessments – a world that was for a long time stuck with multiple choice questions. For example, today the edX platform offers dozens of assessment types including assessing the correctness of software code, circuits, mathematical expressions and diagrams. What of essays or poetry? There is already software in word processing systems for assessing spelling, grammar, sentence structure and plagiarism detection. MOOC providers like edX go a step further with peer grading, in which students grade each other's' assignments. In fact, there is now a rich subfield of research studying benefits of peer assessment.[146] Thanks to peer grading, MOOC providers have a surprisingly rich slate of courses in the humanities, arts and the social sciences.

But the ultimate challenge is **AI-based grading of subjective responses** such as essays. This has proved controversial for reasons both philosophical and pragmatic.[147] However, systems like edX, and its open source software corpus, Open edX, enable third party software to plug in. This will ensure that innovation in AI can continue in parallel and plug in at the discretion of the instructor. Because AI can enable much greater scaling, areas such as AI-based assessment will remain fertile ground for innovation in the years ahead.

One aspect of grading that remains relatively unsolved is **rich feedback**. An automatic grading system such as one in a MOOC may be able to say whether a program or a derived mathematical expression is right or wrong, but cannot provide constructive feedback about where the student when wrong. Or, for that matter, provide insights about the student's mental model.

Similarly, lessons from cognitive science can migrate from traditional education to workforce education. The need for feedback and testing are profound in skill training and online technologies can be of significant help in optimizing their delivery. Because subjective responses and essays are less relevant to much of workforce training, current developments in AI-based assessment can already enhance fit workforce applications.

SCAFFOLDING AND TUTORING

The Soviet psychologist Lev Vygotsky, proposed the concept of a "zone of proximal development" as an optimal difference between a learner and a "more knowledgeable other" who can lead the learner to greater achievement.[148] Too large a difference, he argued, and the learner cannot keep up. Too small, and the learner doesn't learn. More generally, scaffolding is a way to provide the learner support as she gains mastery over the material. In Vygotsky scaffolding, the art lies in calibrating the challenge of the learning to the student's abilities. Anyone who has played tennis with a slightly better player can probably relate to this balance. Good tutors and coaches

are able to calibrate themselves, while an expert who does not possess good coaching skills may suffer from an expert blind spot.[149]

But a careful performance of tasks under the observation and tutelage of a coaching-inclined expert, who can provide guidance to enable continuous improvement, can lead to significant improvements in performance. This idea underlies a technique called "deliberate practice," which has shown significant benefits in a range of learning activities from sports to physics education.[150] For example, Code Academy, a company that offers online computer coding courses, provides a highly scaffolded set of tasks with assessment to teach students how to code a variety of computer languages.

In 1985, Benjamin Bloom captured the benefits of good tutoring in a seminal paper in which he showed a vast improvement over traditional teaching.[151] But, he argued, since tutoring is expensive, how can we improve scalable education to achieve similar results? More recently, the **Cognitive Load Theory** has helped put more flesh on the theory of scaffolding. Novices, the authors argue, have fewer predefined schema to digest new information, and so suffer from high cognitive load because the working memory available to them is limited.[152] Novices therefore require more "fill in the blank" problems. But as the novice becomes an expert, and develops the schema to absorb information, she can be exposed effectively to more open-ended problems.[153] Either way, the key, it appears, is to expend cognitive load on germane – as opposed to distracting—tasks. It is in this respect that Cognitive Load Theory and Desirable Difficulties seem to agree – the importance of avoiding undesirable difficulties.

Education technology and tutoring: Intelligent tutoring systems (ITS's) are computational systems that teach students a subject by modeling the student, the domain being taught and a scheme for instruction and feedback. In many ways, ITS's have been the holy grail of automated education going all the way back to Alan Turing and B.F. Skinner. Modern ITS's, which model the most recent understanding of the working of the human brain, were pioneered by John Anderson of Carnegie Mellon, and resulted the so-called Cognitive Tutor.[154] ITS's remain a key focus for EdTech, and, in many ways, capture many of the aspirations described in this section. ITS's in the ultimate form are also the pinnacle of personalized learning.

Games are another important area of EdTech related to motivation and scaffolding. So-called **serious games** (a term used to contrast with "gamification," noted below) refers to games developed for purposes other than entertainment. Game-based learning refers to serious games for education. Games can lead a student through a series of tasks and create an environment where learning occurs naturally. An example is World Without Oil, an alternate reality game that leads players through a post-oil world, forcing them to think about the implications of an oil shock.[155] While that game was much acclaimed, designing a game to ensure well balanced learning and participation is difficult.[156] Games have been used for education about topics as varied as the environment,[157] gender discrimination[158] and STEM topics.[159] **"Edutainment"** is a different philosophy from serious games, in which gaming is merged into entertainment. However, the value of edutainment has been questioned.[160] A third approach is to neither entertain, nor to be serious per se, but to focus on **playfulness**.[161] The Scratch system, for example, is an extraordinarily successful example of this approach—students focus on creativity with a graphical programming language, "playing to learn" rather than "learning to play."[162] They learn programming in the process. Finally, the word "gamification" has been used somewhat loosely, but should really be interpreted as a fourth category. The idea of gamification is to tap into a social, potentially socially competitive, network, but generally tapping into intrinsic motivation factors similar to those in video games. In some sense, any educational environment can be gamified, but the effectiveness needs to be carefully assessed.[163]

Simulations are a very powerful technique similar to games, but different in that they exclusively model realistic situations and teach real skills. The simulation provides real time feedback and uses this to scaffold the progress of the learning with possible increasing difficulty as the training progresses. Flight simulators, for example, have long played a major part in training pilots, enabling rapid scale-up.[164] During World War II the U.S. military used some 10,000 automated Link Trainers to train half a million pilots.[165] Japan, which lacked comparable simulators, was desperately short of trained pilots by the end of the war. As discussed in section 7, the military is using virtual and augmented reality tools (VR and AR) for the latest generation of simulators applied to a wide range of training needs, from operating aircraft turbines to submarines. Simulators have also been used to teach everything from business strategy[166] to environmental dynamics.[167]

An emerging trend in online platforms such as MOOC platforms is the use of **collaborative tools to enable coaching**. For example, edX is supporting case-based collaborative tools for online learners. Coursera acquired Rhyme Softworks, which enables among other things, a coach to work with a novice as she uses a software tool. Finally, group annotation tools, such as that supported by edX, or the standalone software Nota Bene, help students and teachers annotate the same, or versions of the same, document and provide coaching.

Intelligent tutors, games, simulations and collaborative tools are all highly relevant technologies for workforce education. Each offers new learning capabilities through applying advances in tutoring and scaffolding approaches to learning, delivered from the new technologies that can enhance them. The experiments that are ongoing in education with these technologies need to be incorporated into workforce education.

The following case study attempts to summarize and place emerging new education technologies and approaches into their education delivery context.

MENS ET MANUS

The MIT approach to learning is **mens et manus**, Latin for "mind and hand," reflecting its early emphasis on lab-based learning,[168] and indicates a continuing strong preference for learning by doing. While Descartes argued that the mind and the body were independent, recent scientific findings seem to bear out the wisdom of MIT's historical credo. It is a credo that is captured by the more current phrase "hands-on" learning, which is tied with a related series of educational approaches. Tactile experience, in which a student physically feels angular momentum, or gestures to capture a phenomenon, have been shown to improve learning.[169] Similarly, Generative Learning Theory posits that learning is better when the agency of the learner is engaged in the generation of new information based on prior concepts.[170] More generally, "active learning" is any instructional approach that engages the student in the learning process – as opposed to passive listening.[171] **"Blended learning"** is an approach that mixes online, focused on the information content, and frees up increasing face-to-face time between students and teachers so that the class can be more active, and more opportunities for coaching arise.[172] The **"flipped classroom"** is a term coined by Sal Khan of Khan Academy to describe the use of online courses to leave time in the classroom to do more hands on, blended activities. Project-based learning, problem-based learning and task-oriented learning are all techniques to give students more agency and purpose. Integration is another important aspect of learning, which projects and tasks can help enable. Learning through discipline-aligned courses can lead to "siloed" knowledge. Integration refers to connecting topics across silos and is a central aspect of David Merrill's teaching philosophy.[173] **Teamwork** is another important element of learning that can also be helped by projects and group activities.

Educational technology that enables hands-on activities: There is a small fleet now of prototyping technologies such as 3D printing, Lego Mindstorms, the Arduino, the Raspberry Pi,

App Inventor, and even the programming language Python, that are a form of EdTech that enable hands-on learning. The power at the fingertips of students to actualize their ideas, to learn from the real creation, to seek feedback, and to enjoy the pleasure of achievement is unprecedented – and will increase with time. Competitions such as FIRST robotics have leveraged such technologies to further increase the reach and power of scaffolded mentoring and coaching. This could be characterized as learning by creating.

What if the topic cannot be prototyped on a benchtop? We have already noted simulation. Virtual reality is another step in the direction of creating realistic situations that would be difficult to get physical access to. For example, VR can be used to perform a hands-on, team-oriented task in an undersea environment. Augmented reality can be used for on-the-job training. For example, an engineer who is performing a maintenance task may have an expert view the task in real time over an AR headset and provide subtle feedback.

Hands-on learning is clearly critical to workforce education because so much of it requires training for actual hands-on tasks. The suite of related kinds of learning, from tactile, to active, to blended are all highly relevant to workforce education. The prototyping technologies for learning by creating are further enablers when applied to a range of skill areas, such as manufacturing. Particularly important for workforce education are blended learning and VR and AR technologies. Blended learning can shift more of the rote learning to online and free up expert instructors for coaching and personal and small group problem solving and instructing. Since displaced and older workers will be less ready for online courses, blended appears critical in reaching these groups. VR and AR enable true learning-by-doing in immersive environments, that will be ideal for many aspects of workforce education. The Navy's work on training in these technologies is noted in section 7.

NEW DELIVERY MODALITIES

Clearly, as we have discussed above, the Internet and computers enable a whole new paradigm for education in accordance that will enable us to implement lessons from learning science in dramatic new ways. However, there is an important aspect that we have not discussed: access.

In 2001, MIT made its curriculum free to the world with the launch of OpenCourseWare.[174] To date, more than 300 million downloads have occurred. This spurred a major online revolution that resulted in the launch of MOOC's. Today, the top three MOOC providers, edX, Coursera and Udacity, collectively boast of nearly 100 million enrollments. Goodman and colleagues study of the Georgia Tech's computer science Master's program presents a useful summary. They describe the advantages of access and scale of the Georgia Tech program, and the opportunities online programs create.[175] The benefits of online programs are many, but perhaps the most important is the ability of working people to educate themselves without interrupting work and careers. This is particularly helpful to individuals who have families, or have other reasons that make traditional place-based education difficult. New micro-credentials such as the MicroMasters enable job-friendly academic accomplishments without the need to attend college. These kinds of online offerings multiply education access.

The edX software is also open-sourced under the Open edX name, enabling any institution to download and run their own MOOC's. Universities, entire nations, and companies have taken advantage of this facility to create local education ecosystems. Anyone can be a MOOC creator, and take advantage of the latest technologies and broadband access that edX has created for its platform. In addition, learning management system (LMS) vendors such as Desire to Learn and Canvas have adopted many MOOC-like features which, though not necessarily scalable like the MOOC platforms to hundreds of thousands of users, nevertheless can support university sized user-bases.

Online education does seem to work when done

right.[176] However, Eric Bettinger and researchers at Stamford's Center for Education Policy Analysis, for example, analyzed a for-profit university and found poor results from online courses.[177] They also found that online seems to work less well than a classroom for the least prepared students.[178] A workable economic model for offering MOOCs is still an ongoing project at many universities.[179] Many lessons on online delivery clearly are still to be learned; this indicates that there is nuance in using this powerful new medium.

A deep problem for workforce education is access. With a workforce of over 150 million requiring systematic upskilling and lifelong learning, and a problematic existing delivery system, it is hard to envision how to reach this group without extensive use of the scaling possibilities of online education. New delivery modalities have evolved to expand the reach of online education, from MOOCs to online certificate programs. Clearly online, and the suite of technologies and learning approaches that can enhance it, will be important to workforce education. However, much work needs to be done to adjust online training for the kinds of learning challenges different workforce groups face, including incumbent, displaced and new entrant workers. One size clearly won't fit all, online training will have to be adjusted to worker needs.

CONTENT

That leads us to the point that there are several types of content for the working learner of the future: formal, informal and professional. The technology for each will be different.

In discussing **formal** education, typically academic but also very relevant to workforce, we have already described the pedagogy, the modalities, and the technologies impacting it. In addition, we have stated that there is a cognitive benefit to having learners receive some in-person education. This leads to the opportunity for technologies that support the deeper insights that in-person modalities enable, such as virtual lab equipment. In addition, collaboration software can serve as a middle ground that achieves some aspects of in-person education without physical co-presence. Platforms such as Harvard Business School's HBX online and IE Business School's WoW are examples that enable an in-person experience online.

Informal education has flourished over the last 2 decades. It occurs outside formal institutions and either helps students do better in school or work, or to prepare for standardized tests and certifications such as bar exams. A significant amount of educational technology innovation has occurred in this sphere, and there is a rich ecosystem of downloadable and web-based testing software. Recently, companies such as Squirrel AI claim to have personalized software using AI tools, creating student models as students learn. These companies tend to focus on highly defined topics such as mathematics and seem to offer a new generation of intelligent tutors. Can such technologies be used to teach a student how to write G-codes for a CNC machine tool?

Professional education refers to yet another market in which edtech tools have flourished. Professional education either occurs inside companies, or in fields that require continuing education which can be rewarded with continuing education units (CEU's). Specialized corporate learning management systems such as Skillsoft, Cornerstone and Pluralsight enable corporate learning libraries, which allow integration with HR systems. There is an even an emerging category of recognizing and rewarding informal education in the professional category. Companies such as Degreed and edCast let companies provide this informal content – such as content libraries and even magazine articles – and keep track of learner progress.

These technology developments in all three types of education are potentially relevant to workforce training. Clearly professional education enhanced by new technologies cited here allows firms to provide their own training systems in new ways. But new technologies entering both informal and academic education clearly can carry over to workforce education delivery.

EDTECH AND WORKFORCE EDUCATION – ADDITIONAL TECHNOLOGY STRANDS

Rather than present edtech as a catalog of separate technology capabilities, we have presented it here in the context of pedagogy, modality and content. However, this framework leaves out a few capabilities that are best presented holistically. Each has significant promise for workforce education.

Artificial Intelligence in Education: The idea of using AI in education, and eventually the personalization of education, is very attractive in an era of rapid workforce training. The idea is that smart systems might be able to adapt to and personally guide students, at scale, through a learning journey that ensures better outcomes. However, it is useful to separate what it means to personalize.

First, asynchronous video-based lets students slow down or speed-up delivery, and in this sense enables what we refer to as self-personalization.

Second, the logistics of education can be made smoother using AI and Neuro-Linguistic Programming (NLP). This includes chatbots to address student questions and requests, and to answer frequently asked questions. The much-reported Jill Watson experiment, a virtual teaching assistant used at Georgia Tech to advise students, is a good example.[180]

Third, the ultimate AI-based personalized system might well be the intelligent tutor we have described before. AI systems like Squirrel, however, offer "adaptive guidance" to students using Bayesian and other learning algorithms, but in the end, involve a human teacher who can provide personal attention. This helps manage the load of the human. Perhaps one day AI systems will be able to truly coach the student by understanding their deeply embedded misconceptions. But that may be a few years away.

Sensors: There is much research about the human body's response to learning. This ranges from eletroencephlogram (EEG)[181] responses to eye-tracking.[182] In the future, galvanic skin reflex, expression tracking and heart rate variability may also become key measures. These systems may become valuable in understanding whether a student is comfortable with the learning. However, these high technology approaches will likely take time to be refined, accepted and adopted.

Digital Certificates and Badging: There has been much work in digital badging to recognize learning achievements.[183] As this work has discussed, new credential systems will be needed for workforce education and lifelong learning. But issues about what they mean and their validity remain. Recently, nine universities worldwide, including MIT, launched an effort to make digital badging more scalable and prevalent for use in online courses.[184] Digital credentialing, using strong cryptography and blockchain, can create fraud-resistant, readily verifiable certificates under the control of the credential holder not the education institution, that can be much more detailed about the skill content behind the credential. This can help assure the rapid transportability of credentials and help employers understand what they represent, as discussed in more detail in section 7.

SUMMARY

Online education, coupled with a swarm of complementary new technologies and learning approaches, offers a new tool for workforce education. Given the scale of the workforce education task – a workforce that requires ongoing upskilling and lifelong learning – online education's ability to rapidly scale will play an important role. It provides a dramatic new tool to open up access to workforce education. While online education so far is better if it is combined with face-to-face education for "blended learning," it should become a critical element for workforce education delivery.

The complementary technologies will increasingly enhance it. These include MOOCs,

intelligent tutoring systems, computer games, simulations, collaborative IT tools, VR and AR, AI, digital credentialing, and, potentially, sensors. This bundle of new education tools can also further learning. We are starting to absorb lessons in improving the learning process through new pedagogy tools: "bite sized chunks" (short, focused segments), "desirable difficulties" (through testing, spacing, interleaved content and assessment/ feedback loops), and "hands-on" learning (through tactile, active, and blended approaches). These learning lessons can be boosted in an online context by the new technologies available to help delivery them. New systems and modalities for delivery are also evolving, from MOOCs, to the platform systems that support them, to new companies, to digital certificate systems.

To apply this new toolset we will have to overcome existing barriers. Online MOOCs primarily serve better educated users who are already employed and seeking career and education benefits.[185] Online is only starting to be seen a medium for teaching technical skills used in the workplace, and this lacks a strong system yet for development and implementation. However, workforce education, with its requirements for learning-by-doing and hands-on, could be a direct beneficiary of this mix of new technologies along with our learning about learning. It can also benefit from the new delivery modalities and systems that online has led to. There is much promise here, along with many challenges.

SECTION 6: THE APPRENTICESHIP MODEL

BACKGROUND: AMERICAN APPRENTICESHIP EFFORTS

Apprenticeships historically have aimed at youth and new entrant workers. Nations like Germany, Switzerland and Austria run famous, multi-year apprentice programs serving the majority of their workforce sectors, and have built an envied infrastructure of skilled talent that undergirds strong manufacturing and other industries. The United States lacks this system.

Characteristics of American Labor Markets: Why doesn't the U.S. have a more systematic workforce training system?[186] Labor economist Richard Freeman has found that it has less institutional regulation than other major advanced countries. It relies on decentralized wage setting to determine worker pay and its workers have lower safety nets to cope with unemployment, disability and health problems. He concludes that, "Some see the U.S. market as the nearest thing to the "invisible hand" market of economic theory.[187]

Economist Gary Becker found that American labor markets generally supply suboptimal levels of skills training, as noted in section 1.[188] Companies aren't willing to invest in worker skills because competitors frequently poach these trained employees, avoiding their own workforce training investments and preventing the first company from recapturing its training investment. So employers tend to train for skills needed only by their own firms and are more valuable for their firm than for others – focusing on "specific"[189] skills. For "general" skills, firms tend to require that they be acquired by the worker before joining the firm. The employee, then, has to bear the burden of obtaining the general skills training, which is, in turn, the prerequisite for acquiring the firm-specific skills. Many potential employees are simply not in a position to invest in acquiring general skills, limiting the skilled worker base, which damages the participants in the labor market, both employees and employers. Exacerbating the problem, federal funding for employment training, as noted, has fallen by half as a share of GDP from the mid-1980s to the present.[190] Would apprenticeships, shared across groups of employers within industry sectors, provide one way out of this box?

American Apprentice Programs: According to Labor Department estimates, in an economy with over 150 million jobs, there were 585,000 registered apprentices in a range of fields in the U.S. in 2018 through programs run by labor unions or individual companies.[191] However, this was only a modest rise from the 490,000 apprentices in the early 2000s. This is only 0.4 percent of the total U.S. workforce.[192] The U.S. registered apprenticeship program, run through the Department of Labor (DOL), has been dominated by skilled construction trades, where a long history of construction unions has helped sustain it.

To the extent it has them, Robert Lerman notes U.S. apprenticeships involve adults not youth, and typically require 3 to 4 years of work-based learning and classroom teaching.[193] There are youth apprenticeships, but only in a few states. Lerman has identified some studies that show statistically quite significant gains for apprentices' earnings, exceeding other options.[194] Some reports also indicate that the benefits to companies are also significant.

Youth Unemployment Rate: The U.S. has long had a problem with a high youth unemployment rate, which is a signal of a major underlying problem in transitioning its youth into productive work. During the Great Recession and its early years of recovery, the youth unemployment rate exacerbated the social disruption of the period, scarring that generation. In 2007, going into the recession, youth unemployment was 13%; by 2010 it reached just under 21%,[195] with many remaining unemployed after more than a year of searching for jobs. With the gradual recovery, this number (for those aged 16 to 24 actively looking for work and not in school) declined but was still 9.2% in July 2018.[196] Unemployment was higher among young men (9.8%) compared to women (8.6%), and higher among African Americans (16.5%) and Hispanics (10.8%) compared to young whites (7.6%). Germany, by contrast, had a youth unemployment rate of 6.3% in July 2018.[197] These rates compare to an overall U.S. unemployment rate of 3.9% at that time.

Education and the Youth Labor Market: A Pathways to Prosperity summary provides useful background on the youth labor market.[198] As of 2016, the education levels of the lower end of the American labor force ages 25 to 64 breaks down as follows:

- No High School diploma – 12%
- High School diploma/GED – 26%
- Some college, no degree (including certificates) – 22%

The remainder have associate or bachelors or higher degrees.

The U.S., the inventor of mass higher education and long the leader, is now only 11th among developed nations in its education attainment. The college completion rate is surprising low for college and particularly community college students, and it is dangerously low for students from lower income households. There is a very large number of students without any post-secondary education, despite its growing importance in obtaining solid jobs. But young people who get licenses and certificates for particular technical skills, primarily through community colleges, can still do well compared to better educated peers.

A 2013 report by Jonathan Rothwell of Brookings on "The Hidden STEM Economy" found that there were more technically-skilled "STEM jobs" (science, technology, engineering and math based) than previously estimated.[199] It found that 26 million jobs - 20% of all jobs - required a high level of knowledge in any one STEM field. Interestingly, half of all these STEM jobs were available to workers without four-year college degrees, and they paid good wages, an average of $53,000. While these STEM jobs requiring at least a bachelor's degree were concentrated in certain metropolitan areas, the STEM jobs that didn't require this degree were prevalent in every metropolitan area, paying relatively high wages. This means that there are routes to well-paying jobs for those not on a four-year college degree

path. If there are good jobs for the technically skilled without four year college degrees, how could the connections be made better? The Pathways to Prosperity study found four elements behind the quality employment problem facing young people:[200]

- There is a deep disconnect between education and career paths;
- There is a growing skills gap between youth workers and quality jobs;
- There is a need for post-secondary credentials of some kind to acquire those jobs; and
- A disproportionate number of minorities and low income students aren't positioned for those credentials or jobs.

But there is no getting around the overall reality that the country is upskilling, and those with the post-secondary education credentials are predominantly the winners. As previously noted, the nation has gradually been improving its education credentials. In 1973, almost a third of the nation's 91 million workers were high-school dropouts, while another 40 percent lacked education beyond a high school degree.[201] Thus, those with a high-school education or less made up 72 percent of the nation's workforce. A solid work ethic and a high school degree enabled middle class wages, and 60 percent of high school graduates achieved this. The high school degree was still the dividing line. By 2007, just prior to the Great Recession, this had changed. Although the workforce had grown nearly 70 percent, those with only a high school education or less and no post-secondary experience were just 41 percent of the workforce. While the total number of jobs in America had grown by 63 million, the number of jobs held by people with no post-secondary education had actually fallen by some 2 million jobs. Since 1973, then, nearly all of the net job growth in America has been generated by positions that require at least some post-secondary education. Some college education is now the dividing line. There is a particularly problematic gender gap opening up for young men in postsecondary education. As of 2011, men accounted for only 43 percent of enrollment in four-year colleges, and earned only 43 percent of bachelor's degrees.[202] Because graduate degrees require bachelor degrees, women also account for 60 percent of the nation's graduate students. The overall percentage of those with high school degrees or less is now some 38%.

What about, then, this significant number of young people outside the post-secondary education system? The Pathways to Prosperity Project has argued that given the persisting problem with youth unemployment and the problematic educational attainment numbers cited above, a "college for all" goal seems doomed to failure.[203] Instead, a goal of a much stronger focus on career-oriented programs that leads to occupational credentials for middle-income jobs appears required. Could apprenticeships be part of that process?

THE GERMAN APPRENTICESHIP MODEL

In northern and central Europe, vocational education and training are the norm, supporting young people in the shift from adolescence to productive work and adulthood. In Austria, Denmark, Finland, Germany, the Netherlands, Norway, and Switzerland, after grades 9 or 10 between 40 and 70 percent of young people opt for educational programs that typically combines classroom and workplace learning over the following three years, culminating in a diploma or certificate.[204]

The German apprenticeship model has long been held out as the gold standard of workforce education so any evaluation of apprenticeship models should consider it. Many in the U.S. have been calling for Americans to emulate the German system.

Kathleen Thelen of MIT has identified key characteristics of the German apprenticeship program:[205] 1) it emphasizes skill development, which has been evolving for over a century, primarily through firm-based training complemented by mandatory school-based education; 2) it has strong reliance on the

private sector, with widespread firm-based participation, and financed in significant part by firms, although the program is not compulsory for firms.; 3) it is collective in nature, with firms training to standards that are set jointly by firms, educators, government and unions, with firms held accountable for the quality of their training based on their apprentice's exam performance; 4) it ensures a low level of youth unemployment and all political parties and classes support it; and 5) it remains attractive to Germany's young people although there has been a modest shift to more university education, and now a hybrid approach of a university degree and work-based certification is emerging, as well.

Germany's dual education, apprenticeship program has been able to solve problems that are still unsolved in the United States. It has created a direct connection between secondary education and quality, good paying jobs; those realms are still disconnected in the U.S., with the resulting social disruption from a much higher youth unemployment rate. Germany has also obtained economic benefits, particularly for its strong manufacturing sector, from the productivity gains available from a skilled technical workforce. In contrast, workforce-based productivity gains have tended to be ignored in in U.S. company workforce policies. There, workforce retention is not a focus, workforce training investments are in decline, and wages have been stagnant for fifteen years.

The German model requires close collaboration between employers, educators, and state and federal governments. If education and work opportunities are to be better connected in the U.S., this collaboration seems a prerequisite, although these stakeholders have considerably less history of collaboration in the U.S. Joint funding participation by these actors also seems required. The dual education "work and learn" combination appears central and assures a practical focus. Program certification and standards likewise seem critical if a program is to meet employer needs. Quality standards for teachers and trainers as well as for student assessment are an important part of this. While Germany's labor practices are very different from the U.S., these basic lessons from the German model appear transportable. While direct connections between universities and work are minimal in the U.S., Germany's emerging dual study program combining apprenticeships and its applied technical universities offers an additional interesting model. Whether the differences in education tracking and in worker job security between the U.S. and Germany, as well as the costs of apprenticeships, prove impossible barriers to surmount in implementing apprenticeships remains to be seen.

APPRENTICESHIP LESSONS FROM GREAT BRITAIN

Aside from lessons from Germany, there are some additional lessons from the U.K. if the U.S. attempts to scale up apprenticeships. Paul Lewis of Kings College London, has noted that like many economies, the UK faces shortages in skilled technicians, especially in emerging industries.[206] Apprenticeship programs have been long-established in Britain's manufacturing sector and typically have involved a day or two of a week of off-the-job education coupled with on-the-job training. Britain, emulating Germany, has been making a major effort to expand its apprenticeship programs. To do so it began shifting more control to companies and limiting standards and requirements in favor of more rapid expansion. In recent years, formal certifications for apprenticeships have been established in new fields, including retail. However, the apprenticeship program has not worked well in retail (and comparable services areas) so the UK is now dropping it. It found that while apprenticeships have been found to work for information technology skills, manufacturing skills, and lab technicians, retail and customer services apprenticeships proved less workable. For example, a nine-month certificate in "customer service" tried to serve firms ranging from Harrods, a high-end department store, to small convenience stores, which had very different cultures and needs. This backfired.

Apprentices in retail too often found their

training a waste of time – there wasn't enough difference between skilled and unskilled workers in this sector to justify the time investment in an apprentice program. Lewis argued that successful apprenticeship programs offer a layered pathway to continuing success, where skill acquisition keeps being rewarded with higher pay and status as a worker advances to higher steps. These kinds of continuing skill pathways existed in manufacturing, for example. However, in retail there wasn't really much of a pathway to advancement with additional status and pay through new layers of skills, there were only basic skills that many cases required limited expertise. His conclusion was that if an apprenticeship fails to offer a clear pathway to continuing employment advances, there is limited justification for the apprenticeship program. This may prove a useful lesson for U.S. programs.

AMERICAN EXPERIMENTS WITH VOCATIONAL EDUCATION/CTE AND APPRENTICESHIPS

While slowly rising, in 2010, America's overall 4-year college completion rate was still 32.8%, behind, as noted above, 11 other nations.[207] Because the emphasis on college preparation only at the high school level, has not worked well, a number of education reformers are now calling for a departure from the single pathway of college education in favor of opening up new multiple pathways. The Pathways for Prosperity project noted above has called for developing and delineating these multiple paths for a more connected route for youth into solid work and careers. Employers would need to play a greatly expanded role supporting these new paths.

William Symonds, Robert Schwartz and Ronald Ferguson of the Pathways project have written about some of the elements in a new system would look like.[208] First, pathways to all major occupations would be clearly delineated at the outset of high school so that students and families could see what courses and experiences that would help them gain access to their sought-after field. In contrast to Europe, a positive feature of the American education system has been that it has often tried to keep a number of doors open, not to close them, and to be forgiving, so that students can keep trying. This feature should not be lost; students should retain freedom to change their minds, and shift onto different courses, they should not be locked onto one career option at an early age.

Second, the paper argues that relevant work experience should be built into the new system. A workplace is the best place to experiment with career choices. Third, new learning systems to help teach new technology skills, tied to the right foundational skills, should be part of the new system. Fourth, improved career counseling will be required. The current system of career guidance and counseling in both secondary schools and higher education is inadequate, and many young people are adrift, obtaining little useful guidance.

A fifth point also needs to be included, Andrea Messing-Mathie has argued that particularly in the case of apprenticeships, "good governance" policies are required at the state or federal level to ensure that apprenticeships are not synonymous with cheap labor.[209] Instead, apprenticeships should enable close connections and cooperation between employers, education institutions and community organizations. Messing-Mathie argued legislation should provide guideposts for setting up high quality apprenticeship systems; a legal framework should make clear rights and responsibilities of the apprenticeship partners, but leave the content, testing and certification to agreements between employers and their apprentices or their representatives. The Labor Department's registered apprentice system helps assure this; an issue in efforts to deregulate this system is preserving a sound framework that protects apprentices.

There are numerous experiments now underway in the U.S. on new workforce education systems for young people that fit within the Pathways' concepts of creating multiple pathways from high school to work and careers. A number of these are briefly described below:

- **Washington State's Integrated Basic Education and Skills Training (I-BEST):** This program integrates remedial English and math skills training into community college-level technical education programs in fields ranging from auto repair to nursing[210] using a dual instructor approach.[211] A recent evaluation found that I-BEST participants earned more credits and certificates, and were more likely to persist with their studies, than regular remedial students.
- **Project Lead the Way:** The program promotes STEM education through providing structured programs and rigorous curriculum to thousands of high schools in 50 states through a four-year sequence of courses.[212]
- **The Career Academy** movement began in Philadelphia in 1969, and there are now 7000 academies reaching 1 million high school students using a "school within a school" approach. California, for example, has over 500 career academies.[213]
- **Linked Learning Initiative** operates in more than 100 school districts with learning certifications and analytics to provide pathway data to educators to raise graduation rates, increase college enrollments for low income students and enable them to earn more college-relevant high school credits.[214] It emphasizes career technical education and work-based learning with support systems.[215]
- **Pathways to Prosperity:** supported by the Harvard Graduate School of Education and Jobs for the Future, it supports connected high school to work and career opportunities in the framework summarized above, and is now connected to over 12 states providing a working framework for this approach.[216] Tennessee's program is discussed below.

Tennessee's Career Pathways, a kind of "apprenticeship light," provides an interesting example of an energized state program attempting to merge education and work.[217] Two Governors from different political parties drove significant education system reforms, primarily in response to requests from employers for more skilled and better-trained workers. The state adopted a slogan, "Drive 55," indicating its goal to increase the percentage of state students with post-secondary degrees or certificates. Overall, the state's leaders in the political, business and education fields saw a need to better connect high school students to both postsecondary learning and to employer needs. They also sought to make it easier for students to find efficient routes to good careers.

The state became an early adherent to the Pathways for Prosperity approach, adopting Pathways Tennessee as a statewide effort to give students, starting in high school, access to solid academic and career pathways matched to local and state economic and labor market needs.

In this pathways approach students take academic- and career-focused courses in high school and participate in work-based learning experiences including internships and job shadowing at companies that smooth transitions to both college education and the workforce. Apprenticeships can be complex and expensive for employers, so Tennessee is attempting what Jenna Myers calls an "in between way, requiring less employer commitment than apprenticeships but much better connectivity between educators and employers than in the current fragmented system."[218]

An important additional part of Tennessee's approach is its statewide network of 27 colleges of applied technology, as noted below in section 7, that are separate from community colleges and provide technical training leading to certificates and diplomas in more than 50 occupational fields.[219] These centers have achieved a graduation rate of over 75 percent, three times that of the state's community college system. To help enable these connections to work, the state in 2014 created Tennessee Promise where the state provides a "last-dollar" scholarship to students to cover tuition costs that are not covered through state and federal scholarship and grant programs. Since then, some 16 other states have formed similar programs.[220] It has supplemented this program with Tennessee Reconnect, aimed at incumbent

workers without degrees, also giving them the opportunity to go tuition-free to the state's community or technical colleges. The state has also integrated the efforts of its departments of Education, Labor, and Economic and Community Development, connecting also with its college and university governing agencies and the Business Roundtable.

But what about actual apprenticeships? There are also examples of apprenticeship programs evolving at the state level:

Kentucky Federation for Advanced Manufacturing Education (FAME): The largest sector in Kentucky's manufacturing economy is its automotive industry which employs 65,000 workers at over 400 plants. The largest of these is Toyota's Georgetown plant, with 7,000 workers manufacturing some of the company's top car lines, which is also Toyota's largest plant worldwide. Facing an aging workforce demographic and pending skilled-worker retirements, Toyota entered into a partnership with Bluegrass Community and Technical College (BCTC) in the Lexington area to create the Advanced Manufacturing Technician (AMT) program in 2009. The program offers a multi-disciplinary Associate degree focused on electricity, fluid power, mechanics, and fabrication and has significantly strengthened the supply of young manufacturing workers in the area. The AMT program has expanded to over 15 companies, and now has a regional consortium named the Kentucky Federation of Advanced Manufacturing Education (KY FAME) with some 200 companies.[221]

Michigan Advanced Technician Training Program (MAT^2): Because its automotive manufacturing sector was so hard hit, Michigan had a particularly disastrous Great Recession. Since then its recovery has been one the nation's strongest. However, like other areas, Michigan has an aging workforce with a need for younger workers in its manufacturing system. Skills in mechatronics, a design process that requires mechanical engineering, electronics and computer science, appeared to be a particular need.

In 2013, the Michigan Economic Development Corporation launched the Michigan Advanced Technician Training Program, or MAT^2, along with Henry Ford Community College and Oakland Community College and eleven southeast Michigan manufacturers. The first cohort contained 31 students and focused only on mechatronics, but by the beginning of 2015 MAT^2 had expanded to include 29 employers, 98 students, four community colleges and also offered programs in CNC manufacturing.[222] The program is tuition-free for students, who also earn wages, an Associate's degree and a national Department of Labor credential, as well as a widely-recognized German IHK credential. For the three-year program, employers need to support the student's community college tuition total of $20,000, a school stipend of $14,400 ($200/week), and wages that grow from $10 to $13/hour totaling $34,080.[223] The state Labor Department estimated the three-year employer cost total for this apprenticeship program at $68,480 for 2018.

Manufacturing firms work with the participating community colleges to design the curriculum and core competencies. Graduating high school seniors can elect an alternative route to a four-year university, acquiring theory, practice, and work experience over the three-year apprentice program. Most important, graduates have a skilled technician job with good pay and benefits waiting for them.

North Carolina Youth Apprenticeship: North Carolina offers an apprenticeship program that starts in high school run through its community college system in collaboration with area companies.[224] The state hosts a significant number of European firms that have encouraged the program. The apprenticeships are registered with the U.S. Department of Labor and offered in a series of fields including building trades, utilities, healthcare, information technology, logistics and manufacturing. The program in North Carolina's Research Triangle area is illustrative of other programs in the state.[225] It is a four year program where students join in their

junior year of high school and begin in their senior year. It focuses on manufacturing, with students undertaking 6.400 hours of learning manufacturing skills and 1,600 hours of community college-level education. At the end of the four years, apprentices obtain an Associate degree in mechanical or mechatronics engineering technology from one of the two participating area community colleges. In addition to the degree, graduates obtain a journeyman certificate from the U.S. Department of Labor and the state's community college system. Participants are paid, with wages increasing as they complete program stages.

Wisconsin Youth Apprenticeship: Wisconsin has built a large youth apprenticeship program combining state leadership and regional partnerships with industry and education institutions.[226] At the state level, the Bureau of Apprenticeship Standards in the state's Department of Workforce Development provides oversight, and a network of 33 regional consortia throughout the state operate the program. The consortia are led by a variety of stakeholders: regional education organizations, or technical colleges, or area Chambers of Commerce, or non-profit entities, or local workforce development boards. Each consortia has a steering committee of local employers, high school districts, state technical colleges and workforce organizations. The state sets the standards the regional consortia must meet, for enrollment, completion rates, diploma rates and apprentice certificate content.

It is a business-driven, model, with employers identifying skill standards, interviewing and selecting students, providing students with paying jobs, and assigning them skilled mentors. School-based Youth Apprentice (YA) coordinators at high schools work closely with area employers to ensure the program is working for them. These YA coordinators also manage the outreach to parents and students about the program, advise students on careers and set up the interview process for employers. Skill areas include health services, manufacturing, finance, transportation and logistics, and hospitality.

For the 2016-17 school year, some 2,500 employers and 3,500 students from 342 high schools participated in the YA program. In the previous school year, the program completion rate was 84% and the students' average wage in the program was $9.93 an hour. Students may work before, during or after school hours, as well as during summers and holiday breaks. Students in the YA program therefore obtain on-the-job skills and as paid employees, and the job becomes an extension of the classroom. Skilled mentors supervise and train students on the skills identified for the career cluster. The on-the-job learning is reinforced by related classroom instruction. This can be provided at the high school, the local technical college, online, or at the employer's worksite, depending on the program model adopted by the regional consortium. The coursework must comply with state guidelines. In addition to passing their classes, students must demonstrate proficiency on state-defined competencies, through ratings from their worksite supervisors on a standardized skills checklist.

All three of these programs appear to have incorporated core apprenticeship elements noted above in the discussion of the German model. Close collaboration between the basic stakeholders, employers, educators, and government (in these cases, largely state government) seems to be a prerequisite. Different stakeholders in these three programs assumed leadership: in Kentucky, employers, in Michigan, state government, and in Wisconsin different regional consortia are led by different kinds of stakeholder. But in all cases, collaboration between these stakeholders is required. Two of the programs started the apprenticeship at community colleges right after high school; the other began in high school. Joint funding participation by the stakeholders also seems required. The dual education "work and learn" simultaneous combination appears central and assures a practical focus. Program certification and standards were likewise present, assured by the states, and seem critical if a program is to meet employer needs. Quality standards for

student assessments also appear important to these programs. Likely because there are very limited occupation certification systems in the U.S., each program led as well to community college credits, a more widely recognized qualification system in the U.S., and two to Associate degrees.

THE CHARLESTON, SOUTH CAROLINA YOUTH APPRENTICESHIP MODEL

Background on South Carolina Apprenticeships: German companies from BMW to Mercedes to Bosch have located manufacturing operations in South Carolina which is home to over 28,000 workers in German-owned companies. Because these companies understand the utility of apprenticeship programs, they have promoted the model in the state. Apprenticeship Carolina was formed in 2007 to encourage apprenticeships in the state; there are now 29,800 apprentices, 36 times the number in 2007, in 990 registered programs that operate in all the state's 46 counties with all of the state's 16 two-year technical colleges participating.[227] The state provides employers with a $1000 tax credit for each apprentice. The program has been named a national model by U.S. Department of Labor. Apprenticeship Carolina assists companies in using apprentices by providing free apprenticeship consultants who link them to state resources, assist them in developing standards and training programs, connect them to programs in area technical colleges, and manage the paperwork to register apprenticeships with the U.S. Department of Labor. They also advise on the state's employer tax credit. The program has become a crucial intermediary between its sponsor, the state's technical college system, and employers. It complements ReadySC, formed in 1961 also as part of the state's technical college system, which works with the technical colleges in designing workforce training systems for state employers. Both Apprenticeship Carolina and ReadySC are housed in the Division of Economic Development, which underscores their economic role for the state. According to one survey, South Carolina ranks number one among states in jobs through foreign investment.[228]

While many states still compete with other by trying to lure each other's firms through tax benefits and financial incentives, South Carolina has developed what is proving to be a more far-reaching economic development strategy, attracting companies by offering them a well-trained workforce. This now includes the most successful apprenticeship program in the nation. Since the workforce is a critical contributor to productivity, it has become an increasingly effective strategy.

The apprenticeship in South Carolina has started after high school at the technical college level. It typically consists of the two "work and learn" components we have seen before: on-the-job training at the workplace, and job-related technical instruction at the local state technical college.[229]

The Charleston Youth Apprenticeship: Within this state framework, which has focused on Associate degree technical college students and incumbent workers taking additional courses, Trident Technical College and Charleston area employers have come up with a particularly interesting youth apprenticeship program starting, instead, in area high schools.

There are three parties at the table in the Charleston youth apprenticeship program: the area technical college, Trident Technical College, employers who were initially led by small employers, and the Chamber of Commerce. Each plays a key role. The Chamber paid for Trident's tuition for apprentices, for books, for wages for mentors, and for supplies. High school students enrolled in college for six credit hours receive state lottery-funded tuition assistance, so the expense was about $2100 per student after the lottery funding, which covers about half the cost. The Chamber paid the difference. Employers pay their apprentices' wages. Student apprentices take particularly math and science classes at their high school, take more technical work-related classes at Trident, and work part time and in summers at their employer.

In the first year, there were 6 companies and 13

students. Mitchell Harp and Melissa Stowasser, the program leaders, state that by fall 2018 there were 130 companies with Department of Labor registered apprenticeships and 94 students.[230] As of the fall of 2018, in total there have been 232 apprentices hired from out of the program. Of these, 42% are from minorities, 66% are male, and 34% female. Although Trident students overall are two-thirds women, historically fewer females have enrolled in technical apprenticeships. Along with more women students, Trident has especially been trying to reach African American and Hispanic males who face significant youth unemployment problems.

Small Company Participation: Not every company participates every year. Smaller companies typically participate every other year, and even Boeing (which employs 10,000 in North Charleston) doesn't necessarily participate every year. Harp has hired two staffers at Trident who are constantly out on the street meeting with and assisting employers.

While many policymakers have viewed apprenticeship programs as potentially workable for large employers with deeper pockets, the typical program cost has been viewed as a major barrier to smaller firms. Yet, interestingly, the Charleston youth apprenticeship program was initiated by smaller employers in need of talent and it created an attractive cost equation for companies.

Trident develops a separate partnership strategy for each employer's needs. Smaller companies in the region have been losing employees to large companies so they mentor their apprentices as well as paying apprentices part time salaries to make their programs attractive. Participating employers have spent $5 million since the beginning of program for these costs. Boeing with 10,000 employees is the largest employer in Charleston; Bosch with 3500 employees, is next, and both participate. But the significant majority of companies in the Trident program are smaller companies with small employment bases.

Important to the program is Apprenticeship Carolina, the state intermediary organization noted above. It is especially useful in helping employers with the U.S. Department of Labor, handling the DOL registration paper processes, and does this free of charge for employers. This is a key challenge for smaller employers, and makes it easier for them to participate in the apprenticeship program. In the view of Harp and Stowasser of Trident Tech, the program organizers, youth apprenticeship programs need such a state-level intermediary, as well a local intermediary – both are important for apprenticeships to work. They have found there is a need for some kind of registration for both employer and apprentice roles because there is a need for a formal agreement on both sides allocating responsibilities. The DOL registration provides this and also is important because it enables apprentices to obtain the national DOL journeyman credential, which can help workers in assuring skill level credentials across states. While community/technical college credit is important, it is also key to students to obtain that DOL credential.

High School Student Participation in the Program: Companies can hire rising high school juniors, generally reaching out to them as tenth graders, or rising seniors. The company makes the hiring/apprentice decision not Trident. South Carolina now requires students to prepare individual graduation and career plans at the middle school level, so companies also now go to middle schools for school visits to explain job and career possibilities.

Apprentices can start at ages 16 to 18. They attend high school in the morning, spend the afternoon at Trident for career-specific courses such as in industrial mechanics, then work part time during the school year and full-time in the summer working at their company. Through the program, they get Trident credit, accumulating approximately one year (30 credits) toward their two-year Associate degree. Most apprentices continue on their jobs at their companies after high school graduation, but most also continue

on to obtain their full Associate degrees, and some have continued on to obtain four year degrees, including four year engineering degrees.

The thirteen students who started in the program in 2014 have graduated, 10 with apprentice certificates by 2016 with the others subsequently finishing them. The completion rate, according to Stowasser, for all the students who have been in the program reflects national levels, with approximately an 80% completion rate for whites but less than 60% for minorities. Transportation is a real issue for student participation because it is not easy to get from a low country high school outside Charleston, to Trident, and then to an employer. Trident's reach includes Charleston, Berkeley and Dorchester Counties, a large area; it serves all the public schools and charter schools in the three counties. To participate, students generally need access to a car for the transportation. Public transit is limited so the Chamber is now looking for grants to tackle this transportation issue, and area churches may be able to help. Most small employers hire one to two apprentices and are sited in many locations; the problem for students is less in getting to Trident campuses and more in getting to their employer.

While the Charleston program began with area manufacturing firms, it now has sixteen career pathways available, including industrial mechanics (including engineering CAD technician, machine tool and CNC technician), culinary arts, nursing assistant, emergency medical technician, hotel operations, and various computing skills.[231] It is an attractive package for many high school students. They get out of what can be a disruptive, boring or frustrating high school experience – most high school students have negative views of high school[232] - and into college level work. And they are in a company getting paid starting at $10/hour; this can be a very attractive sum for high school students particularly from poorer backgrounds. Importantly, at the community college and employment settings they are interacting in a much more mature social setting, potentially enabling a break from what can be disruptive high school social settings. The apprentices also get work experience, validation of their career interests, an opportunity to develop professional relationships, college completion credit and career readiness.[233]

A Company Perspective on the Charleston Youth Apprentice Program – VTL Precision, Inc.: Vincent Lombardy, Training and Employee Development Manager for VTL Precision, Inc. provided a firm perspective on the Charleston Youth Apprenticeship program.[234] VTL was one of the original six companies participating in the Trident Technical College program for youth apprentices.

VTL is a division of a U.K.-based transmission company so has had past positive history with apprentices in secondary school. It now produces parts for Cummins, located in the same large North Charleston industrial park, for buses, heavy trucks, and cars for turbo systems. VTL is solely automotive, working on sophisticated drive train and engine parts, which must be high precision. The parts it makes are expensive because of the extremely close tolerances needed.

The company has formed an automated robotic line now running next to its older precision machining line. It has had to upgrade employee skill sets as part of this shift. It uses CNC and robotic equipment, and the operator roles for both lines are highly skilled and very important. The company is planning to shift the machining line to a second automated robotics line soon. The company, then, has new mechatronics, CNC, and robotics requirements with new skill sets required, and it is using a number of employee training programs, both internally and also in training programs offered by its robotics supplier. VTL is now using the youth apprenticeship route as a key source for its employees; these now make up 8% of its workforce

Program's Importance to VTL: Lombardy states that, "This is a good program. It is strengthening VTL's workforce pipeline. There is historically low unemployment in the area and it is hard getting good employees, so this pipeline helps

solve the problem. VTL has had much success with the program." For example, one apprentice, the daughter of an African American preacher in one of the adjacent counties, went on to Clemson's undergraduate engineering program after the Trident apprentice program, but she still works at ITV over holidays and summers. "She is helping redesign the CAD software system, and is a now a critical employee. This employee alone justifies the investment." VTL has made full time job offers to all the apprentices it has had in the program. "We get active, producing employees at end of program."

VTL and other small employers have difficulty competing with large employers (like Mercedes, Boeing, and Bosch) for employees. Although he doesn't have exact numbers, Lombardy sees the apprenticeship program as paying for itself, otherwise it would be hard to justify. The company needs a pipeline of incoming talent, and apprentices are a significant part of its workforce now; the company is getting productive 20 to 40 hour employees from the Trident program.

Clearly, VTL has had a positive experience with the program, using it to help solve its skilled workforce problems and to obtain employees important to the company. Despite the general assumption that apprenticeship programs don't work for small firms, the fact that the Charleston program was organized and used primarily by small firms to solve skilled talent problems is of interest. The area's shortage in skilled workers and generally low unemployment numbers may have created a counterbalance for SMEs that has offset the initial apprenticeship costs. With the tuition cost borne by the Chamber and the state, VTL viewed its apprentices as performing real jobs from close to the outset of their apprenticeship and as generally paying their way. VTL did not report "poaching" problems, but instead found its apprenticeship program, which aims to build relationships with students early on, a reliable source of continuing workers.

Keys to the Charleston Program Success: The Department of Labor in evaluating the Charleston Youth Apprenticeship program, listed four major reasons for the program's success:[235]

- **Business Champions:** Business has been the real driving force behind Charleston program and it was first initiated by one manufacturer and has grown from six manufacturing firms to 130 firms in the region, with 16 career pathways. Trident Tech believes that sector partnerships, where businesses within an industry work together for mutual gains, has been critical.
- **Strong Leadership and Partners:** Trident Tech, with some visionary administrators, is the managing partner. But other partners play critical parts, including the area Chamber, the state's Apprenticeship Carolina, area high schools, and the participating employers. Trident provides support to the participating businesses, school systems and local youth apprentice coordinators to ensure the program is working.
- **Engage Area High Schools:** administrative and technical education staff at Trident work closely with area high school guidance counselors, principals and teachers, to help ensure student participation and positive outcomes for both students and companies. Parents are also a key by supporting students and helping with worksite transportation.
- **Tuition Support:** When Trident Tech and other partners were developing the program, they understood that Trident's tuition for the apprentices would be a challenge both for many families and for smaller firms, who could not afford it. Financial support from the Charleston Metro Chamber of Commerce has been critical in offsetting this cost.

SUMMARY

Despite the growing importance of postsecondary education in obtaining good jobs, the U.S. does not score high in college and particularly community college completion; the rate is especially low for students from low income households. Some 38% of workers have only a high school diploma or less and likely will face increasing trouble in pursuing good careers. But

young people who get licenses and certificates for solid technical skills, primarily through community colleges, can still do well. The key issue is how to get more students into this technical education track because youth unemployment and the social disruption it causes remain too high in the U.S.

There has been progress on policies and programs to better connect the long-separated stovepipes of education and work. For example, "career pathways" linking high school students to community colleges where they can acquire skills needed by regional employers appears particularly important. Nationally recognized, portable, and stackable skill certifications would be an additional step that would further encourage technical credentials. For high schools and community college students, apprenticeships may also be an option. Apprenticeships create a direct line between the stovepipes of education and work. They don't assist with upskilling incumbent or displaced workers, but they could be an important option for young people entering the workforce.

A number of apprenticeship programs are underway in the U.S. These include programs where labor unions are a key stakeholder, particularly in the construction trades. Unions are now working more broadly with management, to try to expand union engagement and support for apprenticeships. But there are also new efforts in Kentucky, Michigan, North Carolina, Wisconsin and South Carolina that have incorporated core elements used in Germany, including close collaboration between the basic stakeholders (employers, educators, and government), although different stakeholders in these examples took on direct leadership. The dual education "work and learn" simultaneous combination was central to each and assured a practical focus. Program certification and standards, and assessment features were likewise present. Because there are few occupation certification systems in the U.S., each program led as well to community college credits, a more widely recognized qualification system in the U.S.

The Charleston, South Carolina youth apprenticeship appeared particularly interesting. It starts with high school juniors or seniors, requires courses in job-related technical skills in the area 2-year technical college, and part time paid work at an employer in the apprentice's field. There were a number of lessons from the program. First, committed companies were critical to creating and maintaining the program. Second, the technical college served as the "managing partner" linking companies, state programs, and high schools, aside from providing technical courses. But the other partners had key roles as well, including the Chamber of Commerce which supplied tuition subsidies for the technical college program to make the program affordable particularly for small and mid-size companies. And close coordination with high schools, including teachers, guidance counselors and administrators, was also key. Apprenticeship program registration for each company helped assure clear requirements for both participating companies and apprentices.

While apprenticeships may work for larger firms, whether these programs are too costly for smaller firms has been a long-standing U.S. policy question. In Charleston, however, the youth apprenticeship program was initiated by smaller firms who remain the major participants. An area labor shortage in skilled workers appeared to be their major motivation. Shifting demographics may continue to provide that pressure for skilled workers long term even if there are economic downturns in the short term. The tuition subsidy for apprentices at the technical college, and support from a state program that enabled employers to easily manage registration paperwork also appeared to be enablers for smaller firm participation.

If apprenticeships could be made to work in the U.S., they appear to have promise as a way to erase the divide in the U.S. between education and work for young workers seeking to enter the workforce. Since the current route from high school into both postsecondary education and work does not work for many, a "work and learn" approach seems well worth experimentation.

SECTION 7: THE NEW CONTENT DELIVERY METHODS

We have identified a series of issues so far: disconnected federal workforce programs, underfunding of existing programs, a broken labor market information system, a deep transition problem between school and work, a problematic degree completion rate particularly at community colleges, and colleges and universities not yet engaged in workforce education despite the increasing importance of their credentials. Despite these problems, however, we have seen solutions that are emerging in such areas as apprenticeships, new education technologies, and improving information systems. As discussed in above sections, three levels of workers need to be reached:

- **new entrant** workers just coming into the workforce,
- **incumbent** workers holding existing jobs who need to upgrade their skills and
- **displaced or underemployed** workers who have lost jobs or are stuck in low-end positions and need to find new skills to reenter the workforce.

We review nine models below for new approaches to content delivery, noting which models reach which group of workers. Some of the nine discuss individual institutions and some discuss particular challenges being tackled by several kinds of institutions in somewhat different ways. Most models concern education institutions, some concern industry and others concern broader system problems such as developing new education technologies.

In the opening models, community or technical colleges play a central role that reach new entrant, incumbent and underemployed workers in different ways. We then turn to a series of other models applied at a variety of organizations. These include vocational and comprehensive high schools, integrating disconnected federal programs at the state level, employer programs for incumbent and new entrant workers, deploying new content for advanced technology skills, and deploying new education technologies. Again, different categories of models will be explored in succession. Each model offers concrete, operating examples for new approaches, not simply policy abstractions. While most require

further data collection and demonstration, they do amount to pragmatic ongoing experiments that can be studied in more detail. Some of these models have been delineated in prior sections and are briefly highlighted here; others are set out in detail. Each category could contain many other examples; the models offered below are a sampling but illustrative of the opportunities starting to evolve.

The first four models below place community or technical colleges in a leading role, although partners from industry and/or government are vital, as well.

MODEL #1 - THE TRIFECTA: ASNUNTUCK COMMUNITY COLLEGE - REACHING COMMUNITY COLLEGE, HIGH SCHOOL AND INCUMBENT WORKERS

In the old Connecticut River valley industrial town of Enfield, Asnuntuck Community College – the Algonquian Indian word means "Fresh Water" - was founded in 1972 with its first campus in a repurposed elementary school. Frank Guluni, a highly-experience expert in workforce development, founded there a vocational ed program in manufacturing at a time, he says, "when voc ed was for 'the other kids.'"[236] The program, however, has grown into a new 50,000 square foot Advanced Manufacturing Technology Center, fitted out with the latest manufacturing equipment.

Gulluni started with a program for dislocated workers who were jobless and in need of retraining. He developed a for credit certificate program in machine technology. To build in-depth, lasting career skills he found these students needed "1000 hours over a two semester timeframe, 30-35 hours a week, not just the typical 12-15 hours a week community college schedule." Pratt and Whitney and a large segment of the American aerospace industry supply system were located in central Connecticut, so there were employment opportunities.

A critical moment for the program was a visit by a recent Connecticut Governor. He arrived with a politician's self-confidence, not seeing manufacturing as part of a real college program or even integral to the State's economic development strategy. He toured Asnuntuck's manufacturing programs and saw its students working on CNC machines, but Gulluni could see as the tour wrapped up that he had not become a manufacturing education believer. "It was a hand-shaking opportunity, he didn't have the picture." Then Gulluni had him sit down in a conference room with some twenty area aerospace industry manufacturers. The first employer to speak, head of a mid-sized aerospace supply firm, told the Governor he was cutting his sales and marketing efforts because he couldn't produce his products in Connecticut, he lacked skilled workers. The state's failure to address workforce needs meant many new jobs were being lost. "You could hear a pin drop – nobody told that to a Governor." But company after company chimed in that they couldn't get the skilled workers they needed. By the end of the meeting the Governor was convinced that there were hundreds of skilled jobs just from the employers in the room that couldn't be filled. Within a month, the Governor proposed a $500 million program for state manufacturing training and new equipment and other elements. Asnuntuck was one of the beneficiaries of the program; three community colleges in different regions of the state were selected to become manufacturing centers, essentially replicating the Asnuntuck model. Asnuntuck built a new $25 million advanced manufacturing technology center funded by the state which opened in 2017. It is a major, clean, modern facility full of the most advanced computer-driven production technologies.

Asnuntuck now offers three programs in advanced manufacturing technology skills -- for community college students, high school students and incumbent workers. Some community colleges offer the first, a much smaller number also offer the second, but offering all three -- the trifecta -- in a synergistic way is rare. Each program in the trifecta is reviewed below.

The Community College "Regular" Program: Asnuntuck runs a regular community college program with 300-400 students for a two semester certificate program in manufacturing, which can also lead to associate degrees in manufacturing. It accepts all those interested in the program; Gulluni says "we assume a have a magical capability to change kids and adults. If a student needs 3 to 5 semesters not 2 to finish the manufacturing program, that's fine." The ages in the program range from 18 to 65, and students can attend part time or full time. They are typically at the program for 6 to 7 hours a day for 32 weeks, participating 30-35 hours a week. Of this time, one quarter is classroom and lab, one quarter is in the computer lab, and the remaining half is hands-on learning in a major technical area.

There are three major manufacturing program elements. **Machining** uses state of the art machine tools ranging up to precision wire Electrical Discharge Machining and the latest in Computer Numerical Controls (CNC), as well as laser-driven metrology and 3D printing. Asnuntuck also offers a third semester in which students can specialize in additive or cad cam. Machining has a 22,000 sq. ft. facility with typically 200 students going through at a time. **Welding and fabrication** students use 75 welding booths, with laser cutting, plasma, and all types of CNC. This has a 7000 sq. foot facility with typically 75 students. **Electro-mechanical** students learn electronics over two semesters then take a third semester with high end specialized courses and equipment, so they can understand the complex new machines, repair them and keep them operating continuously.

The manufacturing program has a 95% job placement rate. It includes a wide range of students from middle-aged career changers to many inner-city minority youth from the Hartford area. Asnuntuck is also in the 3rd year of a prisoners program. The college has moved some 300 prisoners approaching their release into certificate and degree programs in a range of disciplines, including 45 in manufacturing, who spend approximately 25 hours a week on campus.

The student population can afford the program because 85% are low income and Pell Grant-eligible, so they receive up to $6000 from Pell because they are pursuing degree programs. The total tuition is $8300; for the $2300 above Pell coverage, the school stretches out payment periods. Students take internships in their second semester for 8 to 9 weeks, and are paid about $100/day, which brings in some of the additional tuition funding. This brings the program close to breakeven for students.

Gulluni argues that the key to the success of the manufacturing programs at Asnuntuck is that it understands its responsibility to educate for actual workforce needs. Too often in community colleges, he feels, instructors are not current with the latest developments and the equipment is antiquated. But at Asnuntuck, the private sector gives support at every stage, in particular by providing equipment, advice and developing curriculum on the latest skills. For twenty years the manufacturing program has had a close working alliance with the region's aerospace companies and its area association, which keep the college's offerings totally up to date; they want the students they are hiring to be entirely job-ready.

The College Connection Program for High School Students: This program is free for high school students because the state helps cover Asnuntuck's costs to run it and a number of high school districts pay for their students to participate. The program started with high school students in the nearby town of Windsor Locks. It now reaches into as many as 10 school systems in the greater Hartford-Enfield area. The high school students come to the college at noon and they leave at one-thirty, so they get in 8 to 10 hours a week of college-level programs. They complete 6 to 8 community college credits annually and can apply these credits to their Associate degrees and certificates, which gives them a big boost toward completion. Asnuntuck is working with its area high schools and accommodates more than 100 high school students who bus in daily

for afternoons. Because students should not be bussed more than 20 miles to still get their college time in, he and his colleagues have worked to have other regional community colleges adopt the program. The program has a goal to have more 300 students statewide attending College Connections for credit coursework in the next two years, and grow it further in later years. The skill focus areas in these programs is around machining, welding and fabrication. Asnuntuck's President, James Lombella, has a manufacturing background and taught in and came out of its manufacturing program, so he is a strong supporter of the Asnuntuck model. He recently was named to lead a consortium of four community colleges in the area so is in a strong position to further spread the college connection program.

Incumbent Workers Program: Because Asnuntuck has a strong Instructional staff that can teach software, or high level skills that employers want, it has also built a strong incumbent workers program for area employers. Annually, some 750 to 800 workers participate in an Asnuntuck course of study provided at the college or an industrial site.

ACC Instructors go out to the companies to teach; for smaller companies with fewer numbers of employees, there are training consortia between firms. Asnuntuck contracts with the companies, with the area aerospace association arranging the courses and contracting for its 125 member companies. Gulluni notes that it is a great way to reach area manufacturing employers, who appreciate the training and then hire from the regular college program. So Asnuntuck also uses the incumbent worker program to market its regular college students to the companies – it builds a good reputation with the company for offering quality training and the company sees the need to hire students from the regular program. "It's a great two-way street." Gulluni feels Asnuntuck needs all three programs to make its system work – the regular, College Connections, and incumbent programs – because they are mutually reinforcing.

Quality Instructors: Gulluni says, "We don't want PhDs or MAs as instructors – we want career people from manufacturing, who love manufacturing. Asnuntuck then can get them to a level to where they can impart skills very well." Asnuntuck has long been training its own manufacturing instructors, and they coordinate with the area's Central Connecticut University for help in teacher credentialing and training. So two-thirds of Asnuntuck's instructors are graduates of its own manufacturing program who first work for companies for varying periods of time practicing the most current skills, then return to teach. The school tries to bring back its very best students into the fold to teach at Asnuntuck. Gulluni elaborates:

> This is because they understand the program, they have the passion, so training them in teaching in teams with veteran mentor instructors works well. The passion is critical. Along with contemporary skills, they have to know the latest equipment and to have worked with it for years in companies. They are not afraid of the latest CNC mastercam software and the high-end tasks. Our grads have those skills. A number of our instructors go on to Central Connecticut University to get their teaching degrees. The school also now has retirees with specialty skills in the most advanced areas; they do not want to work 40 hours a week. At Asnuntuck they can work 10 to 15 hours, and really contribute and play a key role in the latest areas the companies are developing.

Asnuntuck has more than 40 staff for its College Connection, incumbent and regular college programs who work 35 hours a week teaching and advising their students for 50 weeks a year. Gulluni adds, "This is not a 4-year college instructional load."

Reaching Parents and Area High School Administrators: Asnuntuck's leadership is well aware of parents' negative image of manufacturing from the job losses of the 2000s, and understands that high school guidance counselors and principals have an

outdated image of manufacturing. In response Asuntuck has been taking high school principals, administrators and guidance counselors into a special one or two-week summer bootcamp program in basic manufacturing technology skills, which introduces them to machining, welding and electro-mechanical technologies. If they never had this kind of exposure, they come out understanding how high-tech modern manufacturing has become a meaningful career pathway. Gulluni notes that "parents and educators are the benign enemies of manufacturing, but that is slowly turning around in the schools." President Lombella also wants to launch a major "train the trainers" program in which all the tech trainers in state high schools in career and technical education would go through a certificate program, or at least a special two week bootcamp, to get updated on advanced manufacturing.[237]

Asnuntuck's "trifecta" approach, reaching incumbent workers, community college students and high school students, is an important model showing the broad reach of an engaged community college. Its three programs reach all the worker categories, new entrants, incumbents and underemployed/displaced.

MODEL #2 - CHARLESTON'S TRIDENT TECH YOUTH APPRENTICESHIP – REACHING NEW ENTRANT WORKERS

Charleston's Trident Tech Youth Apprenticeship: As discussed in the previous section, Trident Tech, the technical college in South Carolina that developed a new youth apprenticeship program, provides a model for how to reach new entrant workers. It ends the divorce between learning and work, deeply integrating these worlds and using three established institutions – the high school, the community college and companies – to do it. As detailed in section 6, Trident Tech along with the area Chamber of Commerce became the critical intermediaries between high schools and employers. They were able to assemble a thriving youth apprenticeship program starting in the junior year in area high schools where students emphasize science and math in high school courses, take technical courses at Trident Tech, and work part time and summers with an area company starting at $10 an hour which increases as they build experience. They get out of the often disruptive behavior patterns of high school and are put in a new social and age context, studying with adults at Trident and working with adults at their companies. They earn money that often makes them the envy of high school classmates and are starting on skilled employment that can directly lead them into solid jobs and careers that can fund further higher education. They graduate high school with a high school diploma, credits that take them near completion of a year of technical college, and a Department of Labor skill certification. If programs like this could scale, this could make a difference to America's notorious work/learn gap and its high youth unemployment rate.

There have been a series of keys to the success of the Trident program. First was the interest from small employers in the program. While Charleston had only a very limited manufacturing history, the entry of international companies like Mercedes, Volvo and Boeing into its economy in recent years has created high demand for the skilled workers needed to sustain these industries. All employers felt the skills pinch, particularly the smaller ones; they could not compete with "big brands" like Boeing and the lacked resources and ability to field their own programs for training. The Trident Tech program enabled employers to interview and select the apprentices who would best fit them. So small employers provided the impetus for the youth apprenticeship program, but, second, the other intermediaries played crucial roles. The Chamber of Commerce undertook the initial study that demonstrated the program need, helped organize employer interest and for the first five years funded the community college's tuition costs. (Since then, other funders have joined to allow the program to grow.)[238] Trident Tech, in turn, provided the glue; it created the connections between the business and high school actors as well as forming the technical education program. Third, Trident Tech organized for the effort, dedicating two

critical senior staff to the coordination roles: a dean working full time to make the apprenticeship program fit with the 140 firms now in the program, and an assistant vice president working full time to make the apprenticeship a good match for participating high schools. These administrators proved crucial, and illustrate two roles that could be vital to any youth apprenticeship effort. Fourth, a small state program, Apprenticeship Carolina, has mastered and takes on the paperwork burden that would otherwise limit small employer participation in the Labor Department's registered apprenticeship program. Labor's program in turn allows the training certification and makes clear the obligations of each of the participants, the companies as well as the apprentices. All of these partnership-based steps appear to be crucial program enablers.

Past experience suggests that while youth apprenticeships may work for major companies, they are too expensive for small companies. The mix of shared costs and organizing between the employers, the Chamber, high schools and the technical college shows that a working partnership can resolve this issue. While challenges remain – particularly solving transportation between regional high schools, Trident Tech and employers – the model could be a workable one in many communities.

The Charleston youth apprenticeship model, of course, is not the only one connecting new entrant workers to the workplace. Section 6 illustrates other alternatives, including Tennessee's Career Pathways, Kentucky's FAME, Michigan MAT[2], and North Carolina's and Wisconsin's youth apprenticeships.

MODEL #3 - FIXING THE TWO YEAR COLLEGE COMPLETION RATE – THE TENNESSEE COLLEGES FOR APPLIED TECHNOLOGY (TCATS) – REACHING WORKERS AT ALL LEVELS

Tennessee is another state that didn't abandon its vocational schools but it repurposed them into 1 to 2 year technical schools offering certificates and associates degrees. As noted briefly in section 6, there is a network of 27 TCATs spread across every region in the state. They offer 70 technical career programs leading to certificates and associate degrees; they also offer specialized training for larger area employers. They are quite affordable.[239] The state has created from its lottery fund a Skills Grant where any Tennessee citizen aged 18 or older with or without a high school diploma and without taking the ACT or SAT exams can qualify for tuition funding as either a full or part-time student. In addition, Tennessee Prime (for new entrant workers) or TennesseeReconnect (for older workers) grants provide a "last dollar" scholarship to supplement other state and federal aid, so that students can attend TCATs without paying tuition. TCATs have had remarkable success, While the state's 13 community colleges have a completion rate of 25% within three years and 41% within six years,[240] the 27 TCAT schools have an average completion rate for certificates or degrees of 81%, and 86% find jobs in their field of study. Ninety-seven percent of TCAT alumni rated their programs at satisfactory or above; 96% of employers hiring from TCAT rated its program preparation as satisfactory or above. This is not a single isolated school, this is data on completion and satisfaction rates for an entire 27 college system across a state covering urban, suburban and rural areas. What are the TCATs doing right?

The first major problem faced by community college students in completing their programs is affording the tuition. Tennessee's Promise and Reconnect programs tackle that issue. The other major problem faced by community college students nationwide is that many – in Tennessee it is 64% - come in need of remedial courses. Most never complete these – they never get to college level courses. This appears to be the other major breakdown point for degree completion.[241] The TCATs use a different system for remedial and development courses: everyone takes them, and students start taking their technology CTE courses at the same time. No one gets singled out for having to take remedial work, there is no "upstairs-downstairs." And

all students from day one get right into their chosen career courses so they can see their career opportunities from the outset – they don't have to wait to complete remedial work. Since the placement rate in their field of study is so high, the career opportunity is quite real, it's not a dim light at the end of a three year or longer remedial tunnel.

For the remedial work, all entering students participate in ACT's WorkKeys/WorkTrain program in what the TCATs call "Technology Foundations," using ACT software as the curricula in applied math, reading, locating information, writing, problem solving and teamwork. A TCAT Technology Foundations instructor sets up each student with an individualized learning plan, based on areas where he or she needs additional work – some need more, some need less, but all participate. Each gets a schedule to participate in the Foundations lab, mixed in with occupational courses. Each learning plan is unique, calling for different applications of WorkKey/KeyTrain software. Students receive an hour to an hour and a half long sessions two to three times a week, and learning labs are open five days a week and some evenings, for students to work on their programs and to consult with Foundations instructors. Each student pursues the Foundations program at his or her own pace, it is a highly-blended education model combining online and personal instruction; it is competency-based learning with students mastering a series of stages and skills.

The great majority of students complete their programs shortly after their first trimester, and only a handful have not done so by the third trimester.[242] When they complete their Technology Foundations programs they take ACT's online Career Readiness Certificate Assessment. The goal of the TCATs is to have all students with certificates at a silver and gold level; in 2010, 87% of the 4250 TCAT students completing the Certificate did so. Again, all students enter the ACT remedial program and almost no one fails to complete it. Its competencies are also fully integrated into the occupational and technical education programs students are also taking in parallel. Because it is self-paced, competency-based and geared to individual students, this appears to help those who have not done well in the past in classroom settings. The online curriculum is buttressed by instructors who build relationships with students and communicate with them frequently. Again, this is not a single, isolated example; the "Foundations" approach results in high certificate and degree completion rates across the 27 TCATs colleges. Because it appears to work it may be worthy of emulation as we confront completion rates as one of the most serious barriers to occupational education.

The overall workforce education situation in the U.S. would get dramatically better if community college completion rates were turned around. The TCATs are showing one way this could be done.

MODEL #4 - THE SHORT PROGRAM; VALENCIA COLLEGE, FLORIDA – REACHING DISPLACED AND UNDEREMPLOYED WORKERS

Valencia College's leadership saw a problem that their major community college, with eight campuses and 75,000 students in the Orlando area, wasn't addressing. While Valencia was moving thousands through two-year degrees and certificate programs each year, its programs weren't reaching the approximately 300,000 in poor families in the region, often black or Hispanic immigrants. They were generally working but usually at lower-end services jobs for minimum wage pay, in less than full-time jobs without benefits, often holding two or even three of these jobs to meet family needs. The two-year timetable for an associate's degree or one year for a certificate simply did not work for this group, and night classes didn't fit family demands. They had been left outside the education pipeline, with its two to four-year degree programs, and could see no route to the middle class.

In response, Valencia worked out a new approach, the short program. Lasting ten to

twenty-two weeks, five days a week, eight hours a day, Valencia is running short, intensive courses that offer certificates in advanced manufacturing, construction, heavy equipment, logistics, and healthcare fields. The certificates meet industry standards, such as Manufacturing Skill Standards Council (MSSC) standards in manufacturing, and Veterans Administration's requirements, and also provide credits towards an Associate degree at Valencia. Valencia has been unbundling the specific skills needed for industry certificates for its accelerated training programs. These skill certificates can be stacked for multiple certified complementary skills (such as in welding, CNC equipment operation and mechatronics, in manufacturing) and, as noted, the credits for them count toward a Valencia Associate degree. In turn, Valencia credits are transferable to four year degree programs at nearby Central Florida University. But the key to the program is to put students rapidly into a work/learn environment, then into the workplace, with the skills that promptly command a good wage. Valencia has built ties with area employers to assure jobs for its trainees. The program puts them on the first rung of an employment ladder, with jobs that can pay $20/hour or more with benefits. For wage earners currently holding a services job at Florida's $8.46 minimum wage doing seasonal work, this can bring their families to a new level – it can be a route to the middle class.

This accelerated workforce program is outside the degree programs so it is tuition-funded because it doesn't fit Labor or Education Department financial assistance programs. However, there is therefore no state oversight required so Valencia has been able to move quickly. Valencia can, however, offer tuition subsidies, and it used a repossessed small factory from the county and a Labor Department grant to set up the first program in manufacturing skills. Area employers provide the training equipment. This certificate program has also been extended to area prisons with 100 just-released prisoners entering the program and finding jobs, with a far lower recidivism rate to date. There are now four "Centers for Accelerated Training" shared by Valencia's six campuses in additional fields such as health care and skilled construction trades, with 500 and soon 700 students in these programs. Valencia is aiming for 5000 a year, with 25,000 students completing these certificates in five years. If this goal is reached, it could start to make a real dent on area poverty, and create new lives for many.

How can promising short programs evolve? There is an effort pending in Congress to make short programs like this eligible for federal Pell Grant funding,[243] diverting funding from associate and bachelor programs and open to both non-profits and for-profit education providers. However, the legislation lacks accountability over these providers to assure students actually obtain employment in the fields they trained in.[244] While non-degree credentials (certificates, certifications and licenses) can improve employment prospects, and regional Workforce Development Boards have been offering shorter-term training programs for decades, the value of and best ways to organize short programs need more work. Livia Lam of the Center for American Progress has argued that to a significant extent, education quality is assured when the actors needed in training – educators, students and businesses – work as partners and each has a clear stake in the outcome and can push the other stakeholders to ensure quality.[245] For example, companies hiring the trainees must have quality training for their workers; because they depend on them, they have a major stake in ensuring quality programs. In contrast, without company participation in the outcomes, students have more of an unequal status against education providers and may be subject to poor but expensive programs they are not in a good position to understand. Short programs, as Valencia has shown, may be able to play a key role in filling a gap for underemployed workers. But if these programs expand, guardrails to assure quality are required to avoid repeating, for example, the completion problems noted in section 2 with for-profit institutions. We also need to rapidly open up a number of short program experiments to discover what kinds work best. Poor quality could undermine the whole effort.

There is another issue with short programs – we need to ensure they are not education dead ends. As noted, Valencia is careful to tie its short program to community college credit, to make the credentials stackable and to make them possible routes to associate degrees. This is a key step. Frank Gulluni (cited in the first case study at the outset of this section), has been watching comparable six-week programs evolve at a community college in eastern Connecticut and for-profit schools,[246] and has expressed concern that students in short programs don't get the depth of Asnuntuck Community College's program and will need it. He feels his one-year to two-year long manufacturing technology program builds lifetime skills, including an understanding of the underlying theory behind the skills so that when equipment changes the underlying technical understanding is there. It also includes foundational skills in reading, writing and math that will endure long term. He argues students must get this background to do well in careers. On the other hand, Valencia's short courses can get those they reach onto a much better employment track. And Valencia has built into its short program an access path to longer term and more in-depth skill training and a potential degree, which seems critical. If students can be encouraged to use it – and this is not clear yet - this can get participants into a work/learn pattern that can be recurring and serve them well long term. Valencia's program appears to fit displaced or underemployed workers well, although as this model expands to other institutions we need partnerships, quality assurance features and more experiments to understand what features work best.

Community and technical colleges are not the only educational institutions that could play a role. Model 5 concerns forming new technical or comprehensive high schools. These have the advantage of significantly lowering the "learn to work" barriers; here states or local governments could play a key role.

MODEL #5 - MASSACHUSETTS' TECHNICAL HIGH SCHOOLS – REACHING NEW ENTRANT WORKERS

Diman Regional Vocational Technical High School in Fall River, Massachusetts, an old industrial and shipbuilding city, held its ninth annual job fair on April 2, 2019. Seventy-nine companies and organizations participated, and the school gymnasium was packed with employers at tables with flashy posters and videos about their firms and with hundreds of students jostling about speaking to the employers. The employers were there because Diman has a coop work program for its students starting in the second semester of their junior year. After completing five semesters of technical and academic high school courses in one of 18 fields, the students are considered ready to start skilled jobs in their selected career areas; 80% of the students are placed into coop jobs where they have a 90% retention rate. Diman has a two week/two week program: juniors and seniors in the program work full-time for their coop employers for two weeks, doing homework online at night, then spend two weeks in school completing their academic and specialized technical courses. In the bustle of the spring job fair, employers were clearly vying to employ coop students, where their average weekly pay would be $412.[247] While it doesn't call it this, Diman is effectively running an apprenticeship program somewhat comparable to Charleston's Trident Tech.

Diman, named after and founded by an Episcopal priest as a boys trade school in 1912, has 1400 students; 70% of its graduates go on to community college or 4 year college or both. There is an articulation agreement with the area community college, Bristol, which certifies Diman technical courses for college credit; dual enrollment means Diman students graduate with a high school diploma, a year of community college credits, and skill certifications in one of the eighteen career areas where Diman has programs. Students often continue after graduation with their coop employers at $50,000 or more a year, complete community college at

night, then go on to neighboring Bridgewater State University or UMass Dartmouth, where they have guaranteed transferability to pursue their four-year degrees, working at high paying jobs all the way through. That seems to many to be better than piling up student debt for an uncertain career path. Let's look at one of the eighteen career tracks.

The Advanced Manufacturing Technology program, one of the 18 fields available, is a good example. It offers students manufacturing training, from traditional machine tools where they learn the foundations of the hand-eye coordination behind production, to the most modern CNC, laser cutting equipment, and 3D printers, including a new metal 3D Printer. The state's capital equipment program has been providing the most advanced machining equipment available, sometimes valued at hundreds of thousands a tool in in recent years. Diman has a suite of manufacturing equipment that many mid-sized manufacturers would love to have. Freshmen start off on traditional "Bridgeport"-type, person-controlled machine tools then move into ever-more advanced computer driven equipment and 3-, 4- and 5-axis milling machines as they go through subsequent years. The equipment is arrayed on an approximately 9000 square foot industrial floor, which includes special closed-off spaces for computing and programming equipment and some of the newest "clean" equipment. The faculty believes that students develop much more depth and understanding of the equipment if they start with the person-controlled equipment then move to computer controls. Most students go directly into highly-paid production jobs at more than $20-hour after graduation, although a number go onto the Wentworth Institute and other engineering and technical college programs. In their coop programs, students in this track earn up to $16/hour. All manufacturing programs are competency-based, so students in the advanced manufacturing field who decide to do a coop program during their upper years have achieved strong competency on the advanced equipment by the time they enter their coops.

There is clearly a dedicated faculty at work here. According to Mary Anne Zenni, head of the business tech department, "70% of the Diman faculty are graduates of Diman, which creates great loyalty and dedication." Demand is high for Diman; there is a rigorous admission process and the acceptance rate in 2016-17 was 47%. Once accepted, there is a 98% graduation rate, with 97% passing the Massachusetts Comprehensive Assessment System. In the 2018-19 academic year, Diaman students performed better than two-thirds of the regional academic high schools on the state's comprehensive exams.[248]

Is there a place for vocational or career and technical education (CTE) in the American education system? Studies in the 1960s and 70s showed that low income students were much more likely to be in vocational tracks.[249] In **Keeping Track**, Jeannie Oakes found that an underlying function of vocational education has been to segregate poor and minority students into occupational training programs so middle and upper-class students could access the academic curriculum.[250] John Dewey, the great education reformer and philosopher, opposed vocational education because it built class distinctions into the design of public education. This history was real. Many states dropped their vocational school systems.

But by the 2000s, as previous sections illustrate, good jobs that required only a high school diploma were in decline, they required more skills. Some states did not give up on the CTE idea. David Ferreira, executive director in 2014 of the Massachusetts Association of Vocational Administrators noted that, "The early 2000s was a time of significant change in voc ed. What we wanted to do was create a student who was able to go out and get a job but also able to get accepted into a four-year college or university. The idea was to make sure all students were both career and college ready."[251] Massachusetts had kept its vocational high schools (although their size and programs vary, it has 38 in this category across the state) and allocated resources to rebuild their vocational programs. It has largely succeeded; the academic quality

of its vocational high schools is now on a par with its traditional academic high schools, and their performance is accelerating. Their graduation rate is 24 points higher than other state high schools, the dropout rate is one third of other schools, two thirds of voc ed/CTE graduates go on to post-secondary education, and 4400 students are on voc ed school admission waitlists.[252] The data indicates they are performing their mission: their students are far more career ready than other students. There are other lessons from Diman: emphasis on academic performance must be kept high and made to complement technical skills, instructors and equipment must be kept current with developments at the cutting edge of industries, business advisors must be involved in developing the curriculum, and curriculum should be coordinated with community colleges for joint credit to ease entry to post-secondary education. Diman provides a good example of how these kinds of schools can erase the historic barriers between learning and work, and both enable good careers and higher education entry.

However, how useful is the vocational/CTE school model if many states have dropped it? Will these states actually start funding and creating new secondary CTE schools? These schools require not just classrooms but extensive technology and equipment, at a time that most states have been cutting back their education commitments. Perhaps not likely, but not impossible. Many areas, particularly urban areas, have been creating a plethora of new schools through charter school programs. Parents and legislators are increasingly concerned with the disconnect between work and learning, and numerous employers are worried about obtaining higher skilled workers in a period of aging demographics. So, if organized, a political base could exist for new "technical school" institutions in many areas.

There may also be a middle way. Massachusetts, facing the facts that there are already long waiting lists for its existing vocational high schools, and that 52 cities and towns in the state lack access to these schools, has been creating **"Comprehensive High Schools."** While traditional academic high schools focus on core fields such as English, science, math, languages and social studies, and vocational technical schools focus on technical skills, the comprehensive schools do both. They expand their electives to reach a wider range of students seeking vocational as well as academic education, offering such areas as business technology and finance, machining, information technology skills or early childhood education. These schools can also offer vocational programs operating as a school within a school.

Employers are important partners for most of the education institution models cited here, but the Model 6 category, below, provides three examples of companies and industry associations taking the lead in developing new training or skill certification programs.

MODEL #6 - EMPLOYER ROLES: IBM, THE MANUFACTURING INSTITUTE, MSSC, AND CHAMBER OF COMMERCE FOUNDATION – REACHING NEW ENTRANT AND INCUMBENT WORKERS

The IBM Apprenticeship: IBM has started hiring at the Associate degree level. The number of college computer science degrees is far below the market demand, and IBM wants to reduce its commitment to large numbers of college-educated workers who, given the shortage, require high salaries and benefits. It is starting to hire at the next rung down where it believes it can find comparable talent.

IBM, starting in 2017, has developed 15 different apprenticeship tracks for careers in various growing fields including software engineering, data science and analytics, cybersecurity, mainframe system administration, creative design and IT program management. It began at IBM's mainframe (servers) business unit, which had an aging workforce and needed new talent. Since then, IBM's apprenticeships have grown at twice the expected rate. The website for those interested in apprenticeships starts with a bold

headline: "No degree? No problem!"[253]

IBM's apprenticeship seeks to create what it terms "new collar workers" with solid technical skills. IBM went through the process of using the Department of Labor's registered apprenticeship system; it used some DOL funding for creating the required learning plan and objectives, and the education is competency-based. It is allied with collaborating community colleges for associate degrees and certifications, but all the training is internal to IBM. The apprentices work with IBM employees on the job; they are paid less than full time employees, but have jobs and are taking courses as well as working. They commit to 2000 hours in training, but because it is competency-based, they can complete it in less time. It set up initial apprenticeship sites at its Austin, North Carolina's Research Triangle Park, and Rocket Center, West Virginia facilities and will expand the number of sites. It had 200 apprentices in 2019, and there will be 300-400 by 2020, with further expansion contemplated.

IBM apprentices join a cohort of other apprentices from a number of business units in an IBM locality; during opening weeks they learn about IBM as a company and are introduced to the skills they will learn in the apprenticeship. They develop with managers and mentors a personal skills roadmap, with stages of both learning and demonstrating new knowledge and competencies, with hands-on applications and working within project teams. There are a series of milestones for each apprentice, with digital credentials to validate skills. They come back to join with other apprentices for training and development focused on professional and technical skills, acting as contributing members of a team. In selecting apprentices, IBM says it is looking for competencies in adaptability, communication, client focus, creative problem solving, drive, teamwork, and "taking ownership." The retention rate for apprentices is very high so far.

On January 8, 2019, IBM assembled through the Consumer Technology Association (CTA), a group of eight companies that jointly announced a new commitment to apprenticeships.[254] IBM's then-CEO Ginni Rometty announced the apprenticeship program with the other companies at the massive annual Consumer Electronics Show in Los Vegas. The announcement featured four IBM apprentices that had come through the IBM program. One was a Latino immigrant "dreamer" (who first went through IBM's related P-TECH high school program[255]) and is now an IBM apprentice; his talk about what the apprenticeship meant to him brought down the house, receiving a standing ovation. The other companies' programs will be modeled in large part on IBM's 2017 apprenticeship program. The companies in the CTA coalition included Ford Motor Company, Phone2Action, Postmates, SoftBank Robotics, Sprint, Toyota and Walmart. IBM donated all of the apprenticeship course materials and software it has developed for its program to the coalition. Each company made a pledge to hire apprentices; IBM pledged to create 400 to 450 apprentices a year for five years. Why are the other firms participating? Walmart, for example, is involved because it needs skilled employees in its rural area locations to run its extensive IT systems; it has trouble recruiting them but if it train apprentices from the area it believes it can retain them.

IBM's is not the only new employer-led apprenticeship program, but it is a possible example of what could evolve in the tech sector. It is particularly interesting because it is an employer attempt to move non-college degree students into a field – computer and information technologies – entirely dominated by college degrees, where there is now high employer demand and a major talent shortfall. Because apprenticeships now reach less than one percent of the workforce, for this effort to scale, much more industry collaboration is required for sharing best practices, content and programs. Industry apprenticeships will never scale if each company operates as a lone wolf. IBM's efforts with a group of companies are therefore a positive and instructive step. Overall. the apprenticeship effort needs to be more than one-

off efforts by single companies.

Manufacturing Skills Standards Council (MSSC): The Manufacturing Institute, the National Association of Manufacturers' (NAM) think tank, has issued a series of workforce reports with Deloitte arguing that manufacturing faces major skills shortages. The 2018 report argued the sector's "workforce crisis" will only get worse, with 2.4 million jobs to fill in the coming decade and corresponding risks of curtailing firm growth.[256] Developing skill standards is a critical step for educating and hiring those needed manufacturing skills.

The Manufacturing Skills Standards Council (MSSC) has become the leading certifying body for the nation's front-line manufacturing production and supply chain logistics technicians.[257] It is a non-profit, industry-led certification, training and assessment system based on industry-defined and federally endorsed standards. It is the only certification organization in the manufacturing industry accredited under the international ISO system and has had the support of the National Association of Manufacturers, the leading industry association.[258] Its certifications enable both new entrant and incumbent workers to demonstrate they have the required skills for increasingly technical manufacturing tasks. MSSC has two broad certification programs. Its Certified Production Technician program incorporates a host of tasks within five modules: safety, quality practices and measurement, manufacturing processes and production, maintenance practices, and green production. Its Certified Logistics Technician program has two levels and includes such tasks as global supply chain logistics life cycles, material handling equipment, quality control principles, computing skills, packaging and shipment handling, inventory control, and safe handling of hazmat materials. Both certifications have systems for online assessments and supporting online and blended learning courses, with a supporting system of certified instruction organizations and trainers. MSSC has also now begun a skills development effort around the suite of advanced manufacturing technologies now starting to enter manufacturing firms, including practices in artificial intelligence, robotics, data analytics and computer control programming. The process of taking a technical occupation area and identifying component skills, systems to teach them, effective assessments, and providing corresponding certifications, plus making these living systems that incorporate ongoing developments, is a massive one but crucial to education and training in the area. If an occupation area is missing this standards certification step the actors in the system can be frustrated in their abilities to function: educators don't know what to teach, employers don't know how to evaluate potential employees and employees, and employers don't know how to qualify for jobs and can't transfer their qualifications to other firms or areas. The IT sector has been able to develop skill certifications for key occupation areas, the automotive repair sector certifies qualified mechanics, the medical sector has long had certifications for doctors and nurses, and the MSSC effort, an ongoing project in manufacturing, could be critical for meeting that sector's expected workforce skill demands. Without an educated workforce, new technology areas simply can't grow.

The Chamber of Commerce Foundation: The Chamber is the nation's largest business organization with the ability to reach companies of all sizes and sectors in every region. The Chamber Foundation has developed a training program and curriculum, its Talent Pipeline Management (TPM) initiative, designed to enable business-led efforts allied with other stakeholders to implement new training systems and curriculum.[259] The program, which dates from 2014, reaches both new and incumbent workers to help employers in upskilling their workforces. The training side is called the TPM Academy. The program now has 200 partnerships reaching thousands of employers in 26 states.[260]

The TPM Academy offers both in-person and online training for workforce leaders to learn the TPM approach. It is backed by a customized

curriculum that serves as a toolkit for participants. There is a companion web-based tool that activates the six TPM strategies embedded in the program to streamline data collection and visualization needed for sound program construction. It provides a framework for employers that can be customized to their particular needs in building talent pipelines. The curriculum begins with TPM orientation, connecting classrooms to jobs that fit the involved stakeholders and generate buy-in for the process, and runs through all six TPM strategies, concluding with, post-implementation continuous improvement.

The TPM Academy strategies first create a collaboration that organizes area employer groups to identify shared workforce needs and the best opportunities for engagement. Second, projections for job openings are developed to predict accurately actual job needs and their accompanying skill areas. Next, there is a process of forming competency and credential requirements and communicating them across the employer and stakeholder groups. Fourth, current talent flows and their capacities are examined for their ability to meet demand, and new possible sources are identified. In step five, new talent supply chains are formed to assure a return on commitments. In step six, after the new system has been implemented, the new talent supply data system provides continuing information to allow improvements and adjustments. Overall, the TPM program offers constructive help to employers of all sizes trying to formulate workforce solutions.

Collaborations with Unions: Another workforce coordination space available to some employers is with unions. While unions currently make up only 6 percent of the private sector workforce, some significant industry elements remain unionized, including in construction, manufacturing, aerospace, utilities and healthcare. Industry-union workforce education collaborations can bring in groups of employers. For example, the Wisconsin Regional Training Partnership is an industry-led and worker-focused effort with state, federal and community participation and foundation support, that provides short-term training for skilled manufacturing, construction and healthcare jobs in the Milwaukee area.[261] The program's construction element, Big Step, works with the construction trades' joint apprenticeship programs in the region and has significantly increased entry of minorities and women into area skilled construction jobs and helped meet overall needs for skilled workers.[262] Another example is the Culinary Academy of Las Vegas which had trained some 42,000 workers for skilled jobs in the area's hospitality sector, from professional cook to baker to wine server. A collaboration between area's numerous hospitality employers and the culinary and bartenders union locals, it has emphasized reaching large numbers of minorities, youth and displaced workers with small classes of 15 or less and expert instructors from industry, using a large, specialized training facility that also operates a "hands on" restaurant and catering service.

An underlying feature of the employer-led efforts described above - whether creating apprenticeships, establishing industry skill standards, helping employer groups form training programs or training coordination with unions - is that they are collaborative. Employers face a strong disincentive to work with other employers because they compete with each other for talent. Yet shared programs could lower training costs and risks; these barriers to collective efforts amount to a market failure. The solution is for groups of employers to coordinate their workforce efforts, and each of the above cited programs provides an example. We have also seen in other models listed above where other institutions—particularly government and education institutions - can serve as the coordination force. The above programs represent only a few approaches and there are many more. But underlying all these models is a need to build collaborations between employers to solve workforce problems.

Because education and labor programs historically have been split at both the federal and state levels, model 7, below, examines states

as an essential workforce actor. This section looks at reconnecting these programs at the state level, citing a Massachusetts example. The state role could also be important for adopting education programs in advanced new technologies across state education and workforce development institutions.

MODEL #7 – THE STATE ROLE IN UNIFYING PROGRAMS AND DEVELOPING A NEW SYSTEM FOR EDUCATING FOR ADVANCED TECHNOLOGIES: MASSACHUSETTS - BRINGING TOGETHER WORKERS, EMPLOYERS AND EDUCATORS

One of the deeper problems in workforce education is that the major federal programs – the education programs supported by the Department of Education and workforce programs backed by the Department of Labor – are not well-connected, as detailed in section 2 and don't reach incumbent workers well. These programs, in turn, drive the way the states organize their programs; because the federal programs are the major source of funding for the state workforce programs, state implementation follows the federal patterns. The result is a disconnect at both levels. An ongoing effort in Florida to bring together the state's Manufacturing Extension Partnership (Florida Makes), its labor department workforce programs (CareerSource Florida), and in its community colleges using an innovative NSF-supported Florida Advanced Technology Education (FLATE) program, is a good working model. Another is in Massachusetts. Governor Charlie Baker began hearing from employers across the state starting in his first term in 2015 that a trained workforce was a major problem and a constraint on the state's economy. To remedy this, the Commonwealth of Massachusetts has tried to reconnect the range of programs at the state level.

The Governor formed his "Skills Cabinet" in 2015 with the cabinet heads of the three main departments active in workforce development: the offices of Education, Labor and Workforce Development and Housing and Economic Development. Education covers all public education in the state including the state's vocational technical high schools, community colleges, and the state university system. Labor and Workforce Development focuses on unemployed and underemployed workers, managing Workforce Boards and MassHire, the unemployment and job placement employment services offices, both of which reach throughout the state. It also supports the apprenticeship program, which historically focused on the construction sector but has a new, broader apprentice program for expanding sectors and a new intern program with initial state funding.[263] Housing and Economic Development is the state's economic development agency which encourages firms to locate in the state, and it supports a range of programs including in entrepreneurship and R&D. It supports the MassTech Collaborative[264] which focuses on innovation infrastructure and talent for the state, including an innovative advanced manufacturing initiative. The cabinet members in the Skills Cabinet meet biweekly, and their deputies group meets weekly. They jointly make program decisions and strategic planning. Any new workforce-related program from one agency must be approved by the other two.

The cabinet group is focused on three sectors, advanced manufacturing, healthcare and information technology, viewed as critical to the state's future, and it has been working to assure a strong talent base for each. For example, the state, through the Skills Cabinet, awarded between 2015 and 2018 $52 million in Workforce Skills Capital Grants to 188 vocational technical high schools, community colleges, traditional public high schools and industries, to bring the latest technology and equipment to each to expand skills training programs.[265] An additional $75 million capital equipment program is also now in place.[266] A major initiative has been to develop workforce strategic plans in the state's seven economic regions. Each involves a planning group of affected regional stakeholders that cross the constituencies of the involved state agencies, from community colleges and

vocational technical high schools to Workforce Boards to industry leaders. The Workforce Boards in each region are the lead organizers, convening the key participants to develop workforce plans for how to jointly meet skill demands, particularly in each of the three targeted growth sectors.

Another major effort supported by the Skills Cabinet concerns advanced manufacturing. The state has committed $100 million in cost-sharing with the federal government and industry to five of the nation's 14 advanced manufacturing institutes, each of which has program elements in the state. For example, the advanced fibers institute is headquartered in Massachusetts, the photonics institute has based its training and education program in the state, and the flexible electronics, robotics and biopharma production institutes also have education and technology development programs in the state. No other state has such a broad commitment to these institutes. The state's Massachusetts Manufacturing Innovation Initiative (M2I2) program, a part of the MassTech Collaborative, supports these institute efforts as well as advanced manufacturing capital equipment and training through regional partnerships involving universities, community colleges and companies.[267] The state has developed a state-wide plan for advanced manufacturing and the M2I2 program is deeply involved in the Skills Cabinet's effort to develop regional education and training plans to meet future advanced manufacturing skill needs.

A path-breaking example is the M2I2 program's coordination of an effort by the three state agencies to develop a new state plan for a system of advanced manufacturing education, coordinated across state education and workforce institutions.[268] This will require a new curriculum around new technologies such as robotics and photonics aided by online delivery, to be implemented in the state's community colleges, technical high schools, state universities and manufacturing employers. As discussed, there is no existing system for developing the curricula educating for the new advanced technologies entering the workplace, so this example may well be the first systematic attempt. It could be a critical state model for what the nation needs to undertake. It is being led by the MassTech Collaborative's advanced manufacturing director, Ira Moskowitz, a former vice president for global production for a leading semiconductor device firm headquartered in the state; he has the technical and industry experience to understand both the technology and the training need. Assisting in developing these plans is AIM Photonics, a manufacturing institute that has already developed online education courses and modules for educating engineers and technicians in photonics. Because it has cost-shared their programs, the state is planning to involve four other manufacturing institutes in this effort, contributing know-how on their new technologies and how to educate for them. It plans to apply for Defense Department manufacturing institute funding to help support it. Overall, the new effort is seeking to lead the state's still strong production industries into competitive leadership in advanced manufacturing, a field where there will be stiff international competition. This proposed program will reach incumbent as well as new entrant workers, filling a gap in the current system.

As noted above, the state strengthened rather than dropped its vocational technical high schools, which offer coop/apprenticeship opportunities with area companies starting in the junior year. These programs provide new entrant workers and break down the work/learn barriers. The State is also bringing new technical skills programs into traditional high schools to create comprehensive high school programs. And it has used its MassMEP manufacturing partnership program, which brings new technologies and processes to area manufacturing, as a coordinator for training programs for small manufacturers. While the federal government funds programs for unemployed and underemployed workers, the state has a Workforce Training Fund supported by the Skills Cabinet, that offers grants to employers to upskill their incumbent workforces. It is one of a series of programs to reach this group of workers.

In other words, Massachusetts has developed a suite of new organizational and program elements that attempt to integrate education, workforce and economic development at the state level, making up for the disconnects in these programs at the federal level.

We have seen this in many of the successful programs cited in models above, but Massachusetts also brings together employers, education institutions and state resources. Thomas Kochan, David Feingold and Paul Osterman and have argued that this three-way connection is key.[269] They argue that employers need to be involved in designing and funding workforce programs and in finding jobs for graduates. Classroom education must be integrated with opportunities to apply new skills in real or simulated settings. And training must focus on career pathways, not just skills for a particular job. Massachusetts' programs amount to an attempt to provide this mix.

Meghan Perdue notes that the Massachusetts solution to the workforce program disconnects is "organizing, streamlining and coordinating its existing workforce development programs," filling gaps between them.[270] The state grasps that strong workforce development efforts need to be the at the heart of state economic development efforts – they will be key to retaining and growing companies in the state as well as bringing new ones to it. If the state goes forward with its proposals to develop an education system for new advanced manufacturing technologies – including curriculum, courses and modules to be used in education institutions and industry - this will be another first, and a potentially important new national model.

The next model, number 8, below, concerns development of new information systems needed for much more efficient labor markets, which could create significant benefits for workers, employers and educators. These are evolving, but federal agencies, industry associations and the private sector could play key roles.

MODEL #8 - TOWARD NEW LABOR MARKET INFORMATION SYSTEMS: DEPARTMENT OF LABOR AND CHAMBER OF COMMERCE FOUNDATION EFFORTS - ASSISTING WORKERS, EMPLOYERS AND EDUCATORS

American labor markets lack a good information system – we need job skill information with supporting credentials, that connect to job openings data, are tied to rich data on training and education options, that in turn are structured to fit needed skills and job requirements, which, in turn, link to the training systems themselves. This is largely missing in our system, as detailed in section 3. We need an online navigator that integrates workers, employers and educators and helps them sort out their best options within a data rich environment. There are signs this missing navigator could be evolving.

New models for labor market information navigators are needed but not here yet, as noted in section 3. Two projects, both still works in progress, are noted here as examples for how progress could be made.

Labor Department Efforts: In 2014 Congress in a bipartisan effort, as noted in section 3, required the Labor Department to build a better information system. The Workforce Investment and Opportunity Act (WIOA) called for a new and much larger workforce and labor market information system, and, as labor economist Andrew Reamer has noted, provided a full framework for organizing this system.[271] The Secretary of Labor's advisory council on the legislation developed detailed implementation recommendations in 2018 to form this system.[272] The panel's recommendations sought better identification "of in-demand occupations and industries" and to "fill a career awareness gap" for workers. The report recommended building new data bases from unemployment wage records, expanded information collection on occupations, skills and credentials, a new career awareness education framework, and

better information on the changing nature of work. Improved data sharing, new involvement by states and other agencies, and new analytics, were also recommended. Meanwhile, there has been progress at other agencies. The Census Bureau has created a "Jobkit" site that compiles government job information sources and is also developing more data on post-secondary school employment outcomes.[273] NSF is undertaking a new National Training, Education and Workforce Survey.[274] And the Commerce Department and the White House have created an American Workforce Policy Advisory Board.[275] Income and employment data from the Social Security Administration and the Internal Revenue Service, and other Commerce and Labor Department agencies, given appropriate data privacy protections, could also contribute to a new information system. As noted in section 3, the federal agencies could aggregate their data and allow the private sector to build specialized information systems from it in a public-private model. For example, LinkedIn has been building systems for employers and professionals could be an early beneficiary of additional federal data.

The Labor Department's O*Net online system, also noted in section 3, already provides workers with valuable data about occupations and their prospects nationally and by region. If this new system, including data from the other agencies, can be created, the combination would be a major step towards a workable information system.

Chamber of Commerce Foundation's T3 and JDX Programs: In addition to its Talent Pipeline Management program noted in model 6, the Chamber Foundation with support from the Lumina Foundation formed in 2018 a T3 Network to link businesses, community colleges, technical standards organizations, employment experts and technology firms to create a data system available to all.[276] The network now includes 150 organizations, including federal government agencies. It is organized around four tasks: developing open data standards to harmonize and enable interoperability for skill competencies and worker and student records; identify gaps in the standards for employment, earnings and student records; develop tools for shared competency and skill statements for participants in labor markets, and develop protocols for workers and learners to access and use their skills data and competencies through blockchain and distributed ledgers. The project is taking on complex data gathering and organization tasks across public and private sectors. It could become an enabler for a better labor market information system.

The Chamber Foundation also began its Job Data Exchange (JDX) project in 2018.[277] The idea was that if employers provided much clearer job information, labor markets could better connect worker skills and qualifications with job openings. Participating in JDX are the National Association of Manufacturers and the Labor and Education Departments, as well as state organizations and some major employers including Walmart and Microsoft. The participants are working on a series of pilot projects in six states to develop standardized, structured data for web posting of jobs, and for human resource systems for transferring job data.

The T3 and JDX efforts are not projects that will grab headlines. Like the Labor Department's information efforts, they represent the difficult, complex work with data, standards and systems needed for progress on a job navigation system. But sound information systems will require public and private sector collaboration and these programs attempt to do this.

The last model, number 9, takes up below the issue of developing and implementing new education technologies, which will be important to scaling new workforce education efforts. Here, the military provides an example of what is possible, and universities could play a significant development and dissemination role.

MODEL #9 - INTRODUCING NEW EDUCATION TECHNOLOGIES: THE NAVY, CLEMSON, AND MIT - ASSISTING WORKERS, EMPLOYERS AND EDUCATORS

Naval Air Warfare Center Training Systems Division: Work has long been underway at the Naval Air Warfare Center Training Systems Division on virtual and augmented reality (VR and AR) placed within online gaming simulations and run on high-end gaming computers and touch screens. While software must be developed for each type of equipment, the online hardware platforms are commercially available and the equipment costs have become quite manageable – in the $10,000-$15,000 range. The Navy is now shifting a substantial amount of its training for advanced equipment on ships, submarines and at air bases onto these online systems. These systems are increasingly in place at the Navy's training centers and are moving into the fleet starting with aircraft carriers.

Sailors learn how to operate the equipment using the touch screens, then go through a relentless series of challenges solving a long series of operating and repair problems thrown at them. Through the touch screen they can call up written, verbal and video popups to help in the problem solving. Interestingly, a kind of "digital twins" effect is evolving – on ships the online training program is now kept running next to the actual equipment becoming, in effect, a part of the day-to-day operating system.

The military introduced flight simulators to train pilots starting with the famous Link Trainers in 1934 for the Army Air Force.[278] As noted in section 5, by World War II the military acquired approximately 10,000 Link Trainers to train some 500,000 new pilots, achieving a stunning scale-up rate. The new VR/AR technology is the latest extension of those early training concepts; it enables realistic training without risks to the actual equipment and ensuring the safety of new operators. The new technology enables significant learning by doing, which makes it a major step forward in training. Preliminary findings by the Navy indicate the level of skill that can be acquired through their VR/AR simulations is quite close to actual hands-on learning.

The other military services are also making similar progress, moving rapidly to shift training onto these technologies. Industry, however, is further behind. It is starting to use VR/AR for tasks like inspections but is still a long distance away from introducing it at scale for training. As discussed in section 2, industry overall appears to have been reducing its commitment to training, so responsibility for obtaining training has shifted largely to individuals to get themselves trained and to publicly-funded community colleges. Although the online equipment could make training much less costly for community colleges – they wouldn't have to acquire full factory floors of advanced manufacturing equipment, for example – they do not have the resources or the capabilities to develop the required software. Yet, once the software is developed it could disseminate rapidly online. A key issue, then, is who is in a position to develop the software? Industry could develop software for equipment now in use, but will have trouble developing training for advanced technologies that are not yet widespread because there isn't yet a market. Equipment providers might fill this gap, but only for their own equipment. Universities, many of which have now implemented extensive online courses, could also take on this role. Section 5 details the emerging education technologies and their potential importance; concerning their delivery, two examples of universities adopting online technologies follow below.

Clemson's Center for Workforce Development: Clemson's Center for Workforce Development, discussed in section 4, has worked with South Carolina's system of technical colleges, with support from NSF's Advanced Technology Education (ATE) program, and developed a system of online courses in high-end manufacturing skills. The courses are in modular form, and can be readily adopted into classes at technical and community colleges so face-to-face learning is not displaced but enhanced. The course materials fit the skill standards set by the Manufacturing Skills Standards Council (MSSC), and can lead to MSSC certifications. Interestingly, VR/AR features are also being built into the course modules. Clemson already has

a major focus on advanced manufacturing at its Center for Automotive Research in Greenville, in new manufacturing engineering programs, and through its participation in the robotics advanced manufacturing institute. However, its work on online training with the state's technical colleges breaks new ground.

MIT Open Learning: Our colleagues at MIT Open Learning have a growing list of accomplishments. Working with MIT faculty they have now produced over 170 Massive Open Online Courses (MOOCs) available online around the world involving millions of learners. MIT's long-standing Open Courseware system posts course materials and increasingly lecture videos for nearly all MIT's courses; over 300 million learners worldwide have used it. MIT with Harvard led the creation of edX, the major online course platform that hosts MOOC courses from over 130 universities around the world with many millions of learners. MITx, MIT's online course system, is also developing new certificate programs. It has five new "MicroMasters" programs that group sequences of approximately six courses, including in manufacturing and supply chain management, that now reach over 800,000 enrolled students online. Students who do well on the supply chain MicroMasters can qualify to come to MIT to complete a full MIT masters degree, or a full masters at over three dozen other cooperating universities, on an accelerated schedule with full credit for the MicroMasters courses. The cost of a MicroMasters, which requires assessments and issuing certificates, is $1000, a small fraction of a full MIT masters.

MIT also now has an xPRO suite of online courses developed for particular companies that want to train their technical and engineering staff. For example, Boeing has thousands of systems engineers in many countries but found that they did not have a systems lingua franca. To develop a common understanding of systems engineering across its engineering force it supported MIT Open Learning to develop foundational systems engineering courses. These are widely used at Boeing; because Boeing paid for their development its engineers have a large discount, but the courses are also available to anyone at higher cost. A number of other companies are now developing courses in other areas with MIT Open Learning. And MIT Open Learning has already worked with a number of community colleges that use its MOOCs as modules in their courses. Because MIT Open Learning believes blended learning is best – it can optimize both online and face-to-face learning – it has also been running bootcamps to match up with a series of its MOOC courses. Students who complete MOOCs are eligible to participate for a fee in bootcamps that can vary in length but often consist of a week of intense group learning. Bootcamps allow face-to-face and learning-by-doing features to be added to online education.

MIT Open Learning is also working with nine large universities to develop a digital credentialing system for both online course certificates and university degrees, as noted in section 5.[279] The schools are working to create the standards for a trusted, distributed but shared infrastructure for issuing and verifying academic credentials. Using blockchain and strong cryptography to prevent fraud, credentials can now be owned and displayed by the individual credential-holder – representing a democratizing of transcripts. It will also enable much richer and detailed credentials potentially reflecting particular competencies the student learned, making it much more useful to employers trying to understand the skills and competencies actually behind a degree or certificate. It could help open new pathways for individuals to become what they want to be, as well as a serving as a protected validation system underpinning online credentials.

In addition, MIT is home to the AIM Photonics advanced manufacturing institute's education and training programs. AIM has already developed MOOCs for the MITx/edX platforms on photonics and optics skills at the engineering and technician level and is working on more. It is also working with the state of Massachusetts and in cooperation with MIT Open Learning on a plan for a state-wide advanced manufacturing education

system noted above where online courses will be an important feature. So MIT Open Learning is already engaged in numerous workforce education projects, and has the assets and interest to do more.

These two schools and work at others suggest university models that could play a role in supporting entry of new online technologies into education and training. Because of the way online can quickly scale, not every university has to consider undertaking this – a small number could play lead roles, which was the way MOOC platforms developed. The work at the Naval training center and at other military training centers provide examples of what the new technologies can accomplish in training.

SUMMARY – THE NEW DELIVERY MODELS

This section has explored nine models for workforce education delivery, reaching the full range of affected workers - new entrants, unemployed or underemployed and incumbents. The models require different institutional leads. To recap, the first four models involve community or technical colleges in leading roles for training, apprenticeship, completion and short certificate programs, although employer and state partners play important roles in each example. Model 5 concerns new technical or comprehensive high schools which can reach new entrant workers. They have the advantage of significantly lowering the learn to work barriers; here states could play a key role. Under Model 6, employers are central, with companies and industry associations as leads in developing new training or skill certification programs. Because education and labor programs historically have been split at both the federal and state levels, model 7 concerns reconnecting these programs at the state level, citing a Massachusetts example. The state role could also be important for adopting programs for advanced new technologies across state education and workforce institutions. Model 8 concerns development of new labor market information systems – here, federal agencies, industry associations and the private sector could play key roles. Model 9 takes up the issue of developing and implementing new education technologies; here, the military provide an example of what is possible in VR and AR, and universities could play a role in developing online training. Each of these models is briefly summarized in Table 11.1, noting the worker categories each is designed to reach.

Together, the models amount to approaches that states, education institutions and employers could adopt, filling significant gaps in the current workforce education system. The models are complementary – no single model is adequate to the range of workforce challenges but a combination could have a significant effect. There are also implications from each program for federal education and labor programs.

Delivery Model	Location	Reaches New Entrant Workers	Reaches Displaced or Underemployed Workers	Reaches Incumbent Workers
#1 The Trifecta: Asnuntuck Community College (community college, high school and incumbent programs)	Enfield, Conn.	X	X	X
#2 Youth Apprenticeship: Charleston's Triden Tech	Charleston, S.C.	X		
#3 Fixing the Two Year College Completion Rate: the Tennessee Colleges for Applied Technology (TCATs) Model	Tenn.	X	X	X
#4 The Short Program: Valencia College, Florida Model	Orlando and Osceola, Fla.		X	X
#5 Technical and Comprehensive High Schools: Massachusetts	Mass.	X		
#6 Expanded Employer Roles: IBM, MSSC, and Chamber of Commerce Foundation programs	New York and nationwide	X		X
#7 Unifying State Programs and Educating for Advanced Technologies: Massachusetts Skills Cabinet - Bringing together Labor, Education and Employer programs	Mass.	X	X	X
#8 New Labor Market Information System Models: Department of Labor and Chamber of Commerce Foundation Efforts	Wash., DC and nationwide	X	X	X
#9 Introducing New Education Technologies: Navy, Clemson, and MIT	Orlando, Fla., S.C., Mass.	X	X	X

Table 11.1 - New Workforce Education Delivery Models

SECTION 8: POLICY RECOMMENDATIONS

The current system faces a deep resourcing problem at nearly every level. The federal Labor programs are particularly inadequately funded which affects the state role because federal funds support so many state efforts. Community colleges are also seriously underfunded, which also needs to change. Employers, the largest training provider, appear to have been cutting back on workforce efforts in the past. But new models are appearing. The goal of this study project has been to go to the heart of how social policy generally evolves: to identify replicable models that can be scaled up to achieve societal impact. Examples were set out in the last section. But there is not going to be a single implementation approach – different states and regions will have different strengths, and the actors, including educators and companies that step forward to lead, will vary by area. But nearly all the models will require collaboration between government, business, educators and workers. For all programs, research on and continuing assessment of program performance is needed.

So who needs to do what? We examine policy implementation below at the provider level: the state role, the federal role, the role of the range of education institutions (including community colleges and universities), and the role of employers. Each listed recommendation is tied to the policy models listed above, or to relevant sections of this report.

Recommendations for States:

- **Use community and technical colleges to deliver workforce education not only to community college students, but simultaneously to incumbent workers and high school students (Model #1).**
- **Use community colleges along with high schools and area employers to create youth apprenticeships that begin in high school (Model #2).**
- **Reverse the low community college completion rate through reorganization of remedial and development education (Model #3).**
- **Create short 10 to 20 week technical training programs at community colleges for underemployed workers, with credits that can lead to degrees and broader certificates (Model #4).**

- **Revive career and technical education in high schools, through technical schools or programs in comprehensive high schools (Model #5).**
- **Create lifelong learning programs at higher education institutions (Section 4).**
- **Require stronger career advising and workforce skill education in higher education (Section 4).**
- **Work to unify state labor, education and economic development programs to support complementary program delivery (Model #7).**
- **Create a state-wide plans and effort to bring education in advanced technologies, including in information technologies and advanced manufacturing, to the workforce (Model #7).**

Recommendations for the federal government:

- **Put adequate resources into the key Labor Department programs, the Workforce Investment and Opportunities Act (WIOA) the Trade Adjustment Assistance Act (TIAA) as well as the Education Department's the Perkins Act (Section 2).**
- **Undertake coordination across the involved federal agencies, with consolidated budgeting for workforce development and specific a set of shared criteria for evaluating proposals and dispersing funds. These criteria should reflect what we understand about the critical elements in a robust, collaborative workforce system (Section 2).**
- **Restructure these programs so they better reach new entrant and incumbent workers who need upskilling, as well as displaced and underemployed workers (Section 2).**
- **Experiment by supporting student aid pilot projects for non-degree workforce education where education quality is assured through partnerships between educators, students and businesses (Section 4).**
- **Expand federal support for apprenticeship and career technical education (Section 6, Model #2).**
- **Undertake a concerted effort across agencies and with employers and educators to build a robust workforce information system (Model #8).**
- **Expand the Advanced Technology Education (ATE) Program at NSF to reach more community colleges (with collaborating universities) with advanced technology skill development (Section 2).**
- **Strengthen the Advanced Manufacturing Institute workforce education programs, and encourage them to enter into development efforts with states for new advanced manufacturing curricula and delivery (Section 2).**

Recommendations for Universities:

- **Use their relationships with other actors, including states, community colleges and industry, to help organize new delivery frameworks for workforce education, particularly for higher end skills (Section 4);**
- **Develop online delivery systems for workforce education, including development and implementation of new education technologies - virtual and augmented reality, application of computer gaming and simulations, use of artificial intelligence and digital tutors (Model #9, Section 5).**
- **Prepare content and delivery for higher-end workforce skills that will be entering the workplace, including for new information and other technologies where universities have expertise (Section 4).**
- **Develop lifelong learning curriculum and offerings particularly for higher end skills and new advanced technologies, and improve career counseling and programs (Section 4).**
- **Develop the learning science for optimal teaching approaches which can be incorporated in both online and classroom education and applied to workforce education ((Section 4).**

Recommendations for Community Colleges:

- **Significantly increase completion rates for their degrees and certificates, where major barriers appear to be remedial and**

developmental education courses as well as cost. Work to mitigate the social and economic life circumstances that cause students to drop out, including through expanded mentoring and career advising for students. (Model #3).

- **Expand connections to high schools on workforce education, to youth apprenticeships, internships and other programs to open community colleges to new entrant workers (Models #1 and #2).**
- **Implement short term skill programs, but create credits for them that tie to degrees and broader certificates (Model #4).**
- **Reach incumbent workers and closely link on an ongoing basis to employers to ensure the relevance of their courses to meeting employer needs (Model #1).**
- **Link to universities and to NSF's ATE program and the Advanced Manufacturing Institutes for support in developing materials for workforce education, particularly to obtain access to online courses and modules on high level technical and advanced skills for emerging new technologies (Sections 2 and 4).**

Recommendations for Employers:

- **Collaborate with educators and state and local governments as well as labor organizations in developing workforce education systems, including apprenticeships and internships at high school and community college levels and incumbent worker upskilling (Models #1, 2, 4 and 6).**
- **Collaborate with other employers, including small and medium size employers on workforce development, to break the pattern of "one-off," non-replicable programs by single employers (Model #6, Section 2).**
- **Use industry associations and work with educators to develop skill standards and certification systems (such as the MSSC system) for existing and new technical tasks and occupations (Model #6, Section 2).**
- **Support new labor market information systems (Model #8).**

We can start to see from the above recommendations a pattern of collaborative engagement that will be needed. A new workforce education system will mean integrating classroom education with hands-on training that is linked with area employers and their needs; forming groups of area employers to work together and with education providers to support efforts to train and employ their graduates; expanding education and training and orienting it not just to a particular job but to more lasting career development; building a lifelong education and training system between employer groups and schools that can continue to upgrade skills across the workforce; and introducing new education technologies than can scale up to meet the size of this challenge.[280] These elements amount to criteria for new workforce education efforts.

The list of recommendations here is a long one. One might ask if there was just one step to take what would it be? Unfortunately, it's not that simple. Workforce education must operate in a complex system with a multitude of actors – as we have seen these include employers, employees, education institutions, and governments at all levels. We are also going to have apply our existing institutions, we are not going to start from scratch. However, there are gaps at many levels in the existing system. We have identified a series of new models that could fill these gaps and make a significant difference in the way this system performs. They will not be the only models and many require further testing and demonstration. But they are all now in operation and not simply at the idea stage. All offer new possibilities. If the range of workforce actors can find ways of collaborating to bring them about, our workforce education system might actually become a working, thriving system. In the early 20th century, the demands of a rapidly industrializing economy created a need for high schools nationwide. With a remarkably short period of several decades, a new secondary education system was built. We need an effort like this now to meet a new set of societal workforce challenges.

ENDNOTES

SECTION 1: INTRODUCTION

1. William B. Bonvillian and Peter L. Singer, Advanced Manufacturing – The New American Innovation Policies (Cambridge, MA: MIT Press 2018), 1; Federal Reserve Bank of St. Louis, FRED, All Employees: Manufacturing (MANEP), https://fred.stlouisfed.org/series/MANEMP.

2. William B. Bonvillian, Donald Trump's Voters and the Decline of American Manufacturing, Issues in Science and Technology 32, no. 4 (Summer 2016), http://issues. org/32-4/donald-trumps-voters-and-the-decline-ofamerican-manufacturing/.

3. Melissa S. Kearney, Brad Hershbein, and Elisa Jacome, Profiles of Change: Employment, Earnings and Occupations from 1990–2013 (Washington, DC: Brookings Institution, 2015).

4. Kearney, et al, Profiles of Change. See also, Gregory Mankiw, Why Aren't More Men Working? New York Times, June 15, 2018.

5. Kearney, et al, Profiles of Change, Table 1.

6. David Autor, David Dorn and Gordon Hanson, The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade, Annual Review of Economics, v. 8, 2016, 205-240.

7. Bonvillian and Singer, Advanced Manufacturing, 53-55, 265.

8. Bonvillian and Singer, Advanced Manufacturing, 245-254.

9. Bureau of LaborStatistics (BLS), Occupational Employment Statistics, 51-0000 Production Occupations, May 2015, http://www.bls.gov/oes/current/oesstru. htm#510000.

10. See Bureau of Labor Statistics (BLS), Concepts and Methodology, http://www.bls.gov/cps/documentation. htm#concepts.

11. Paul Osterman and Andrew Weaver, Skills and Skill Gaps in Manufacturing, in Production in the Innovation Economy, ed. Richard Locke and Rachel Wellhausen (Cambridge, MA: MIT Press, 2014), 17, 20.

12. Alicia Sasser Modestino, The Importance of Middle-Skill Jobs, Issues in Science and Technology, v. 33, n. 1, Fall 2016, https://issues.org/the-importance-of-middle-skill-jobs/.

13. See discussion in Alicia Sasser Modestino, The Importance of Middle-Skill Jobs, Issues in Science and Technology 33, no. 1 (Fall 2016), 42 (cited BLS data).

14. Census Bureau, Real Median Family Income in the United States [MEFAINUSA672N], FRED, Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/MEFAINUSA672N.

15. Facundo Alvaredo, Anthony B. Atkinson, Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, The World Wealth and Income Database, http://www.wid.world/.

16. Claudia Goldin and Lawrence F. Katz, The Race Between Education and Technology (Cambridge, MA: Harvard University Press 2008).

17. Social Security, Research, Statistics and Policy Analysis, Education and Lifetime Earnings, Nov. 2015, https://www.ssa.gov/policy/docs/research-summaries/education-earnings.html. See also, discussion in section 4 of this work.

18. David H. Autor, Polanyi's Paradox and the Shape of Employment Growth, Proceedings of the Federal Reserve of Kansas City, August 2014, 139-142. See also, David H. Autor and David Dorn, The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market, American Economic Review v. 103, n. 5, 2013, 1553-1597.

19. Gary S. Becker, Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education (New York: National Bureau of Economic Research, 1975).

20. Council of Economic Advisors, Issue Brief: Active Labor Market Policies: Theory and Evidence of What Works, White House, December 2016, 4, https://obamawhitehouse.archives.gov/sites/default/files/page/files/20161220_active_labor_market_policies_issue_brief_cea.pdf.

21. Council of Economic Advisors, Active Labor Market Policies,1-2.

22. Martin Ford, Rise of the Robots: Technology and the Threat of a Jobless Future (New York: Basic Books, 2015); Tyler Cowen, Average Is Over: Powering America Beyond the Age of the Great Stagnation (New York: Dutton Penguin Group 2013); Carl Benedikt Frey and Michael A. Osbourne, The Future of Employment: How Susceptible Are Jobs to Computerisation? (Oxford, UK: Oxford Martin School, University of Oxford, Oxford, September 17, 2013), http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf.

23. MIT Work of the Future Task Force, The Work of the Future, Shaping Technology and Institutions, Oct. 2019.

24. Shawn Sprague, Below Trend: The U.S. Productivity slowdown since the Great Recession, Beyond the Numbers, Bureau of Labor Statistics, v. 6, n. 2, January 2017, https://www.bls.gov/opub/btn/volume-6/below-trend-the-us-productivity-slowdown-since-the-great-recession.htm. See also, Adams Nager, Trade vs. Productivity: What Caused U.S. Manufacturing's Decline and How to Revive It, Information Technology and Innovation Foundation (ITIF) report, February 13, 2017, https://itif.org/publications/2017/02/13/trade-vs-productivity-what-caused-us-manufacturings-decline-and-how-revive.

25. Robert D. Atkinson, How to Reform Worker-Training and Adjustment Policies for an Era of Technological Change, Innovation and Information Technology Foundation (ITIF) report, February 2018, 7, http://www2.itif.org/2018-innovation-employment-workforce-policies.pdf?_ga=2.110161607.390165303.1536533172-1797272473.1536533172.

26. Melanie Arntz, Terry Gregory, and Ulrich Zierahn, Risk of Automation for Jobs in OECD Countries, a Comparative Analysis, OECD Social, Employment and Migration Working Paper 189, OECD, Paris, June 16, 2016. See also, David Autor and Michael Handel, Putting Tasks to the Test: Human Capital, Job Tasks, and Wages, Journal of Labor Economics 31, no. 2 (2013): S59–S96; Organization for Economic Cooperation and Development (OECD), Automation and Independent Work in a Digital Economy, Policy Brief, OECD, Paris, May 2016, 2, http://www.oecd.org/employment/Policy%20brief%20 %20Automation%20and%20Independent%20Work%20in%20a%20Digital%20Economy .pdf.

27. McKinsey Global Institute (James Manyika, Susan Lund, Michael Chui, Jacques Bughin, Jonathan Woetzel, Parul Batra, Ryan Ko. and Saurabh Saurabhvi), What the future of work will mean for jobs, skills and wages, report, Dec. 2017, https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages.

28. MIT Work of the Future Task Force, The Work of the Future: Shaping Technology and Institutions, Fall 2019, https://workofthefuture.mit.edu/sites/default/files/2019-09/WorkoftheFuture_Report_Shaping_Technology_and_Institutions.pdf.

29. Other alternatives include Institutional and policy changes such as rebalancing bargaining power and raising labor standards and minimum wages, in addition to tax alterations to redistribute income. Educational approaches, however, appear more politically viable.

30. Strengthening Career and Technical Education for the 21st Century Act, Public Law 115-224, H.R. 2353, passed with Senate Amendment 3408 (passed Senate July 23, 2018), enacted July 31, 2018.

31. Presidential Executive Order on Expanding Apprenticeships in America, June 15, 2017, https://www.whitehouse.gov/presidential-actions/3245/. See also, Task Force on Apprenticeship Expansion, Final Report to The President of the United States, Submitted by Secretary of Labor R. Alexander Acosta and Secretary of Education Betsy DeVos, May 10, 2018, https://www.dol.gov/apprenticeship/docs/task-force-apprenticeship-expansion-report.pdf.

32. Chamber of Commerce Foundation, Center for Education and Workforce, Workforce Development initiatives, https://www.uschamberfoundation.org/workforce-development.

33. Workforce Information Advisory Council, Recommendations to Improve the Nation's Workforce and Labor Market Information System, Submitted to Alexander Acosta, Secretary of Labor, January 25, 2018, https://www.doleta.gov/wioa/wiac/docs/Second_Draft_of_the_WIAC_Final_Report.pdf.

34. Michelle Weise, Andrew Hanson, Allison Salisbury and Kathy Qu, Strada Institute, On Ramps to Good Jobs (report), Strada Institute, January 31, 2019, 2,37, https://go.stradaeducation.org/on-ramps.

35. Pew Research Center, The Rising Cost of Not Going to College (report), 2014. http://www.pewsocialtrends.org/2014/02/11/the-rising-cost-of-not-going-to-college/.

36. Margaret Cahalan, L. W. Perna, M. Yamashita, J. Wright, and S. Santillan, Indicators of Higher Education Equity in the United States, Historical Trend Report, Pell Institute for the Study of Opportunity in Higher Education, Council for Opportunity inEducation (COE) and Alliance for Higher Education and Democracy of the University of Pennsylvania (PennAHEAD), 2018, 96, http://pellinstitute.org/downloads/publications-Indicators_of_Higher_Education_Equity_in_the_US_2018_Historical_Trend_Report.pdf.

37. Raj Chetty, Nathaniel Hendren, Patrick Kline, and Emmanuel Saez, Where Is the Land of Opportunity? The Geography of Intergenerational Mobility in the United States, Quarterly Journal of Economics, v.129, n.4, Nov. 2014, 1553-1623.

SECTION 2: BREAKDOWNS IN TODAY'S WORKFORCE EDUCATION SYSTEM

38. Paul Osterman, Presentation to Aspen Institute Future of Work and MIT Work of the Future initiatives, forum, Washington, D.C., May 20, 2019.

39. Kenneth C. Gray and Edwin L. Herr, Workforce Education, The Basics (New York: Pearson 1997). Council of Economic Advisors (CEA), Issue Brief: Active Labor Market Policies: Theory and Evidence of What Works, White House, December 2016, 1-2, https://obamawhitehouse.archives.gov/sites/default/files/page/files/20161220_active_labor_market_policies_issue_brief_cea.pdf.

40. Harry J. Holzer, Workforce Development as an Antipoverty Strategy: What Do We Know, What Should We Do? IZA, DP No. 3776, Oct., 2008, 1, http://ftp.iza.org/dp3776.pdf.

41. Paul Osterman, Securing Prosperity, The American Labor Market: How it has Changed and What to Do about It (Princeton, NJ: Princeton University Press 2000). See also, David Autor, Introduction, in David Autor (ed.), Studies of labor market intermediation (Chicago, IL: University of Chicago Press 2009), 1-26.

42. Paul Osterman, Presentation to Aspen Institute Future of Work and MIT Work of the Future initiatives, forum, Washington, D.C. May 20, 2019.

43. Council of Economic Advisors, 2015 Economic Report

of the President, Achievements and Challenges in the U.S. Labor Market, c.3, 2015, 146-147, https://obamawhitehouse.archives.gov/sites/default/files/docs/2015_erp_chapter_3.pdf.

44. Jeffrey Waddoups, Did Employers in the United States Back Away from Skills Training during the early 2000s? Industrial and Labor Relations Review, v.69, n. 2, Dec. 2015, https://journals.sagepub.com/doi/10.1177/0019793915619904.

45. Jeffrey Waddoups, Has complementarity between employer-sponsored training and education changed during the 2000s?, Education Economics v.26 n. 2, August 2017, 1-16.

46. Robert I. Lerman, Are Employers Providing Enough Training? Theory Evidence and Policy Implications, paper for the National Academy of Sciences Symposium on the Supply Chain for Middle Skill Jobs, 2017, 3, https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_168146.pdf.

47. Use of these terms is detailed in, Paul Osterman, In Search of the High Road: Meaning and Evidence, Industrial and Labor Relations Review, v.71, n.1, Oct. 23, 2017, https://iwer.mit.edu/wp-content/uploads/2018/04/In-Search-of-the-High-Road.pdf. The context of high and low road employer options is discussed at length in, Thomas Kochan, Shaping the Future of Work: What Future Worker, Business Government Leaders Need to Do for All to Prosper (New York: Business Expert Press 2015).

48. CEA Issue Brief, Active Labor Market Policies, 3; CEA, The Long- Term Decline in Prime-Age Male Labor Force Participation, June 2016, 27-28, https://obamawhitehouse.archives.gov/sites/default/files/page/files/20160620_cea_primeage_male_lfp.pdf.

49. Paul Romer, Endogenous Technological Change, Journal of Political Economy, v.98, n.5 (1990), 72-102, http://web.stanford.edu/~klenow/Romer_1990.pdf; Eric Hanushek and Ludger Weissmann.. Universal Basic Skills: What Countries Stand to Gain, OECD Publishing, 2015. http://dx.doi.org/10.1787/9789264234833-en.

50. Suzanne Berger and the MIT Task Force on Production in the Innovation Economy, Making in America (Cambridge, MA: MIT Press 2015), 17-20, 44-64.

51. Business Roundtable, Workforce Education Committee, https://www.businessroundtable.org/about-us/committees/education-workforce-committee, https://www.businessroundtable.org/time-to-align-americas-skills-gap-and-how-to-overcome-it.

52. Chamber of Commerce Foundation, Center for Education and Workforce, Workforce Development, https://www.uschamberfoundation.org/workforce-development.

53. Manufacturing Institute, Workforce Skills Certification, http://www.themanufacturinginstitute.org/Skills-Certification/Skills-Certification.aspx).

54. Niv Elis, Union membership falls to record low of 10.3 percent, The Hill, Jan. 22, 2020 (citing BLS data), https://thehill.com/policy/finance/479400-union-membership-falls-to-record-low-of-103-percent.

55. Thomas J. Kriger, Director of Research, North America's Building Trades Unions (NABTU) , and Brad Markell, Executive Director, Industrial Union Council, AFL-CIO, meeting, Wash., D.C., February 27, 2020 (source for content in this subsection).

56. Holzer, Workforce Development as an Antipoverty Strategy, 5-6.

57. Department of Labor, Employment and Training Administration, WIOA Overview, https://www.doleta.gov/wioa/Overview.cfm.

58. National Skills Coalition, America's Workforce: We can't compete if we cut, August 2018, https://www.nationalskillscoalition.org/resources/publications/file/Americas-workforce-We-cant-compete-if-we-cut-1.pdf.

59. Benjamin Collins, Trade Adjustment Assistance for Workers and the TAA Reauthorization Act of 2016, Congressional Research Service, August 14, 2018, 3, https://fas.org/sgp/crs/misc/R44153.pdf.

60. Department of Labor, Employment and Training Administration, Apprenticeship, Data and Statistics, Registered Apprenticeship to 9/30/18, https://doleta.gov/oa/data_statistics.cfm.

61. College Board, Trends in Higher Education, Total Pell Grant Expenditures and Number of Recipients over Time, 20117-18, https://trends.collegeboard.org/student-aid/figures-tables/pell-grants-total-expenditures-maximum-and-average-grant-and-number-recipients-over-time.

62. Department of Education, Federal Student Aid Office, Gainful Employment Information, https://studentaid.gov/data-center/school/ge. Created in 2010, these regulations have been revoked effective July 2020. Federal Register, Program Integrity: Gainful Employment, A Rule by the Department of Education, 7/1/19, https://www.federalregister.gov/documents/2019/07/01/2019-13703/program-integrity-gainful-employment.

63. Department of Education, Federal Student Aid Office, Federal Pell Grants, https://studentaid.ed.gov/sa/types/grants-scholarships/pell.

64. Robert Kelchen, Examining Trends in the Pell Grant Program, July 3, 2017, https://robertkelchen.com/2017/07/03/examining-trends-in-pell-grant-program/. See also, Department of Education, Pell Grant Annual Data Report, Statistics by Type and Control of Institution for Award Year 2017-2018, Table 18, https://www2.ed.gov/finaid/prof/resources/data/pell-data.html; Sung-Woo Cho, James Jacobs, Christine Zhang, Community College Research Center, Columbia Teacher's College, Demographic and Academic Characteristics of Pell Grant Recipients at Community Colleges, CCRC Working Paper no. 65, Nov. 2013, 3, https://ccrc.tc.columbia.edu/media/k2/attach-

ments/demographic-academic-characteristics-pell-grant.pdf.

65. Senate Committee on Health Education and Pensions, Report on For Profit Higher Education: The Failure to Safeguard the Federal Investment and Ensure Student Success, July 30, 2012, https://www.help.senate.gov/imo/media/for_profit_report/PartI-PartIII-SelectedAppendixes.pdf. The committee found that while for-profit two-year programs have low completion rates comparable to low rates at community colleges, the significantly higher cost of the for-profit programs made them a much higher risk for students and for the federal taxpayers funding student loans. It found that while 96% of students attending for-profit colleges borrow to attend, only 13% of community college students do so.

66. College Scholarships.org, Technical School Loans, http://www.collegescholarships.org/loans/technical.htm; Department of Education, Office of Federal Student Aid, Federal student loans, https://studentaid.ed.gov/sa/types/loans.

67. Alexandre Tanzi, U.S. Student Debt in 'Serious Delinquency' Tops $166 Billion, Bloomberg, Feb. 19, 2019, https://www.bloomberg.com/news/articles/2019-02-16/u-s-student-debt-in-serious-delinquency-tops-166-billion, https://www.bloomberg.com/news/articles/2019-02-16/u-s-student-debt-in-serious-delinquency-tops-166-billion ("serious delinquency" defined as in default or unpaid for three months; data calculated from Federal Reserve Bank of N.Y.'s quarterly household-debt report).

68. Advance CTE, Strengthening Career and Technical Education for the 21st Century Act (Perkins V) (review of new legislation), 2018, https://www.careertech.org/perkins.

69. Zuzana Cepia, National Immigration Forum, Fact Sheet: What is the Perkins CTE, July 25, 2018, https://immigrationforum.org/article/fact-sheet-perkins-cte-serve-immigrants/; Advance CTE, Perkins V.

70. Higher Learning Advocates and Advance CTE, 101: Career Technical Education, online paper, June 2019, https://ejm0i2fmf973k8c9d2n34685-wpengine.netdna-ssl.com/wp-content/uploads/2019/06/CTE-101-Career-Technical-Education-FINAL.pdf?mc_cid=8c5d3ce5bf&mc_eid=b4a13b655.

71. Presentation by Gregory Henshall, Department of Education, Office of Career Technical and Occupational Education, to Manufacturing Innovation Institute Workforce Education Directors, ManTech, Alexandria, Va., Feb. 5, 2020.

72. Jeannie Oakes, Keeping Track, How Schools Structure Inequality (New Haven, CT: Yale University Press 2005, 2nd ed.).

73. The Alliance for Vocational Technical Education, High Quality Career Technical Education in Massachusetts, March 2, 2018, https://skillworks.files.wordpress.com/2018/03/avte-white-paper_final-2-8-18-1.pdf.

74. David J. Deming, Claudia Goldin and Lawrence F. Katz, The For-Profit Postsecondary School Sector: Nimble Critters or Agile Predators? Journal of Economic Perspectives, v.26, n.1, Winter 2012, 139, https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.26.1.139.

75. Deming, Goldin and Katz, The For-Profit Postsecondary School Sector, 139; Department of Education, National Center for Education Statistics, Table 304.50 Total fall enrollment in private for-profit degree-granting post-secondary institutions, 2014-2015, https://nces.ed.gov/programs/digest/d16/tables/dt16_304.50.asp.

76. Deming, Goldin and Katz, The For-Profit Postsecondary School Sector, 164.

77. Christina Cauterucci, More Single Moms are Going to College than Ever, But Few Will Graduate, Slate, 2017, https://slate.com/human-interest/2017/09/for-profit-schools-and-low-graduation-rates-plague-a-rising-population-of-single-student-mothers.html.

78. Thorpe and Goldstein, Our Higher Calling, 2.

79. U.S. Government Accountability Office, For-Profit Colleges: Undercover Testing Finds Colleges Encouraged Fraud and Engaged in Deceptive and Questionable Marketing Practices, GAO-10-948T, August 4, 2010, http://www.gao.gov /products/GAO-10-948T; Deming, Goldin and Katz, The For-Profit Postsecondary School Sector, 154.

80. Stastica, U.S. college enrollment statistics for public and private colleges, 2016, https://www.statista.com/statistics/183995/us-college-enrollment-and-projections-in-public-and-private-institutions/ (Compared to private colleges, public college enrollment was 74 percent in 2016 of total enrollment).

81. Bridget Terry Long, State Support for Higher Education: How Changing the Distribution of Funds Could Improve College Completion Rates, Miller Center, University of Virginia, December 2016, http://web1.millercenter.org/commissions/higher-ed/Long_No9.pdf.

82. Richard D. Kahlenberg, How Higher Education Funding Shortchanges Community Colleges, The Century Foundation, May 28, 2015, https://tcf.org/content/report/how-higher-education-funding-shortchanges-community-colleges/.

83. Education Commission of the States, 50-State Comparison: Transfer and Articulation Policies, June 2018, https://www.ecs.org/transfer-and-articulation-policies-db/.

84. Ellie Ashford, A smoother path for computer Science, American Association of Community Colleges, Community College Daily, Oct. 27, 2017, http://www.ccdaily.com/2017/10/smoother-transfer-path-computer-science/ (citing studies from the Community College Research Center at Columbia Teacher's College and the Association for Computing Machinery).

85. ATE Central, Supporting Advanced Technology Education, https://atecentral.net/index.php?P=Home

86. National Science Foundation, FY2018 Budget Request, Education and Human Resources Funding by Divi-

sion and Program, Summary Tables 17, May 23, 2017, https://www.nsf.gov/about/budget/fy2018/pdf/fy2018budget.pdf.

87. Statista, Community colleges in the United States – Statistics and Facts, https://www.statista.com/topics/3468/community-colleges-in-the-united-states/; Discussion with Celeste Carter, Director, National Science Foundation Advanced Technology Education Program, at American Association of Community Colleges Workforce Development Institute, Jacksonville, Fla., Jan. 22, 2020.

88. Manufacturing USA, Program Details, https://www.manufacturingusa.com/pages/program-details.

89. Manufacturing USA and the National Institute of Standards and Technology (NIST), 2017 Annual Report, NIST AMS 600-3, August 2018, 13, 20, https://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.600-3.pdf.

90. Bureau of Economic Analysis, Underlying Detail of Industry Economic Accounts Data: GDP by Industry, Value Added by Industry, Nov. 1, 2018, https://apps.bea.gov/iTable/iTable.cfm?reqid=56&step=2&isuri=1#reqid=56&step=2&isuri=1.

91. Manufacturing USA and NIST, 2017 Annual Report, 16.

SECTION 3: THE BROKEN LABOR MARKET INFORMATION SYSTEM

92. Frederick Hayek, The Use of Knowledge in Society, American Economic Review, v. 35, n. 4, 1945, 519-530, https://www.econlib.org/library/Essays/hykKnw.html. This section is drawn from, Sanjay E. Sarma and William B. Bonvillian, Fixing an Imperfect Labor Market Information System, Issues in Science and Technology, Fall 2018; we thank the editor for permission to use this material here.

93. Discussion with Andrew Reamer, October 6, 2017.

94. Credential Engine, Counting U.S. Secondary and Postsecondary Credential – April 2018 Report, April 5, 2018, 3, https://www.credentialengine.org/articles/ba957e1e-8aef-45ec-8bb4-237ae3902e75/Counting_U_S__Secondary_and_Postsecondary_Credentials___April_2018_Report.

95. LinkedIn Job Search https://www.linkedin.com/jobs/; LinkedIn recommendation engine - content and collaborative-based filtering https://www.linkedin.com/pulse/recommendation-engine-content-based-filtering-ashish-kumar/.

96. O*NET Online, Build your future, https://www.onetonline.org (accessed May 2019).

97. MIT Media Lab, Skillscape, http://skillscape.mit.edu/#/skills/17 (accessed August 2018).

98. Head AI, Microcompetencies, https://www.microcompetencies.com (accessed August 2018).

99. Meeting with Anu Passi-Rauste of Head AI Jan. 3, 2018; SITRA (Heli Nissinen), Artificial intelligence shows rhat Finland can do and "postiveCV" reveals hidden talent of young people , summary of what its "PositiveCV" is attempting to do for students, 2017, https://www.sitra.fi/en/news/artificial-intelligence-shows-finland-can-positive-cv-reveals-hidden-talents-young-people-winners-sitras-100-million-euro-ratkaisu-100-challenge-competition/. See also, SITRA, We should all have our own "PositiveCV", 2017, https://www.sitra.fi/en/articles/we-should-all-have-our-own-positive cv/ and https://www.youtube.com/watch?v=HrgfshEXszI.

100. Michelle R Weise, Andrew Hanson and Saleh Yustina, The New Geography of Skills: Regional Skill Shapes for the New Learning Ecosystem, Strada Institute for the Future of Work, Indianopolis, Ind., Dec. 2019.

101. Reamer, Information Resources to Facilitate Middle Skills, 10-15.

102. Department of Labor, Workforce Information Advisory Council, Recommendations to Improve the Nation's Workforce and Labor Market Information System, Jan. 25, 2018, https://www.doleta.gov/wioa/wiac/docs/Second_Draft_of_the_WIAC_Final_Report.pdf.

SECTION 4: THE UNIVERSITY ROLE IN WORKFORCE EDUCATION

103. Claudia Goldin and Lawrence Katz, The Race Between Education and Technology (Cambridge, Ma.: Harvard Univ. Press 2009). See also, Claudia Goldin and Lawrence Katz, "The Future of Inequality", Milken Institute Review, July 2009 (3rd Quarter), 26-33, http://assets1b.milkeninstitute.org/assets/Publication/MIReview/PDF/26-33mr43.pdf; David H. Autor, Skills, education, and the rise of earnings inequality among the 99 percent, Science, v. 344, n. 6186 (May 23, 2014), 843-851, http://www.sciencemag.org/content/344/6186/843.abstract.

104. Of course, a college degree is not necessarily tied to the more technical requirements of many workforce careers, and there is also a question about whether these degrees are up-to-date in teaching students about current and ongoing technological advances. Arguably, however, given the absence of data on other measurements, they represent a broad, useful proxy for general skill acquisition.

105. Anthony Carnevale, Tanya Garcia, and Atem Gulish (Georgetown Center on Education and the Workforce), Career Pathways: Five Ways to Connect College and Careers, Georgetown Center on Education and Workforce, July 11, 2017, https://cew.georgetown.edu/cew-reports/careerpathways/.

106. Georgetown Center for Education and the Workforce (Anthony Carnevale, Tamara Jayasundera, and Artem Gulish), America's Divided Recovery – College Haves and Have Nots (2016), https://1gyhoq479ufd3yna29x7ubjn-wpengine.netdna-ssl.com/wp-content/uploads/Americas-Divid-

ed-Recovery-web.pdf.

107. APLU, How does a college degree improve graduates' employment and earnings potential? APLU fact sheet (2017), http://www.aplu.org/projects-and-initiatives/college-costs-tuition-and-financial-aid/publicuvalues/employment-earnings.html.

108. Lumina Foundation, A Stronger Nation, Learning beyond high school builds American talent, Lumina Foundation (report), Feb. 12, 2018, https://www.luminafoundation.org/resources/a-stronger-nation-report.

109. This section is drawn from Bonvillian and Weiss, Technological Innovation in Legacy Sectors, 99-100.

110. Accenture, Burning Glass and Harvard Business School, Bridge the Gap: Rebuilding America's Middle Skills, 2014, 17-18, https://www.hbs.edu/competitiveness/Documents/bridge-the-gap.pdf.

111. Pew Research Center, Sharp Partisan Division in Views of National Institutions, republicans increasingly say colleges have negative impact on U.S., July 10, 2017, http://www.people-press.org/2017/07/10/sharp-partisan-divisions-in-views-of-national-institutions/. See also, Paul Fain, Deep Partisan Divide on Higher Education, Inside Higher Education, July 11, 2017, https://www.insidehighered.com/news/2017/07/11/dramatic-shift-most-republicans-now-say-colleges-have-negative-impact.

112. Association of American Colleges and Universities (AACU), Liberal Education and the Future of Work, Selected Finding from Online Surveys of Business Executives and Hiring Managers, July 2018 (conducted by Hart Research), 3-4, https://www.aacu.org/sites/default/files/files/LEAP/2018EmployerResearchReport.pdf.

113. Doug Shapiro, Afet Dundar, Faye Huie, Phoebe K. Wakhungu, Ayesha Bhimdiwala, and Sean E. Wilson, Completing College: A National View of Student Completion Rates – Fall 2012 Cohort (Signature Report No. 16). Herndon, VA: National Student Clearinghouse Research Center, December 2018, https://nscresearchcenter.org/signaturereport16/.

114. Shapiro, et al, Completing College, National Student Clearinghouse, 11-12.

115. Shapiro, et al, Completing College, National Student Clearinghouse, 6, 13-20

116. Association of Public and Land Grant Universities (APLU), Ready for Jobs, Careers, and a Lifetime: Public Research Universities and Credentials that Count (2017), http://www.aplu.org/library/ready-for-jobs-careers-and-a-lifetime/file.

117. APLU, Ready for Jobs, 9.

118. APLU, Ready for Jobs, 10.

119. Daniel J. McInerney, Becoming a Bilingual Advocate for Your Discipline and Your graduates, Liberal Education, v. 104, n. 3 (Summer 2018).

120. Anthony Carnevale, Ban Cheah and Martin Van Der Werf, ROI of Liberal Arts Colleges, Value Adds Up, Georgetown Center on Education and the Workforce, 2020, Figures 1 and 2. However Figure 7 in the report suggests that part of the reason may be that 4-year liberal arts colleges have lower numbers of lower income students.

121. Clemson University Center for Workforce Education, vision statement, http://cecas.clemson.edu. Discussion below is based on Meeting with Kapil Chalil Madathil, Faculty Director, and Eddie Bennett, Curriculum Marketing Manager, Clemson Center for Workforce Education, October 30, 2018.

122. Clemson University Center for Workforce Development, https://www.educateworkforce.com.

123. Meeting with Kapil Chalil Madathil, Faculty Director, Clemson Center for Workforce Education, October 30, 2018.

124. Georgetown Center on Education and the Workforce (Anthony Carnevale, Tanya Garcia, Atem Gulish), Career Pathways: Five Ways to Connect College and Careers, July 11, 2017, https://cew.georgetown.edu/cew-reports/career-pathways/.

125. Association of Public and Land Grant Universities (APLU), Ready for Jobs (2017).

126. The Economist, Special Report on Lifelong Learning, January 2017, https://www.economist.com/special-report/2017/01/12/lifelong-learning-is-becoming-an-economic-imperative.

127. Wendy Nelson, Community Colleges and Guaranteed Transfer Programs, August 23, 2018, https://www.mykidscollegechoice.com/2018/08/23/community-colleges-and-guaranteed-transfer-programs/.

128. Nathan D. Grawe, Demographics and the Demand for Higher Education (Johns Hopkins University Press 2018).

SECTION 5: THE NEW EDUCATION TECHNOLOGIES

129. Sanjay Sarma, The Boundless Mind (2019 manuscript, publication pending).

130. Hermann Ebbinghaus, Memory: A Contribution to Experimental Psychology (Henry A. Ruger and Clara E. Bussenius, translators)(New York: Teachers College, Columbia University 1913).

131. Karen Wilcox, Sanjay Sarma and Philip Lippel, Online Education: A Catalyst for Higher Education Reform, MIT Online Education Policy Initiative, April 2016, https://oepi.mit.edu/files/2016/09/MIT-Online-Education-Policy-Initiative-April-2016.pdf; Peter C. Brown, Henry L Roediger and Mark A. McDaniel, Make it Stick, The Science of Successful Learning (Cambridge, MA: Belknap Press

2014); Sarma, the Boundless Mind.

132. Plato, Theaetetus.

133. As a disclosure, author Sanjay Sarma, serves on the board of edX, and edX is 50% owned by MIT.

134. Justin Kruger and David Dunning Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments, Journal of personality and social psychology, v. 77, n. 6 (1999), 1121.

135. Elizabeth L. Bjork and Robert A. Bjork, Making things hard on yourself, but in a good way: Creating desirable difficulties to enhance learning, Psychology and the Real World: Essays Illustrating Fundamental Contributions to Society, 2011, 56–64.

136. Wilcox, Sarma and Lippel, Online Education.

137. Wilcox, Sarma and Lippel, Online Education.

138. Dominic A. Simon and Robert A. Bjork, Metacognition in motor learning, Journal of Experimental Psychology: Learning, Memory, and Cognition, v. 27, n. 4, 2001, 907.

139. Paul Kelley and Terry Whatson. Making long-term memories in minutes: a spaced learning pattern from memory research in education. Frontiers in human neuroscience v. 7 2013, 589.

140. Wilcox, Sarma and Lippel, Online Education.

141. Chien-Ho Janice Lin, Barbara J. Knowlton, Ming-Chang Chiang, Marco Iacoboni, Parima Udompholkul, and Allan D. Wu, Brain–behavior correlates of optimizing learning through interleaved practice, Neuroimage v. 56, n. 3, 2011, 1758-1772.

142. Matthew Jensen Hays, Nate Kornell, and Robert A. Bjork, The costs and benefits of providing feedback during learning, Psychonomic bulletin & review v. 17, n. 6, 2010, 797-801.

143. Gary Wolf, Want to Remember Everything You'll Ever Learn? Surrender to This Algorithm, Wired, April 21, 2008, ISSN 1059-1028 (accessed January 30, 2019).

144. Brendan, Tomoschuk and Jarrett Lovelett. A Memory-Sensitive Classification Model of Errors in Early Second Language Learning, Proceedings of the Thirteenth Workshop on Innovative Use of NLP for Building Educational Applications,2018, 231-239.

145. Dan Davis, René F. Kizilcec, Claudia Hauff, and Geert-Jan Houben, Scaling Effective Learning Strategies: Retrieval Practice and Long-Term Knowledge Retention in MOOCs, Journal of Learning Analytics v. 5, n. 3, 2018, 21-41; Dillon Dumensil, The Effects of Spaced Repetition in Online Education. MEng Thesis, Department of Electrical Engineering and Computer Science, MIT. 2016.

146. Bart Huisman, Wilfried Admiraal, Olga Pilli, Maarten van de Ven, and Nadira Saab, Peer assessment in MOOCs: The relationship between peer reviewers' ability and authors' essay performance, British Journal of Educational Technology, v. 49, n. 1, 2018, 101-110.

147. Steve Krolowich, Writing Instructor, Skeptical of Automated Grading, Pits Machine vs. Machine, The Chronicle of Higher Education, April 28, 2014.

148. Saul A. McLeod, Lev Vygotsky, Simply Psychology, August 5, 2018, https://www.simplypsychology.org/vygotsky.html.

149. Mitchell J. Nathan, Kenneth R. Koedinger, and Martha W. Alibali, Expert blind spot: When content knowledge eclipses pedagogical content knowledge, Proceedings of the third international conference on cognitive science, 2001, 644-648.

150. K. Anders Ericsson, Deliberate practice and acquisition of expert performance: a general overview, Academic emergency medicine v. 15, n. 11, 2008, 988-994; David J. Jones, Kirk W. Madison, and Carl E. Wieman. Transforming a fourth year modern optics course using a deliberate practice framework, Physical Review Special Topics-Physics Education Research v.11, n. 2, 2015, 020108.

151. Benjamin S Bloom, The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring, Educational researcher, v. 13, no. 6, 1984, 4-16.

152. John Sweller, Cognitive load theory, in J. P. Mestre & B. H. Ross, eds. The psychology of learning and motivation: Cognition in education Vo. 55 (San Diego, CA, US: Elsevier Academic Press 2011), 37-76.

153. Fred Paas and Tamara Van Gog, Optimising worked example instruction: Different ways to increase germane cognitive load, 2006, 87-91.

154. Steven Ritter, John R. Anderson, Kenneth R. Koedinger, and Albert Corbett, Cognitive Tutor: Applied research in mathematics education, Psychonomic bulletin & review v. 14, n. 2, 2007, 249-255.

155. Jane McGonigal, Reality is broken: Why games make us better and how they can change the world (New York: Penguin, 2011).

156. Nassim JafariNaimi and Eric M. Meyers, Collective intelligence or group think?: Engaging participation patterns in world without oil, Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing, ACM, 2015, 1872-1881.

157. Eric Klopfer and Kurt Squire, Environmental Detectives—the development of an augmented reality platform for environmental simulations, Educational technology research and development, v. 56, no. 2, 2008, 203-228.

158. D. Fox Harrell, Pablo Ortiz, Peter Downs, Maya Wagoner, Elizabeth Carré, and Annie Wang, Chimeria: Grayscale: an interactive narrative for provoking critical reflection on gender discrimination, MATLIT: Materialities of Literature, v. 6, n. 2, 2018, 217-221.

159. Thomas M. Connolly, Elizabeth A. Boyle, Ewan

MacArthur, Thomas Hainey, and James M. Boyle, A systematic literature review of empirical evidence on computer games and serious games, Computers & education, v. 59, n. 2, 2012, 661-686.

160. Zühal Okan, Edutainment: is learning at risk? British Journal of Educational Technology, v. 34, no. 3, 2003, 255-264.

161. Mitchel Resnick, Edutainment? No thanks. I prefer playful learning, Associazione Civita Report on Edutainment, 14, 2004, 1-4.

162. M. Resnick, J. Maloney, A. Monroy-Hernández, N. Rusk, E. Eastmond, K. Brennan, A. Millner, E. Rosenbaum, J.S. Silver, B. Silverman and Y.B. Kafai, Scratch: Programming for all, Commun. Acm, v. 52, n.11, 2009, 60-67.

163. Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke, From game design elements to gamefulness: defining gamification, Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments, ACM, 2011, 9-15.

164. Robert T. Hays, John W. Jacobs, Carolyn Prince, and Eduardo Salas, Flight simulator training effectiveness: A meta-analysis, Military psychology v. 4, n. 2, 1992, 63-74.

165. See generally, National Museum of the US Air Force, Link Trainer, fact sheet, May 4, 2015, https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196852/link-trainer/ (accessed June 2019).

166. Thomas Clarke and Elizabeth Clarke, Learning outcomes from business simulation exercises, Education+ Training (2009).

167. Stephen R. Carpenter and Lance H. Gunderson, Coping with Collapse: Ecological and Social Dynamics in Ecosystem Management: Like flight simulators that train would-be aviators, simple models can be used to evoke people's adaptive, forward-thinking behavior, aimed in this instance at sustainability of human–natural systems, BioScience, v. 51, n. 6, 2001, 451-457.

168. A.J. Angulo, William Barton Rogers and the Idea of MIT (Baltimore, MD: Johns Hopkins University Press 2009).

169. Carly Kontra, Susan Goldin-Meadow and Sian L. Beilock, Embodied learning across the life span, Topics in cognitive science, v. 4, n. 4, 2012, 731-739; Carly Kontra, Daniel J. Lyons, Susan M. Fischer, Sian L. Bellock, Physical experience enhances science learning, Psychological Science, v. 26, no. 6, April 24, 2015, 737-749.

170. Logan Fiorella and Richard E. Mayer, Eight ways to promote generative learning, Educational Psychology Review, v. 28, n. 4, 2016, 717-741.

171. Michael Prince, Does active learning work? A review of the research, Journal of engineering education, v. 93, n. 3, 2004, 223-231.

172. Charles R. Graham, Blended learning systems, in Curtis J. Bonk and Charles R. Graham, eds., The handbook of blended learning (New York: Wiley Pfeiffer Publishing 2005) 3-21.

173. M. David Merrill, First principles of instruction, Educational technology research and development, v. 50, n. 3, 2002, 43-59.

174. Carey Goldberg, Auditing Classes at M.I.T., on the Web and Free, New York Times, April 4, 2001.

175. Joshua Goodman, Julia Melkers and Amanda Pallais, Can online delivery increase access to education? Journal of Labor Economics v. 37, n. 1, 2019, 1-34.

176. David Figlio, Mark Rush and Lu Yin, Is It Live or Is It Internet? Experimental Estimates of the Effects of Online Instruction on Student Learning, Journal of Labor Economics, v. 31, n. 4, 2013, 763-784; William G. Bowen, Matthew M. Chingos, Kelly A. Lack and Thomas I. Nygren, Interactive Learning Online at Public Universities: Evidence from a Six- Campus Randomized Trial, Journal of Policy Analysis and Management, v. 33, n. 1, 2014. 94-111.

177. Eric Bettinger, Lindsay Fox, Susana Loeb, and Eric Taylor, Virtual Classrooms: How Online College Courses Affect Student Success, American Economic Review, v. 107, n. 9, 2017, 2855-2875.

178. Eric Bettinger and Susan Loeb, Promises and Pitfalls of Online Education, Brookings Economic Studies, Evidence Speaks Report, v. 2, n. 15, June 9, 2017.

179. Fiona Hollands and Devayani, MOOCs: Expectations and Reality, Center for Benefit-Cost Studies of Education, Columbia University Teachers College, May 2014.

180. Ashok K., Goel and Lalith Polepeddi, Jill Watson: A virtual teaching assistant for online education, Georgia Institute of Technology, College of Computing Technical Reports, 2016, http://hdl.handle.net/1853/59104.

181. Xiaowei Li, Bin Hu, Tingshao Zhu, Jingzhi Yan, and Fang Zheng, Towards affective learning with an EEG feedback approach, Proceedings of the first ACM international workshop on Multimedia technologies for distance learning, ACM, 2009, 33-38.

182. Ellen M., Kok, and Halszka Jarodzka, Before your very eyes: The value and limitations of eye tracking in medical education, Medical Education, v. 51, n. 1, 2017, 114-122.

183. David Gibson, Nathaniel Ostashewski, Kim Flintoff, Sheryl Grant, and Erin Knight, Digital badges in education, Education and Information Technologies, v. 20, n. 2, 2015, 403-410.

184. Suzanne Day, Nine universities team up to create infrastructure for digital academic credentials, MIT Office of Open Learning, April 23, 2019, http://news.mit.edu/2019/nine-universities-team-up-global-infrastructure-digital-academic-credentials-0423; Jeffrey R. Young, MIT Starts University Group to Build New Digital Credential System, EdSurge, April 23, 2019, https://www.edsurge.com/news/2019-04-23-mit-starts-university-group-to-build-new-digital-credential-system.

185. Chen Zhenghao, Brandon Alcorn, Gayle Christensen, Nicholar Eriksson, Daphne Koller and Ezekiel Emanuel, Who's Benefiting from MOOCs, and Why, Harvard Business Review, Sept.22, 2015, https://hbr.org/2015/09/whos-benefiting-from-moocs-and-why.

SECTION 6: THE APPRENTICESHIP MODEL

186. The following material is drawn from, William B. Bonvillian and Peter L. Singer, Advanced Manufacturing, The New American Innovation Policies (Cambridge, MA: MIT Press 2018), 221-222.

187. Richard B. Freeman, America Works, The Exceptional U.S. Labor Market (New York: Russell Sage Foundation 2007), 3.

188. Gary S. Becker, Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education (New York: National Bureau of Economic Research, 1975).

189. Pedro Nuno Teixeira, Gary Becker's early work on human capital, IZA Journal of Labor Economics, n. 3, v. 12, Nov. 2014, section 4.2.

190. Robert Atkinson, ITIF, Restoring Investment in America's Economy, report (Wash., DC: Information Technology and Innovation Foundation (ITIF) June 13, 2016), 8, http://www2.itif.org/2016-restoring-investment.pdf?_ga=1.113675271.1482316035.1476207219.

191. President's Council of Advisors on Science and Technology (PCAST), Advanced Manufacturing Partnership, Report to the President on Accelerating Advanced Manufacturing, (Washington DC: White House PCAST October 2014)(AMP 2.0), 34, https://www.manufacturingusa.com/sites/prod/files/amp20_report_final.pdf; Department of Labor, Employment and Training Administration, Apprenticeship, Data and Statistics, Registered Apprenticeship to 9/30/18, https://doleta.gov/oa/data_statistics.cfm.

192. Erica Smith and Ros Brennan Kemmis, Towards a model apprenticeship framework: a comparative analysis of national apprenticeship systems, International Labor Organization and The World Bank, 2013.

193. Robert Lehman, Are Employers Providing Enough Training? Theory, Evidence and Policy Implications, paper, National Academy of Sciences, Symposium on the Supply Chain for Middle-Skill Jobs, 2017, 17, https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_168146.pdf. See generally, Robert Lerman, Can the United States Expand Apprenticeship? Lessons from Experience IZA Policy Paper No. 46, 2012.

194. Robert Lehman, Are Employers Providing Enough Training? 18. See also, Robert Lerman, Do Firms Benefit from Apprenticeship? IZA World of Labor, 2014, http://wol.iza.org/articles/do-firms-benefit-from-apprenticeship-investments; Robert Lerman, Lauren Eyster, and Kate Chambers, The Benefits and Challenges of Registered Apprenticeship: The Sponsors' Perspective, The Urban Institute Center on Labor, Human Services, and Population, Washington, DC., 2009, http://www.urban.org/UploadedPDF/411907_registered_apprenticeship.pdf.

195. United Nations Statistics Division, Youth Unemployment Rate, Aged 15-24, Millennium Development Goals, https://unstats.un.org/unsd/mdg/SeriesDetail.aspx?srid=597.

196. Bureau of Labor Statistics, Employment and Unemployment Among Youth – Summer 2018, August 16, 2018, https://www.bls.gov/news.release/pdf/youth.pdf.

197. Trading Economics, Germany Youth Unemployment Rate, Sept. 2018, https://tradingeconomics.com/germany/youth-unemployment-rate.

198. Bob Schwartz and Amy Loyd, Pathways to Prosperity Project, Pathways 101: An Introduction to the Network and the Work, October 23, 2018, https://ptopnetwork.jff.org/sites/default/files/Pathways%20101-%20Introduction%20to%20the%20Pathways%20to%20Prosperity%20Network.pdf.

199. Jonathan Rothwell, Brookings Institution, The Hidden STEM Economy, Brookings Institution, June 10, 2013, https://www.brookings.edu/research/the-hidden-stem-economy/.

200. Schwartz and Loyd, Pathways to Prosperity Project, Pathways 101, 2017.

201. William Symonds, Robert Schwartz and Ronald Ferguson, , Pathways to Prosperity: Meeting the Challenge of preparing Young Americans for the 21st Century, Pathways to Prosperity Project, Harvard Graduate School of Education, Feb. 2011, 2, http://www.gse.harvard.edu/sites/default/files//documents/Pathways_to_Prosperity_Feb2011-1.pdf.

202. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 2.

203. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 7.

204. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 15.

205. Kathleen Thelen, Presentation to MIT's Work of the Future Initiative, Workforce Task Force, Jan. 14, 2019, 1. See also, Kathleen Thelen, How Institutions Evolve: The Political Economy of Skills in Germany, Britain, the United States and Japan (Cambridge, U.K.: Cambridge Univ. Press 2004).

206. Paul Lewis, Presentation to Manufacturing USA Workforce Education Directors, Workshop sponsored by the Association of Public and Land Grant Universities, Washington, DC, March 9, 2018. See also, Independent Panel (the Auger Report), Report to the Review of Post-18 Education and Funding, Presented to Parliament by the Secretary of State for Education, May 2019, chapters 2 and 5; Ian Collier and Paul Shakspeare, Manufacturing – The Future

Workforce, Catapult High Value Manufacturing and Gatsby Foundation, Jan. 2020, https://hvm.catapult.org.uk/mtfw/.

207. College Board, The College Completion Agenda, 2012 Progress Report, 6-7, http://media.collegeboard.com/digitalServices/pdf/advocacy/policycenter/college-completion-agenda-2012-progress-report.pdf.

208. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 24-26.

209. Andrea Messing-Mathie, Apprenticeship Systems for Middle-Skill Employment: Comparative Lessons in Innovation and Sector-Base Strategies for Apprenticeships, National Academies of Sciences, Committee on the Supply Chain for Middle-Skill Jobs: Educatin, Training and Certification Pathways, 2017, 10-11, https://sites.nationalacademies.org/cs/groups/pgasite/documents/webpage/pga_170050.pdf.

210. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 27.

211. Washington State Board for Community and Technical Colleges, Integrated Basic Education Skills and Training, https://www.sbctc.edu/colleges-staff/programs-services/i-best/.

212. Project Lead The Way (PLTW), Bringing Real World Learning to PreK-12 Classrooms, https://www.pltw.org/about-us/our-approach.

213. Symonds. Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 27.

214. Linked Learning Alliance, At Scale, For Equity, Annual Report for 2017/2018, http://www.linkedlearning.org/wp-content/uploads/2018/10/annual-report-2018-final-1026.pdf.

215. Linked Learning, About Linked Learning, http://www.linkedlearning.org/en/about/.

216. Pathways to Prosperity, About Us, https://ptopnetwork.jff.org/about-us.

217. Richard Kazis, Pathways Tennessee Balances Bold State Policy and Regional Flexibility, Pathways to Prosperity and Harvard Graduate School of Education, 2017, https://jfforg-prod-prime.s3.amazonaws.com/media/documents/Tennesee-Case-Study_v5a_012918.pdf.

218. Jenna Myers, Employer Engagement in College and Career Pathways in Middle Tennessee, paper, Workforce Education Project, MIT Office of Open Learning, July 29, 2019, 2.

219. Symonds, Schwartz and Ferguson, Pathways to Prosperity: Meeting the Challenge, 27.

220. Jen Mishory, The Future of Statewide College Promise Programs, The Century Foundation, March 6, 2018, 1, https://tcf.org/content/report/future-statewide-college-promise-programs/?session=1.

221. Kentucky FAME, KY FAME Comes into Its Own, Sets Sights on Expanding Missions, August 2017, http://kyfame.com/ky-fame-comes-into-its-own-sets-sights-on-expanding-missions/.

222. Brookings, Skills and Innovation Strategy, 23.

223. MAT2 Fact Sheet for Employers, Oct. 27, 2017, https://www.mitalent.org/Media/Default/Files/MAT2/MAT2_EmployerFactSheet.pdf. See also, Michigan Talent Connect, MAT2 Employer Information, https://www.mitalent.org/mat2-employer-information.

224. ApprenticeshipNC, North Carolina Youth Apprenticeship Guide, https://www.apprenticeshipnc.com/sites/default/files/file-uploads/nccc-printablehandbook-final-r1-print_quality.pdf.

225. North Carolina Traingle Apprenticeship Program (NCTAP), Presentation, http://nctap.org/#about (accessed July 2019).

226. Department of Labor, Office of Apprenticeships, High School Apprenticeship Toolkit, July 2018, Wisconsin Youth Apprenticeship Case Study, 1-4, https://www.dol.gov/apprenticeship/high-school/. See also, State of Wisconsin, Department of Workforce Development, Wisconsin Youth Apprenticeship website, https://dwd.wisconsin.gov/youthapprenticeship/.

227. Apprenticeship Carolina, By the Numbers, https://www.apprenticeshipcarolina.com/by-the-numbers.html

228. Division of Economic Development, ReadySC, Rankings and Stats (accessed 2019, https://www.readysc.org/rankings-and-stats.html.

229. Brookings, Skills and Innovation Strategy, 25.

230. Information on the Trident Tech youth apprenticeship program in this section is from, Meeting with Mitchell Harp, Dean of Apprenticeships, and Melissa Stowasser, Assistant Vice President for Community Partnerships, Trident Technical College, North Charleston, S.C., November 1, 2018 (W. Bonvillian meeting notes).

231. Department of Labor, Charleston Youth Apprenticeship Case Study, 2.

232. Julia Moeller, Marc A. Brackett, Zorana Ivcevic, and Arielle E. White, High school students' feelings: Discoveries from a large national survey and an experience sampling study, Learning and Instruction, v. 66, April 2020, 101301 Department of Labor, Charleston Youth Apprenticeship, 3

233. Department of Labor, Charleston Youth Apprenticeship, 3.

234. Information on in this section on VTL and the Trident Tech youth apprenticeship program is from, Meeting with Vincent Lobardy, Training and Employee Development Manager, VTL Precision, Inc., North Charleston, S.C., November 1, 2018 (W. Bonvillian meeting notes).

235. Department of Labor, Charleston Youth Apprenticeship, 4.

SECTION 7: THE NEW CONTENT

DELIVERY MODELS

236. Discussions with Frank Gulluni, Manufacturing Technology Center, Director Emeritus, Manufacturing Program and System Development, Asnuntuck Community College, Feb. 19, 2019 and May 30, 2019.

237. Discussion with James Lombella, President, Asnuntuck Community College, May 30, 2019.

238. Tia Marie Vice, Can Apprenticeships Alleviate a Regional Skills Gap? A Case Study of Programs at Trident Technical College in Charleston, SC, thesis, Department of Urban Studies and Planning, MIT, February 2019, 45.

239. TennesseeReconnect, The Tennessee Colleges of Applied Technology, https://www.tnreconnect.gov/ChooseaDegree/CollegePath/TNReconnectCollegesandUniversities/TheTennesseeCollegesofAppliedTechnology/tabid/5253/Default.aspx (accessed June 2019).

240. Tennessee Board of Regents (TBR), The College System of Tennessee, Community College Graduate Rates, https://www.tbr.edu/cc/community-college-graduation-rates-real-story (access June 2019); WREG (News Channel 3), Tennessee community college graduation rates on the rise, March 26, 2019 (AP Story), https://wreg.com/2019/03/26/tennessee-community-college-graduation-rates-on-the-rise/

241. While in many states affordability is the other cause, the TenneessePromise program offers free community college tuition, paying the "last dollar" of tuition after other federal and state scholarships. TennesseePromise, About, https://www.tn.gov/tnpromise/about.html (accessed June 2019).

242. John Hoops and Complete College America, A Working Model for Student Success: The Tennessee Technology Centers, Complete College America, Washington, DC,, 2010, 22, https://files.eric.ed.gov/fulltext/ED536826.pdf.

243. JOBS Act of 2019, S.839, introduced by Sen. Tim Kaine (D-Va.) and 10 bipartisan cosponsors, https://www.congress.gov/bill/116th-congress/senate-bill/839/text.

244. Mary Alice McCarthy and Livia Lam, Making the JOBS Act Work, The Hill, June 14, 2019, https://thehill.com/blogs/congress-blog/education/448622-making-the-jobs-act-work.

245. Livia Lam, Center for American Progress, discussion, June 24, 2019.

246. Debra West, Facing Corporate Exodus Over Unfilled Skill Job, Connecticut is Willing to Pay to Educate Them, T74, June 17, 2019, https://www.the74million.org/article/facing-corporate-exodus-and-thousands-of-unfilled-skilled-jobs-connecticut-pours-millions-into-tech-ed-career-readiness/.

247. Section drawn from, Discussions with Diman Faculty and Administrators (Michael Valario,Advanced Manufacturing Technology department head, Anne Marie Zenni, Business Technology department head, Mitchell Sweet, Drafting faculty, Kenneth Lazarro, director, cooperative education program, and Elvio Ferreira, Principal), Dimon Regional Vocational and Technical High School, April 2, 2019; Diman 2018 Annual Report, https://www.dimanregional.org/cms/lib/MA01929605/Centricity/Domain/139/Official%20Annual%20Report%202018.pdf.

248. Amanda Burke, Diman Voc-Tech boosts attendance, makes academic progress, Oct. 1, 2019, https://www.dimanregional.org/site/default.aspx?PageType=3&DomainID=135&ModuleInstanceID=1499&ViewID=6446EE88-D30C-497E-9316-3F8874B3E108&RenderLoc=0&FlexDataID=5977&PageID=277.

249. Emily Hanford, American Public Media, American Radio Works, The Troubled History of Vocational Education, Sept. 9, 2014, http://www.americanradioworks.org/segments/the-troubled-history-of-vocational-education/.

250. Jeannie Oakes, Keeping Track, How Schools Structure Inequality (New Haven, CT: Yale University Press 2005, 2nd ed.).

251. Hanford. The troubled History of Vocational Education.

252. Tom Birmingham, Voc-tech schools are a Massachusetts success story, Commonwealth, Feb. 6, 2017.

253. IBM, New Collar Jobs, Discover what you can do at IBM, https://www.ibm.com/us-en/employment/newcollar/apprenticeships.html (accessed June 2019).

254. Computer an Electronics Show (CES) Press Release, CTA and IBM Announce Apprenticeship Coalition to Help Close U.S. Skills Gap, Jan. 8, 2019, https://www.ces.tech/News/Press-Releases/CES-Press-Release.aspx?NodeID=20769cf6-315a-435f-a70e-ba05c7ce76c4; Cat Zakrzewski, Technology companies turn to apprenticeships in tight labor market, The Washington Post, Jan. 8, 2019.

255. P-TECH, What is P-TECH? http://www.ptech.org.

256. Deloitte and the Manufacturing Institute, Skills Gap in Manufacturing – 2018, 2018, https://operationalsolutions.nam.org/mi-skills-gap-study-18/. Given its workforce concerns, the Manufacturing Institute has developed a detailed series of toolkits for employers to meet workforce demands, train workers and develop apprenticeships, and for communities to close workforce development gaps using skills certification systems. It also has developed a list of high schools, community colleges, technical schools and universities that have programs for educators teaching manufacturing to industry standards and educator toolkits on building education programs to encompass industry certifications. Manufacturing Institute, Tools We Offer, http://www.themanufacturinginstitute.org/~/media/0EC097AA93EA4953BEEC2E01E8288B61.ashx (accessed June 2019).

257. Manufacturing Skill Standards Council (MSSC), https://www.msscusa.org/history/.

258. Chamber of Commerce Foundation, Talent Pipeline Management Initiative, https://www.uschamberfoundation.

org/talent-pipeline-management (accessed June 2019).

259. Chamber of Commerce Foundation, Talent Pipeline Management Initiative, https://www.uschamberfoundation.org/talent-pipeline-management (accessed June 2019).

260. Chamber of Commerce, Talent Pipeline Management, Overview and History, https://www.uschamberfoundation.org/sites/default/files/2019_TPM_History.pdf (accessed June 2019).

261. Wisconsin Regional Training Program, Industry Led and Worker Centered, https://wrtp.org.

262. Wisconsin Regional Training Program, Big Step Services and Center of Excellences, https://wrtp.org/about/.

263. MassTech Collaborative, MassTech Intern Partnership, http://www.masstech.org/intern/other-programs-and-resources (accessed July 2019)

264. Mass.gov, Department of Labor and Workforce Development, Division of Apprenticeship Standards, Apprenticeship Program for Expansion Industries (advanced manufacturing, healthcare and technology), https://www.mass.gov/guides/registering-an-apprenticeship-program-for-expansion-industries (accessed July 2019); MassTech Collaborative, About, http://www.masstech.org/masstech (accessed June 2019).

265. Mass.gov, Executive Office of Education, Massachusetts Skills Capital Grants, https://www.mass.gov/service-details/massachusetts-skills-capital-grant-program (accessed June 2019)

266. Mass.gov, Workforce Skills Cabinet, Workforce Skills Cabinet Kicks of Regional Planning Initiative, April 5, 2017, https://www.mass.gov/news/workforce-skills-cabinet-kicks-off-new-regional-planning-initiative (accessed June 2019).

267. MassTech Collaborative, Massachusetts Manufacturing Innovation Initiative, M2I2 http://m2i2.masstech.org (access June 2019).

268. Planning Meeting, MassTech Collaborative, Mass. state offices of Education, Labor and Workforce, Housing and Economic Development, Department of Defense Mantech program, and AIM Photonics Manufacturing Institute, at MIT, May 14, 2019.

269. Thomas Kochan, David Finegold and Paul Osterman, Who Can Fix the "Middle Skills" Gap? Harvard Business Review, Dec. 2012, 2103.

270. Meghan Perdue, Massachusetts Work Training Case Study (paper), MIT Workforce Education Project, June 2019, 2. This case study provides a detailed study of the current workforce education system in the state.

271. Reamer, Information Resources to Facilitate Middle Skills, 10-15. 2101

272. Department of Labor, Workforce Information Advisory Council, Recommendations to Improve the Nation's Workforce and Labor Market Information System, Jan. 25, 2018, https://www.doleta.gov/wioa/wiac/docs/Second_Draft_of_the_WIAC_Final_Report.pdf.

273. Jobkit, Data Partnership for the American Worker, https://jobkit.data.gov (accessed May 2019); Census Bureau, Post-Secondary Employment Outcomes (PSEO), https://lehd.ces.census.gov/data/pseo_beta.html (accessed May 2019).

274. National Science Foundation, National Center for Science and Engineering Statistics (NCSES), Data Sources to Measure and Understand the Science and Engineering Workforce and the Skilled Technical Workforce, May 3, 2019 https://www.dropbox.com/s/x7qdto29qm5cado/Possible%20Data%20Sources%20for%20the%20S%26E%20Workforce%20and%20STW%20%2805-03-19%29.pdf?dl=0 (accessed May 2019).

275. Department of Commerce, American Workforce Policy Advisory Board, https://www.commerce.gov/americanworker/american-workforce-policy-advisory-board (accessed May 2019).

276. Chamber of Commerce Foundation, T3 program, https://www.uschamberfoundation.org/t3-innovation/pilot-projects, (accessed June 2019).

277. Chamber of Commerce Foundation, JDX program, https://www.uschamberfoundation.org/press-release/job-data-exchange-jdx-pilot-launches-modernize-labor-market-data (accessed June 2019).

278. See generally, National Museum of the US Air Force, Link Trainer, fact sheet, May 4, 2015, https://www.nationalmuseum.af.mil/Visit/Museum-Exhibits/Fact-Sheets/Display/Article/196852/link-trainer/ (accessed June 2019).

279. Suzanne Day, Nine universities team up to create infrastructure for digital academic credentials, MIT Office of Open Learning, April 23, 2019, http://news.mit.edu/2019/nine-universities-team-up-global-infrastructure-digital-academic-credentials-0423.

SECTION 8: POLICY RECOMMENDATIONS

280. See generally, Kochan, Finegold and Osterman, Who Can Fix the Middle Skills Gap?

ABOUT THE RESEARCH GROUP

Sanjay E. Sarma is the Fred Fort Flowers (1941) and Daniel Fort Flowers (1941) professor of mechanical engineering and the Vice President for Open Learning at Massachusetts Institute of Technology. He is credited with developing many standards and technologies in the commercial RFID industry. Sarma is co-author of The Inversion Factor: How to Thrive in the IOT Economy (MIT Press, 2017), along with Linda Bernardi and the late Kenneth Traub. Sarma also serves on the board of the MOOC provider edX as a representative of MIT. In November 2012, Professor Sarma was appointed the first Director of Digital Learning at MIT with a mandate to assess how initiatives such as MITx and EdX are affecting instruction on campus. The MIT Office of Digital Learning, established in 2013, then included MITx and MIT's historic OpenCourseWare project. Sarma was later named Dean of Digital Learning, and in April 2013, he was appointed as a co-chair of the Task Force for the Future of Education at MIT. The Task Force published its final report in August 2014, delivering a series of recommendations for MIT's education on campus and beyond. Based on the report's recommendations, in February 2015, MIT President L. Rafael Reif announced a significant expansion of MIT's programs in learning research and online and digital education — from early childhood through higher education to lifelong learning. In this announcement, Sarma was appointed Vice President for Open Learning, where he now leads MIT Open Learning which oversees MIT's digital learning initiatives like MITx and MIT OpenCourseWare, as well as new programs launched under Sarma's leadership including the MicroMasters Program, the MIT Integrated Learning Initiative (MTili) and Abdul Latif Jameel World Education Lab (J-WEL), and this Workforce Education Project. He has degrees from IIT, Carnegie Mellon and Berkeley.

William B. Bonvillian is Senior Director, Special Projects, in MIT Open Learning at the Massachusetts Institute of Technology and Lecturer in the MIT Science Technology and Society Department. Prior to this position, from 2006-17, he was Director of the MIT's Washington, D.C. Office, reporting to MIT's President. In this position he worked to support MIT's longstanding relations with federal R&D agencies, and its role on national science policy. He has assisted with major MIT technology policy initiatives, on energy technology, the "convergence" of life, engineering and physical sciences, advanced manufacturing, and online higher education. Prior to that position, he served for seventeen years as a senior policy advisor in the U.S. Senate, where his legislative efforts included science and technology policy and innovation issues. He is on the National Academies of Science standing committee for its Innovation Policy Forum, chairs the American Association for the Advanced of Science (AAAS) standing Committee on Science, Engineering and Public Policy (COSEPP), and was elected a Fellow in 2011 by the AAAS. He is the coauthor of three books and coeditor of another and has authored numerous articles. His recent book, Advanced Manufacturing: The New American Innovation Policies, with Peter L. Singer, was published in 2018 by MIT Press. He has degrees from Columbia and Yale.

Jenna E. Myers is a PhD candidate in the Organization Studies program at the MIT Sloan School of Management. She uses qualitative research methods to study education and training, organizational and institutional change, and topics related to the future of work. She is currently completing a project examining the promotion of education as a workforce development strategy through state and local reforms that create career pathways in secondary and post-secondary institutions that are aligned with regional workforce needs. Prior to MIT Sloan, Jenna was a Teach for America Corps Member in Memphis, TN teaching high school chemistry and physics. She was also part of a team that started a new Master of Science program at Northwestern University's School of Communication.

Meghan Perdue is a Digital Learning Fellow in the Digital Learning Lab at MITx. In her role, she works with MIT faculty to create online

courses and digital learning tools for the School of Humanities, Arts, and Social Sciences, and researches and conducts experiments into the best practices in online pedagogy. She recently completed a Masters Degree in Political Science at Harvard University, where her thesis focused on developing a policy proposal for federal funding to support more cohesive relationships between universities, community colleges, and private industry to create a rich body of online work training resources. Prior to her work at MITx, she was a Project Manager in the Political Science department at MIT, where she managed a portfolio of research projects looking at government–citizen engagement and methods for increasing citizen self-efficacy in sub-Saharan Africa.