September 2014

Dear Mr. President,

In your 2014 State of the Union Address, you called for this year to be a year of action, stating that what unites the people of this Nation, regardless of gender, race, region or party, whether young or old, rich or poor, is the simple, profound belief in opportunity for all—the notion that if a person works hard and takes responsibility, he or she can get ahead.[1] The infusion of technology into the workplace is complicating the process of claiming a piece of the American dream by changing the kinds of skills needed to gain employment, and it is creating new needs for incumbent workers to enhance their skills. Slow and uneven responses to changing workplace demands among employers, educators, and workers can lead to a jobs-skills mismatch. Information technology can help bridge this mismatch by connecting people with jobs and providing targeted training. PCAST's observations on these issues complement the White House's July 2014 *Ready to Work* report.[2] PCAST goes beyond that report by urging a more holistic, integrated approach. This letter seeks to motivate more coordinated and effective government-industry-education partnership around this issue. It argues for using technology to connect different actions and actors to maximize synergies and minimize unproductive duplication of effort. PCAST forecasts that this interconnection will not be driven by market forces, and it recommends supportive steps by the Federal Government.[3]

Background

The middle-skill imperative. The challenges of engaging more Americans in good jobs play out in three broad segments of the workforce. At one end are jobs needing lower levels of skill, with minimal requirements for technical training. Here, the challenge of placing people into higher-skill jobs is complicated by lack of literacy.[4] At the other extreme is the high-skill segment, people with post-

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[1] Obama, B. "President Barack Obama's State of the Union Address," The White House, Office of the Press Secretary, January 28, 2014. http://www.whitehouse.gov/the-press-office/2014/01/28/president-barack-obamas-state-union-address

[2] Biden, J. *Ready to Work: Job-Driven Training and American Opportunity*, July 2014. http://www.whitehouse.gov/sites/default/files/docs/skills_report.pdf

[3] PCAST developed the ideas presented here through its own discussions beginning in late 2013 and through consultation with several experts at meetings, during conference calls, and, in particular, at a workshop on December 18, 2013. Key contributors are listed in a supplementary document on the PCAST Web site and include Guyatri Agnew (Wadhwani Foundation), Maura Banta and Stanley Litow (IBM), Kristina Bartsch and James Franklin (Bureau of Labor Statistics), Dick Clark (University of Southern California), Emily DeRocco (Engage Educate Employ), Carol Diamond and Gail Fierstein (Markle Foundation), Frank DiGiovanni (Department of Defense), Susan Gallagher (National STEM Consortium), Meg Garlinghouse (LinkedIn), Harry Holzer (Georgetown University), Alan Inouye and Larra Clark (American Library Association), Parminder Jassal (ACT Foundation), Nirmala Kannankutty (National Science Foundation), Roger Magoulas, O'Reilly Media, Merrilea Mayo (Innovate+Educate), Matthew Muench and Whitney Smith (Joyce Foundation), Paul Osterman (MIT), Josephine Reed-Taylor (Technical College System of Georgia), Robert Simpson (Kettering University), Sydney Smith-Heimbrock (Office of Personnel Management), and Philip Zelikow (Markle Initiative for America's Economic Future in a Networked World). PCAST is both grateful for these inputs and responsible for the conclusions presented here.

[4] OECD. *Time for the U.S. to Reskill? What the Survey of Adult Skills Says*, OECD Skills Studies, OECD Publishing, 2013. http://dx.doi.org/10.1787/9789264204904-en http://skills.oecd.org/Survey_of_Adult_Skills_US.pdf

secondary degrees employed in professional, managerial, or scientific and technical positions, some of which PCAST addressed in its work on STEM education.[5] The remainder is what we call the middle-skill[6] segment, the largest proportion of the workforce. For the purposes of this letter, middle-skill jobs are defined historically as those requiring the equivalent of a two-year degree, occupational license, or certification,[7] typically with wages in the range of $40,000 and up.[8]

The middle-skill segment came into focus late in the 20th century with growth in jobs relating to information technology (IT)—both its production and, more broadly, its use across the economy. Although health care, skilled trades, and other domains also feature middle-skill jobs, IT jobs provide a microcosm of the opportunities and challenges. Calling for both conventional literacy and comfort with technology, IT jobs have become prominent in both large and smaller businesses and they are central to many start-up businesses, which drive job growth. The need for IT workers spans all sectors of the economy, and non-IT industries currently employ two-thirds of private sector IT workers.[9] IT workers and jobs exist in a broad range of industry sectors, with manufacturing being the second largest. IT jobs involve skills that can be relatively straightforward to assess, and they are candidates for training delivered in far smaller units than a four-year degree,[10] as well as for training that is delivered online. An exemplar of how IT can be used to deliver quality training for IT professionals is a DARPA-sponsored effort (Box 1) illustrating that validated, compelling results are possible—and require investment.

Box 1: DARPA Education Dominance Digital Tutor

The Education Dominance program, undertaken by the Defense Advanced Research Projects Agency (DARPA), developed a Digital Tutor tool that simulates the educational effects of one-on-one, expert-to-pupil tutoring delivered in a conversational style and emphasizing active and authentic problem-solving via a scalable platform. The Digital Tutor was developed by interviewing, closely observing, and digitizing the specific tutoring techniques and practices of individuals who were experts in both subject matter and education. In a pilot study, the Navy placed a group of novice IT pupils in a rigorous 16-week Digital Tutor program. The students were then entered into a competition that tested their subject mastery and problem-solving skills against other students from longer conventional educational

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[5] PCAST has addressed science, technology, engineering, and mathematics (STEM) education in two reports, *Engage to Excel* (http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf) and *Prepare and Inspire* (http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf).

[6] "Middle-skill" refers to those jobs that require more education than high school but less than a four-year degree. The postsecondary education or training requirements can include associate's degrees, vocational certificates, significant on-the-job training, previous work experience, or some time enrolled at a four-year college.

[7] In this letter, certification refers to industry recognized credentials and should not be confused with a "certificate." Certification implies an ongoing training process whereas a certificate could be given for a weekend workshop, for example. Stackable credentials refer to certifications that could be applied towards a degree.

[8] Although routine tasks within middle-skill jobs have been subject to automation, other aspects (problem-solving, adaptability, interpersonal interaction, common sense) reinforce the durability of these kinds of work. See: Autor, David H. "Polanyi's Paradox and the Shape of Employment Growth." Draft prepared for the Federal Reserve Bank of Kansas City's economic policy symposium on "Re--Evaluating Labor Market Dynamics," August 21-23, 2014, Jackson Hole, Wyoming.

[9] CEB TalentNeuron, 2013. Unpublished research and analysis on crawling of public profiles and skill-predictor algorithms discussed with White House staff.

[10] Mims, Christopher. "Programming Is a Trade; Let's Act Like It." *The Wall Street Journal*, 2014, p. B1, B6. http://online.wsj.com/articles/computer-programming-is-a-trade-lets-act-like-it-1407109947

programs as well as seven-to-nine-year veterans in the field. In all assessments, the Digital Tutor students outperformed their competition by wide margins. The pilot study demonstrated that, while the development of a job-specific Digital Tutor is expensive (in part because of the time required to study what experts do), the potential returns are substantial. There are many possible applications of an artificial-intelligence platform able to impart high-level conceptual understanding and skills to novice students. The scalability of such a platform would allow large numbers of students to take advantage of personal—and personalized—tutoring concurrently. While this Digital Tutor is specific to Navy IT needs, the technology could be used for other middle- or high-skill jobs.

The difficulty that employers sometimes have filling middle-skill jobs is not only driven by differences between the skills possessed by job seekers and those required by employers, but also the ability of job seekers to signal their skill sets in a way that employers trust when they do not have a degree. A traditional degree is a known quantity, and its payoff continues to be demonstrated.[11] But most middle-skill workers do not attain four-year degrees, and the skills required for middle-skill jobs, in particular, may not require all aspects of a four-year degree program.[12] Even with a broad societal goal of growing college-degree attainment,[13] there are near-term needs for broadly available training that is faster and more focused as well as recognition of alternative credentials among both employers and those seeking employment.[14] The source of training may vary: Depending on the nature of an organization, employers may seek workers who already have significant skills, or they may offer formal training or on-the-job training. The varied nature of skill-development sources makes it all the more important that employers provide clarity about what credentials or assessments they will use for hiring decisions. This letter focuses on situations where people acquire skills outside of their place of employment.

Seeing the situation as a system. Adaptation to labor-market change can be conceptualized as an information system that operates on a triangle of relationships to match jobs and talents (Figure 1).

At one vertex of the triangle are the people who either have, or need to obtain, the training and skills associated with available job opportunities. At the second vertex is the aggregate of employers who seek workers with specific skills and attributes. At the third vertex is the set of educational and training organizations that can provide prospective employees with the skills that make them attractive to potential employers. Effective interplay within this worker-trainer-employer (WTE) triangle will be key to overall national competitiveness in the middle-skill segment of the working population and hence expansion of economic opportunity for many Americans. Taken together, the different kinds of actors in this system compose an ecosystem.

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[11] Carnevale, A., et al. "Recovery: Job Growth and Education Requirements through 2020," Georgetown Public Policy Institute, Center on Education and Workforce, June, 2013. https://cew.georgetown.edu/recovery2020

[12] Holzer, H., et al. "The Promise of High-Quality Career and Technical Education: Improving Outcomes for Students, Firms, and the Economy," The College Board and the Georgetown Law Center on Poverty, Inequality, and Public Policy, October, 2013. http://www.careertechnj.org/wp-content/uploads/2013/11/Georgetown.BR_.CB-CTE-report-11.2013.pdf

[13] See: http://www.whitehouse.gov/reach-higher/

[14] A variety of public and private efforts are aimed at enhancing non-degree credentials; much work remains to be done.

Figure 1. Worker, Trainer, and Employer Triangle: Enabling Response to Workforce Trends and Matching Talent to Jobs
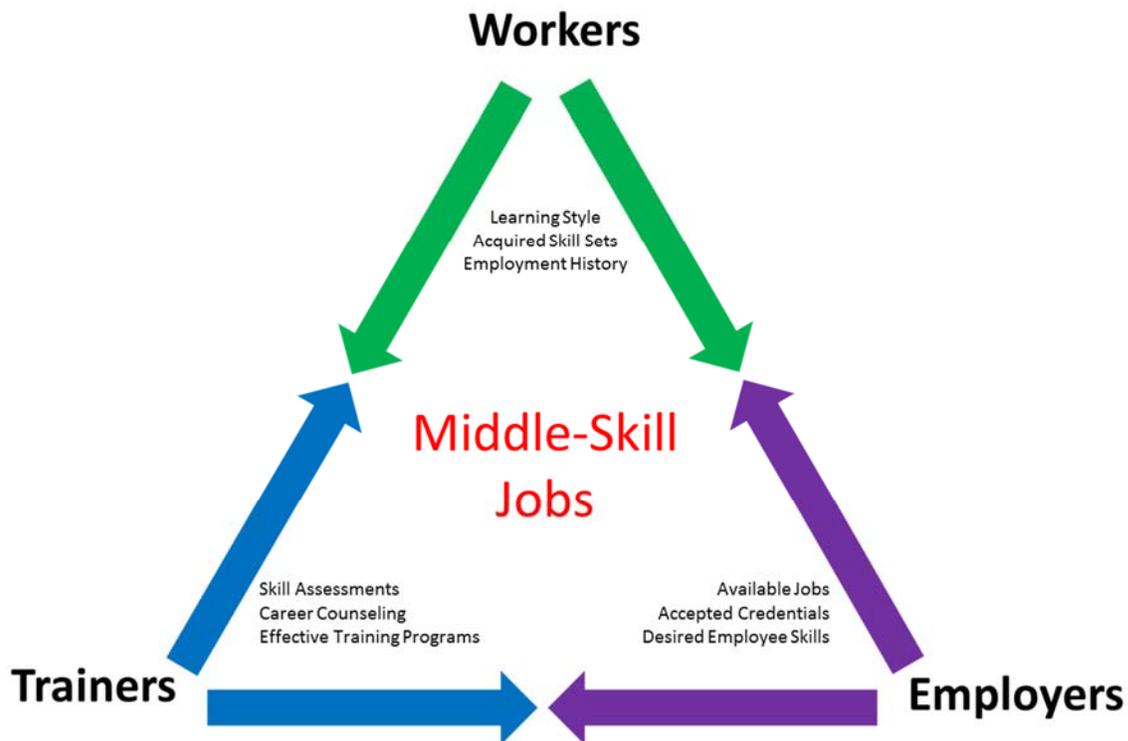

It is time to reimagine the message about achieving the American dream by expanding guidance to people aspiring to middle-skill careers to include options beyond secondary school for acquiring targeted skills. Such guidance should convey the value of obtaining quality skills-based credentials that can increase and/or maintain employment readiness by demonstrating mastery of specific knowledge, skills, and abilities. The future expectations of individuals who have obtained credentials, including college graduates, should include to a greater extent than before a periodic need for training—lifelong learning is becoming the norm, with people punctuating their careers with training to enhance their skills (Figure 2).

Figure 2. Boosting the Nation's Middle-Skills: Redefining the Path to the American Dream. Skilling and re-skilling for the middle-skill arena will differ dramatically from the traditional model (A) in which a learner was expected to negotiate three stages: K-high school (with the possibility of career and technical education), college or postsecondary education/training, and work. The new landscape (B) is far more complicated and includes innovative education and training models that challenge old assumptions about education and training at all levels, as well as paths to careers. A new, bimodal paradigm of the "student-employee" presumes that individuals will oscillate between the student or employee phases during a working life-time to adapt to changing skills needs in an increasingly technology-infused workplace. (*See next page.*)

(A) Former middle-skill training model
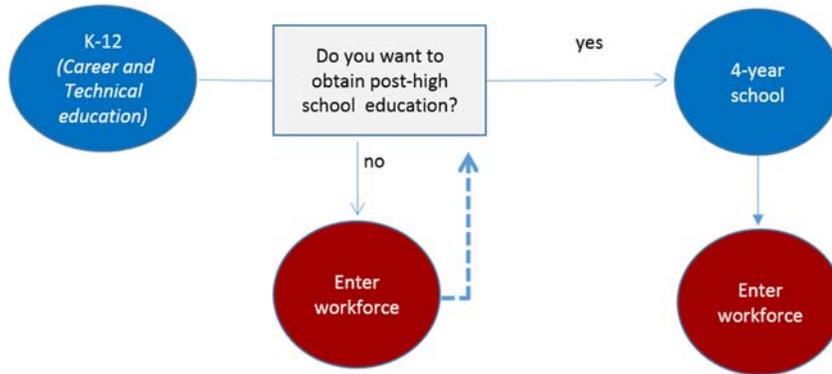
(B) Evolving landscape of middle-skill training options—more complex than the traditional model and now includes the bimodal paradigm of the ''student-employee''
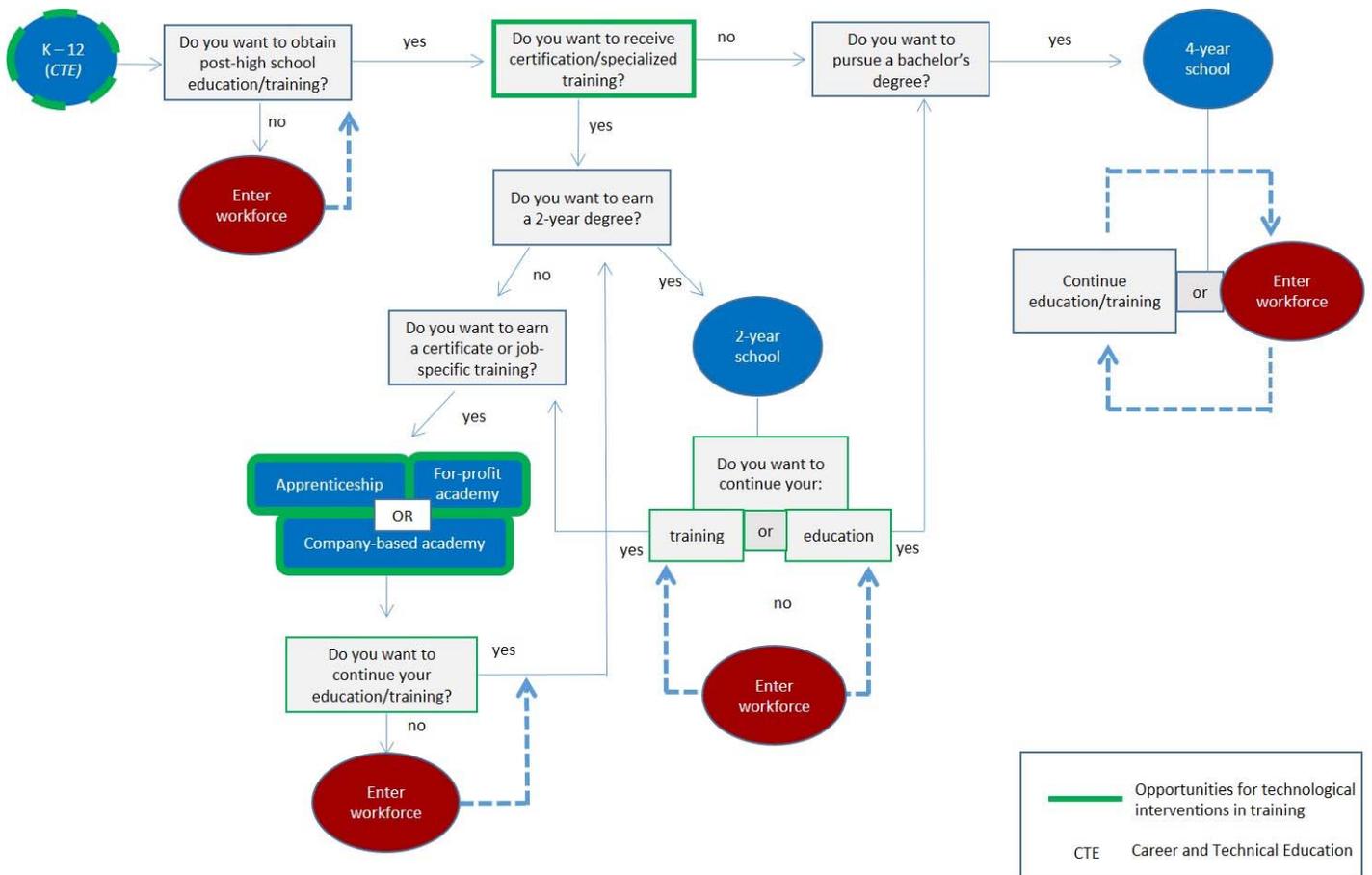
This diagram does not take into consideration the impact of cost or quality.

That reality implies a need for training that works for people at different ages and stages of their careers and lives. IT can help in tuning training to meet the personalized needs of students.

Key challenges in today's jobs ecosystem include: (1) providing better information to workers on available jobs and effective (measured by learning and employment outcomes) training programs,[15] (2) fostering better connections between training institutions and industry to ensure that curriculum, infrastructure, and staff development are up to date and provide job-relevant skills, and (3) helping employers identify talent to fill jobs, including people who may be qualified but present themselves in ways that lead them to be rejected by conventional screening systems.[16] IT can assist the interactions within this triangle in a variety of ways: analyzing and characterizing skill requirements, assessing existing skill levels (and other employment-relevant attributes) of current or potential workers, and providing support for training and learning. These functions can be supported by distinct sets of tools (Box 2) that support assessment of skills and interests, as well as deliver training. The more that the pertinent information can be exchanged across this ecosystem, the better the process of matching people with trainers and/or jobs will become, regardless of where they start out.

Box 2: Web-Based Tools for Workers, Trainers, and Employers

Tools for current and future workers. Workers at different career stages will need distinct sets of tools. For the early-career individual, online career-counseling services may be helpful in identifying optimal career choices (given a student's interests and aptitudes) and requisite education/training, increasing awareness of academic and financial requirements for pursuing higher education, and connecting students to other helpful resources to enable more-informed decisions. Career-counseling tools could help students make better choices among academic majors or certificate programs based on job trends and post-training outcomes associated with specific training programs. For the incumbent worker or unemployed individual, these tools could systematize the job-search process to make it less daunting and also present career options that are related to current skill sets or "one certification away." There is also a need for Web-based skills assessments that link directly to programs (online, blended, or traditional) that confer skills identified as lacking in assessments. A critical input to decisions of workers is information on the outcomes of education and training on skill development, employment and earnings. Without this information, workers are left with a gamble about the career-payoff of their educational choices.

Tools for employers. How well employers understand and express what they need from workers varies. Traditionally, employers have relied on the attainment of educational degrees or credentials as a proxy for skills. Demand is growing for specialized and higher-level cognitive skills that can be hard to measure. This trend suggests that competency-based assessments that can gauge specialization and the readiness of potential employees to be productive within a business may become more common in the hiring process. Technology can help in skills-assessment. A key input consists of the data that support analyses of how to decompose jobs into component skills (and occupations into component jobs). Assessment tools are proliferating, and online offerings are often packaged with human interpretation and counseling.

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[15] This is a goal of the job-driven checklist put forth by the Vice President in *Ready to Work*.
[16] Additional challenges relate to the cost of training and who pays for it, both longstanding and not a focus of this letter.

Tools for education and training organizations. Training institutions face many challenges, including differing baseline skill-levels of students, varied connections to local industry and awareness of skills needs, and limited capacity and infrastructure to maintain relevant curriculum and staff capabilities. Institutions need job-forecasting tools with accurate data on region-specific, short-term job demands and skill needs, assessment tools, and remediation tools that can help bring students up to speed. Finally, institutions also need better mechanisms for connecting trainees to local and national job opportunities. Such institutions as Western Governors University and College for America at Southern New Hampshire University demonstrate some of what is possible in trainer-employer collaboration in defining desired competencies and the use of technology to help develop those competencies.

Information to make markets work

The triangular WTE system works best with broad access to high-quality information about jobs and skills. The reality is that information is uneven in quality and accessibility. In terms of job demand, currently the best and most readily available information about current and projected employment is from the government. The Bureau of Labor Statistics (BLS)[17] data address occupations and are broader and more general than descriptions of actual jobs, which is consistent with the BLS goal of supporting general career planning. A variety of data from Federal Government agencies are being shared through the Open Data Initiative and repurposed by innovators[18] in ways that help to address specific aspects of the triangular WTE system. Data at state and local levels, where most job-matching occurs, may also be more accessible in the future.[19] But even these advances do not capture the near-real-time evolution of job opportunities or of the skills that are required for a specific person to do a specific job.

The most precise information about jobs and skills comes from employers, who specify jobs, make hiring decisions, and train their workers (to at least some degree). The high degree of variability of job descriptions and the fact that many job descriptions do not fully reflect skill requirements have complicated the task among educators and policy-makers/analysts of understanding labor-market trends. A more standardized approach to describing skill needs in a common format and schema across job postings would make this task much easier. Some Web-based businesses (e.g., Monster.com[20]) have used IT to aggregate, analyze, and share such data (and ancillary information) with their customers; some focus on matching workers to employers.[21] These services are, while growing in scale and sophistication, partial views of the labor market developed by competitors who do not have an incentive to share proprietary data or techniques. Several companies have proprietary databases of skills required across employers for occupational categories. Two approaches to collecting this information are first, through automated

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[17] See: http://www.bls.gov/emp/ to explore that underlying program and http://www.onetonline.org/ to see how, through the Occupational Information Network (O*NET), the occupational information is packaged (outside of BLS) and delivered.
[18] The Office of the Chief Technology Officer has helped to engage innovators through 'Data Jams" and "Datapaloozas," including the June 2014 21st Century Jobs Data Jam led by the Vice President. See:
http://www.whitehouse.gov/blog/2014/07/11/vice-president-biden-use-open-data-and-innovation-help-americans-find-jobs
[19] State and local job banks analyze employment data; states develop demand-driven occupational projections at the State and sub-State levels and analyze different kinds of information from employers and other sources. Opportunities may exist to use Department of Labor levers to help State job banks impose better screens on job postings (e.g., require that employers only post real jobs, use certain syntaxes, etc.).
[20] See: http://www.monster.com/
[21] For an example of task-matching that does not emphasize middle- or high-level skills, see: https://www.taskrabbit.com/.

collection of information from employers about skill needs from job postings and deriving common skills that employers may describe with different language. This is the approach that companies like Burning Glass[22] have taken to be able to paint a picture of the most common skills required for a range of jobs. The other is to assess the skills possessed by workers who are currently in jobs. This is the approach that LinkedIn[23] has taken with its Skills Dictionary, which aggregates self-reported information from users about their skills. Although such businesses as LinkedIn began by focusing on high-skilled workers and jobs, anecdotal evidence indicates that their coverage of middle-skill opportunities is growing, especially for IT workers and jobs.

In addition to information about job and skill demand, other critical elements of the WTE information ecosystem are the supply of skilled workers and information on which education and training providers are equipping workers with skills that are aligned to employer needs. Knowing the outcomes of education and training programs—how many people become and stay employed and what they earn—is important both to help job seekers decide what training to pursue and to help programs continuously adjust to improve outcomes. Training programs should measure outcomes, evaluate their programs, and convey this information to participants and employers. Many states are making progress in this area with longitudinal data systems that link education and workforce data, allowing them to report the employment and earnings outcomes of training providers. The Federal Government should continue to provide incentives for data collection and reporting on outcomes. For example, the fourth round of $450 million Job-Driven Community College Grants (TAACCCT)[24] directed that funds be used to encourage community colleges to track data on graduates' employment and earnings and create employment results scorecards to help students choose an educational track that fits their job aspirations. As another example, the summer 2014 enactment of the Workforce Innovation and Opportunity Act[25] created deadlines for the Departments of Labor and Education as well as other partners to design and implement performance measures and scorecards for information about employment and earnings performance outcomes for Federally funded training providers. Opening up the resulting training-program data would help workers, job seekers, employers, elected officials, and policymakers make better decisions about where to spend their time and money.

Education and training for the middle-skill labor market

Preparation for middle-skill jobs can take place through many channels; an important one is career and technical education (CTE), which can be found at high-school and post-secondary levels.[26] CTE provides pathways from school to employment, for example via associated diplomas (dual-enrollment high schools and two-year institutions or dedicated vocational schools and technical colleges), regional training centers,

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[22] See: http://burning-glass.com/

[23] See: https://www.linkedin.com/

[24] The TAACCCT Grant Program, managed by the Department of Labor in partnership with the Department of Education, is a $2B initiative focused on simultaneously helping adults acquire the skills and credentials required for high-skill jobs while also meeting the high-skill staffing needs of employers. TAACCCT funds programs at community colleges and other qualifying institutions that have two-year or shorter technical training programs that specifically target low-skill, low-resource adults. See: http://www.doleta.gov/taaccct/

[25] PL 113-128; see: http://www.doleta.gov/wioa/

[26] CTE varies broadly at all levels, from single-course offerings to so-called career pathways that combine education, training, and support aimed at appropriate certification and employment in a given industry. See: Dortch, Cassandra. *Career and Technical Education (CTE): A Primer,* R42748, Congressional Research Service, February 10, 2014.

employee-based traineeships, postsecondary certificates, and registered apprenticeships.[27] CTE programs are either terminal or an intermediate step toward more advanced credentials. Given the dynamism of technology, industries, and jobs, the challenge for CTE providers involves maintaining relevant curriculum, infrastructure, and staff capabilities. The job-driven checklist presented in the White House's *Ready to Work* report is intended to help alleviate this challenge. Nevertheless, the best-case scenario, where accurate information is available and updated regularly, does not guarantee that institutions will have sufficient motivation or capabilities to respond, in part because adaptation is costly (especially where specialized equipment and facilities are involved as well as possible needs to retrain faculty). The challenge of change is particularly acute at community colleges, which can be hampered by having to support a dual mission of (four-year) college preparation and CTE but which are at their best when well connected to local employers. TAACCCT has been a major Federal investment in community-college CTE, but it is awarding its final grants in Fall 2014. It will be important to evaluate its results and apply those lessons to future investments.[28]

Our discussions with CTE experts, economists, and others corroborate our instinct that technology can help to make community-college-based and other CTE more effective. Of particular value may be online tools to help students make better choices about CTE. Any given institution may be limited by its resources and its connections to programs that are aimed at a specific range of jobs and employers. Students will be most effective when they choose programs and career paths that are most closely tied with their interests and aptitudes. Institutions often underinvest, due often to a lack of resources, in basic assessment, advising, and counseling capabilities; technology can amplify and customize such services. Already, several online assessments attempt to provide measures of general cognitive capacity of students as well as evaluate affective development.[29] Research and development support through the National Science Foundation and Department of Education (ED) could help to enhance what is available.

Technology can also help in the delivery of CTE in much the same way it is helping in the delivery of education generally; the MOOC phenomenon represents the most recent wave of educational innovation, and it continues to evolve.[30] Illustrating how MOOCs are moving beyond conventional courses and programs, the recent launch of the so-called Nano Degree by MOOC-provider Udacity in partnership with AT&T suggests the potential to leverage MOOC platforms in unconventional ways that may benefit those seeking jobs-training.[31] This program offers online certification in six to twelve months and is designed to provide the required basic programming skills for an entry-level position at AT&T as a data analyst.[32] As with apprenticeships, this program provides a direct connection between training and a job. MOOC providers are experimenting with ways to connect education, students, and employers, building on their early success in attracting students who wanted to strengthen employment-relevant skills.[33] Coursera and

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[27] See Cassandra Dortch (*ibid.*).

[28] Evaluation and leveraging of lessons learned from the Advanced Technological Education (ATE)[28] at the National Science Foundation (NSF) and other organizations are also essential.

[29] For examples of basic skills and affective development assessments see the National Center for Postsecondary Improvement's Inventory of Higher Education Assessment Instruments:
http://www.stanford.edu/group/ncpi/unspecified/assessment_states/instruments.html

[30] See: http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_edit_dec-2013.pdf

[31] See: https://www.udacity.com/nanodegrees

[32] See: http://about.att.com/story/att_and_udacity_launch_online_training_program_nanodegree.html

[33] Reports indicate that many of the students who were most likely to complete the initial MOOCs were highly self-motivated individuals that either already had postsecondary degrees or were currently employed. These individuals are most likely to

Udacity are offering career-counseling services in addition to their course offerings, while edX ventured into the jobs-matching space but discontinued its pilot job-placement program.[34] These new offerings can be expected to evolve with experience—and insights derived from the big-data analytics intrinsic to the platforms.

Early MOOC experience, along with the promotion of "digital badges,"[35] points to the need for validating the quality of nontraditional credentials. The proliferation of new kinds of training from new kinds of providers issuing new kinds of credentials suggests that third-party evaluation may become increasingly important—and it, too, can be enabled by technology.[36] One way that the Federal Government can promote validation of skills assessments and associated credentials is through increasing focus on competency-based assessments at two- and four-year institutions, or elsewhere, which could be supported by ED.[37] One important avenue that the Federal Government has to encourage competency-based assessments and education is through mechanisms that enable competency-based programs to qualify for Federal financial aid and Pell Grants, which represent over $20 billion in financing for post-secondary education annually. ED could continue to build on recent activities in this area, such as its work to use the Direct Assessment provision in the Higher Education Act, to allow for accreditation of competency-based programs like those at Western Governors University, and the Competency-Based Education Pell Grant Experimental Sites Initiative announced in July 2014, which provides flexibility in how institutions provide Federal student aid to students enrolled in self-paced competency-based education programs.[38]

Making connections

The triangular WTE system described above depicts a challenge that should be addressed holistically. As described in the White House's *Ready to Work* report and elsewhere, there are many promising pilots and programs scattered across the nation. However valuable those are, alleviating the jobs-skills mismatch requires a more integrated approach, one that is cognizant of the variety of stakeholders and that approaches different actors and activities as parts of an interconnected ecosystem. IT can help not only in effecting discrete projects and programs, it can also help with interconnection.

How can the Nation achieve broader use and exchange of information about jobs, skill requirements, training, and available talent? The open-data activities represent one Federal lever, although those data may support new private services and offerings that, as businesses, are closed. One challenge for matching talent to jobs is the variability and inconsistencies in how requirements for skills and other capabilities are specified.[39] Efforts to tackle those problems are beginning to emerge and should be encouraged. For

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utilize MOOCs for an accelerated pathway to jobs. See: Christensen, Gayle, et al. "The MOOC Phenomenon: Who Takes Massive Open Online Courses and Why?" November 6, 2013, working paper available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2350964.

[34] Kolowich, Steve. "edX Drops Plans to Connect MOOC Students With Employers," *Chronicle of Higher Education*, December 16. http://chronicle.com/blogs/wiredcampus/edx-drops-plans-to-connect-mooc-students-with-employers/

[35] See, for example, the work of the Badge Alliance, supported by private philanthropy. See: http://badgealliance.org/

[36] Codility provides an example for evaluation of software-coding ability. See: https://codility.com/

[37] The National network of Business and Industry Associations, supported by the ACT Foundation and the Business Roundtable and bringing together employers from across the economy, is promoting human-resources practices based on competencies. See: http://actfdn.org/what-we-do/optimize-solutions/national-network-business-industry-associations/

[38] See: https://experimentalsites.ed.gov/exp/approved.html

[39] Another is the unevenness of measuring a job-seeker's capabilities, which may be addressed by tools such as those described in Box 1.

example, the American National Standards Institute seeks to establish common terminology to describe the features of credentials, supporting comparability while adding criteria useful for quality assurance. It will draw on the work of the Learning Registry, a joint effort of the Departments of Education and Defense to develop and share educational content. [40],[41] The Administration could explore opportunities for collaboration with companies like LinkedIn, Burning Glass, Monster, and others to develop a metadata language and schema based on how employers and job-seekers are actually describing jobs and skills. One critical component of such an effort would be ensuring the adoption of resulting schemas by employers and education and training providers alike. A successful example is emerging in cybersecurity. [42]

Although our recent examination of big-data analytics[43] points to the growth in insight achievable in a given system from unstructured information, if the goal is to facilitate sharing and benefiting from information across disparate entities nationwide, there are ways to structure or to complement (via metadata) that information to promote interoperability. And although this is a context that invites the presentation of information in a way that people can understand, as we have proposed in encouraging more interoperability of health data, Federal publication of metadata language for describing data could be helpful.

The many ways in which the US economy, labor market, and education and training system are decentralized make clear that integration is not likely to occur on its own. Your Administration's use of specific levers (publication of open data, funding for TAACCCT and other programs, the new job-driven checklist, promotion of competency-based assessment and its role in academic accreditation, and more) represent important steps forward. They are complemented by a growing variety of private initiatives. [44]

How can your Administration foster more integration? At a nationwide scale, this will be hard; the worker-trainer-employer ecosystem is huge, decentralized, and dynamic. But it is possible to exercise leadership by helping employers and educators/trainers understand the concept of an integrated WTE system, promoting opportunities for interconnection at local levels, supporting development of the kinds of tools that can facilitate the assessments and training that can help people get jobs, engaging the Federal Government as an employer (and trainer), and enhancing coordination among key Federal entities.

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[40] See: http://learningregistry.org/

[41] Although big-data analytics can be helpful in making sense of the inconsistent information that does exist, more consistent terminology would nevertheless benefit all actors in the triangle, not least because of inconsistent access to the tools and products of big-data analytics.

[42] The Department of Commerce, through the National Institute of Standards and Technology, leads the National Initiative for Cybersecurity Education, which features a National Cybersecurity Workforce Framework with a taxonomy and standard terminology for relevant skills, tasks, and jobs.

[43] See: http://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_big_data_and_privacy_-_may_2014.pdf

[44] The urgency of the training challenge is becoming more widely recognized, and efforts beyond the public sector are mobilizing. For example, see: (1) the Markle Economic Future Initiative: http://www.markle.org/economic/markle-economic-future-initiative; (2) The Aspen Institute Skills for America's Future Program: http://www.aspeninstitute.org/policy-work/economic-opportunities/skills-for-americas-future; (3) the Wadhwani Foundation: http://wadhwani-foundation.org/; (4) the employment programs of the Joyce Foundation: http://www.joycefdn.org/; and (5) IBM has fostered a new educational model bridging high-school and early college, the Pathways in Technology Early College High Schools (P-TECH): http://www-03.ibm.com/press/us/en/presskit/42300.wss and http://www.ptechnyc.org/ptech.

Recommendations

PCAST makes the following recommendations:

(1)   Improve the operation of the worker-trainer-employer ecosystem by better coordination of related Federal efforts. In addition to continuing to support the important activities at the Departments of Labor and Education, as encouraged by the White House's *Ready to Work* report, engage the convening power of the Department of Commerce, which can help to bring industry together with government to foster improvements to the WTE system, as well as encourage activity such as technical standards-setting and approaches to facilitate information exchange across the associated ecosystem. The Secretary of Commerce has already moved to engage the National Advisory Council on Innovation and Entrepreneurship on industry-led worker training.[45] The Administration could also use its convening power across the Departments of Labor, Education, Commerce, and others to bring together industry with training providers, the public workforce system, and other partners to foster these improvements.

(2)   Continue to support development of information technology to facilitate assessment of skills and training needs, counseling about training and career options, and delivery of training that culminates in credentials that can be validated. Research supported by agencies participating in the Federal Networking and Information Technology Research and Development (NITRD) Program will be key to this progress, as well as support by the Department of Education for new approaches to assessment. Federal support for IT research can not only generate new capabilities, it can also promote commercial use by helping to prove concepts and lower costs.

(3)   The Federal Government should lead by example in exploring opportunities to use information technology, in particular large-scale Web services in the private sector and machine-learning capabilities emerging from research, to identify and forecast the detailed skills required in the evolving Federal workforce and to match candidates from across the country with those opportunities. Further, in skill development, the Federal Government should look to harness both private-sector and captive IT-based training mechanisms to deliver the ongoing skills development required for new and existing Federal employees. The President should direct the Office of Personnel Management to work with agencies to allow coordinated training and certification programs, within the private sector and beyond, to be fully accepted by Federal employers for middle-skill jobs in addition to, or in lieu of, conventional diplomas. Existing Federal workforce planning and human resources functions should be redirected to enable incorporation of Federal job opportunities into emergent national Web-scale worker-trainer-employer matching systems.

Concluding Comment

We hope you and your other advisors in this domain, as well as the various Federal Departments and agencies directly, find the recommendations your PCAST has put forth here to be useful. Whereas our

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[45] See June 2014 press release: http://www.commerce.gov/news/press-releases/2014/06/17/us-commerce-secretary-penny-pritzker-announces-call-new-members-natio

letter on MOOCs advocated letting the market work, in this letter we suggest that that is not sufficient to progress in middle-skill training and job-matching.

Respectfully submitted,

The Members of PCAST

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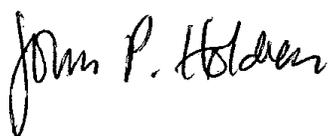
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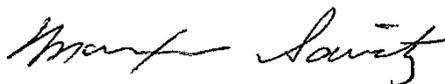
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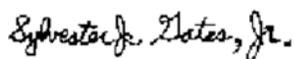
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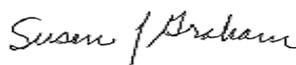
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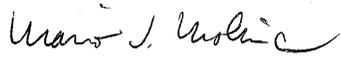
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