The Human Side of Service Engineering, Vol. 108, 2023, 78–89
https://doi.org/10.54941/ahfe1003109

A Proposed Roadmap to Close the Gap Between Undergraduate Education and STEM Employment Across Industry Sectors Further Explored

Yassi Moghaddam[1], Martha Russell[2], Josephine Yuen[1], and Haluk Demirkan[3]

[1]ISSIP, CA, USA
[2]Stanford University, CA, USA
[3]University of Washington, WA, USA

ABSTRACT

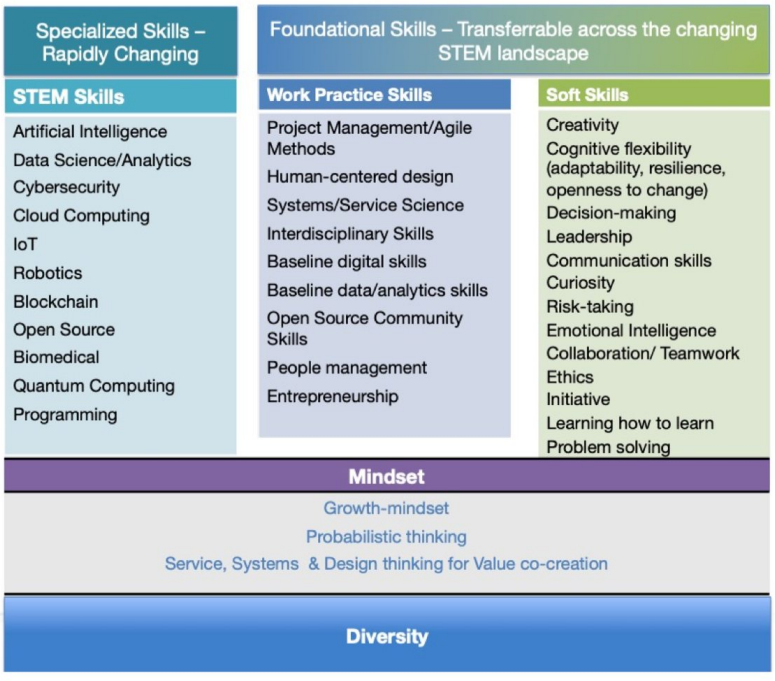
Driven by advances in technology and automation, work and jobs are changing rapidly, and the pace of change has supercharged in the aftermath of the COVID-19 pandemic crisis (McKinsey, 2021). As more and more repeatable tasks are relegated to machines, millions of existing jobs may be displaced by machines, while millions of new ones, especially in Science, Technology, Engineering, and Mathematics (STEM), may emerge where people together with machines are the engine to innovation leadership (World Economic Forum, 2020). For new STEM jobs to offset the losses, an adaptable workforce with a new and evolving set of skills is crucial now and in the future. Preparing the workforce for the STEM jobs of the future, however, requires massive upskilling, and close collaboration between industry-academia and government service systems to prepare the workforce for new and future STEM jobs.It is in this context that, in 2019, the International Society of Service Innovation Professionals (ISSIP), with support from the National Science Foundation (NSF), embarked on (what turned out to be) a two-phase research project to inform higher education leaders in the US about industry perspectives on how STEM undergraduate educational institutions might best meet industry's expected demands for new and future skills. The first phase of the research culminated in "A Proposed Roadmap to Close the Gap Between Undergraduate Education and STEM Employment Across Industry Sectors" (Moghaddam, Kwan, Freund, Russell, 2021) where a framework for "Specialized" and "Foundational" skills required by industry for future entry-level STEM jobs was laid out. During the course of this initial phase a few ensuing research questions emerged: 1) How has the industry perspective on skills demand changed as a result of the COVID-19 crisis? (The crisis hit the US toward the tail end of the first phase.) 2) How are industry recruiters and hiring managers screening STEM graduates for both "specialized" and "foundational skills?" 3) From an industry perspective, which colleges/universities' curricula/pedagogies better align with industry demand? 4) Can a set of desirable curriculum/pedagogy attributes be developed from the findings? And, 5) How are industry recruiters using badging and certification to assess job readiness for college graduates? In this paper, the authors present mainly the findings from the second phase of their research.

Keywords: Stem employment, Stem skills, Future of work, Future of learning

INTRODUCTION

Technology and digital transformation are causing major disruption and displacement in America. Jobs with repeatable tasks are being eliminated by automation, while new jobs and entirely new job categories are being created, mostly in Science, Technology, Engineering, Mathematics (STEM). Jobs like data modeler, human-centered design analyst, digital talent specialist, people's analytics manager, social & influencer marketing lead, ChatGPT prompt engineer, and many others did not exist 10 or even 5 years ago. By 2025, 85 million jobs may be displaced by machine, while 97 million new roles may emerge where machines are enhancing workers capabilities (World Economic Forum, 2020). Furthermore, this trend has been accelerating following the COVID-19 pandemic. McKinsey estimates that up to 25% of workers will need to switch occupations in the aftermath of the pandemic (McKinsey Global Institute, 2021).

Getting America's workforce ready for the STEM jobs of the future requires massive workforce upskilling. An ecosystem of industry-friendly undergraduate education options, which can prepare the workforce for new and future STEM jobs, is of paramount importance. Thus, in 2019, the International Society of Service Innovation Professionals (ISSIP), with the support from the National Science Foundation (NSF), embarked on a research project to inform higher education leaders about industry perspectives on how STEM undergraduate educational institutions might best meet industry's expected demands for new and future skills. That research culminated in the publication of "A Proposed Roadmap to Close the Gap Between Undergraduate



Source: Moghaddam, Y. Kwan, S., Freund, L., Russell, M. G. (2021)

Figure 1: Framework 1.0: an industry perspective on skills requirements for the future.

Education and STEM Employment Across Industry Sectors" (Moghaddam et al., 2021), in which a framework ("Framework 1.0") was outlined for future high-demand skills from an industry perspective (see Figure 1).

The required skills in Framework 1.0 were outlined along two dimensions: 1) Specialized Skills designating those technical and scientific skills for which requirements keep changing rapidly as technologies advance, and 2) Foundational Skills which include those skills that are long-lasting and transferable across technologies, jobs, companies, and even industries.

Building on this earlier research, and inspired by Visioning Report from NSF (2020), ISSIP set out on a new project in 2021, also sponsored by the National Science Foundation, to further seek industry perspectives on a range of research topics that emerged at the end of the earlier project. The research questions were:

1. How have industry perspectives on Framework 1.0 (Figure 1) changed in the aftermath of the COVID-19 crisis?
2. How are industry recruiters and hiring managers screening STEM graduates for both Specialized and Foundational Skills?
3. Which university curricula does industry view as best aligned with their needs? – Can attributes be articulated for higher education pedagogy and curricula that industry has most and least success in terms of industry's hiring, developing, and retaining new graduates.
4. How are industry recruiters using badging and certification to assess job-readiness for college graduates?

A description of the research approach and the findings follows.

METHOD

The project was comprised of two main components, 1) Stakeholder Feedback (including the "STEM Futures Survey" or "Survey", and "Dialogues") and 2) a series of workshops ("the Workshops"). A panel of experts ("Expert Panel") was assembled (see Section 3 for the selection process) and their input was obtained through both project components. Some of the Survey submittals were augmented by teleconference Dialogues that were held with Expert Panel survey respondents primarily to select and empanel workshop presentations on key issues.

The project components were carried out in 2 phases. The first phase, March 24 - Dec 15, 2021, "Phase 1," included the period from the start of the project to and including the date of the 4th Workshop. The second phase, "Phase 2," began immediately after the completion of the 4th Workshop and ended with the submission of this Report to NSF (March 31, 2022).

- **Expert Panel** – The Expert Panel was assembled by developing a list of 120 industry leaders from the ISSIP membership roster and the Co-PIs' expert networks who were known to have responsibility or visibility into the corporate college hiring process, either as HR leaders, as direct hiring managers, or as business strategists. The list represented experts from diverse industry sectors including ICT, media & entertainment, internet services, professional services, government, automotive, aviation, healthcare, transportation, financials, manufacturing, agriculture and financials.

The size of the Expert Panel was set to a minimum of 25 and a maximum of 35 members (based on the number of the panels, and duration of the workshops). To avoid exceeding the maximum number requirement (35), only 50 from the list of 120 were selected and invited to join the Expert Panel. (The 50 were those who had recently been engaged in various ISSIP future-of-work initiatives.) Thirty one of the 50 experts accepted.

All 31 Expert Panel members were invited to participate in the workshops. Of the 31, 30 accepted to participate in at least one of the workshops. All 30 accepted to either moderate or speak during one of the workshop panels.

- **Stakeholders Feedback**
  Futures STEM Survey - The goal of the Survey was to understand changes in industry perspective from the prior research findings (Figure 1) in the aftermath of the COVID-19 crisis. In Phase 1, the project team developed a survey consisting of ten items which were based on prior industry research (Moghaddam et al., 2021). The survey then was refined by obtaining feedback from 6 members of the Expert Panel. An IRB review was then conducted (by University of Washington Human Subjects Division), and a waiver was granted. During Phase 1, (Oct 1 and Nov 1, 2021), the Survey was distributed to all the members of the Expert Panel plus others from the ISSIP list of 120 experts. By Nov 1st, fifty-one responses had been collected. Interim Survey results, based on these 51 submittals, were studied to identify crucial topics and candidate speakers for the workshops (total of 4). The results were shared (and feedback obtained) during Workshop 1 & 2. Then, between Jan 5 – Feb 15, 2022, the Survey was distributed more extensively to increase the number of stakeholder responses. By Feb 15, 2022, when the Survey closed, ninety-five responses had been obtained across diverse industry sectors including ICT, telecommunication, media and entertainment, internet, professional services, financial service, healthcare, transportation, infrastructure, insurance, education, and government.
  Stakeholder Dialogues – In Phase 1, the team conducted dialogues (on Zoom) with each member of the Expert Panel to obtain more clarification on their survey responses and to jointly identify crucial workshop topics, plus their role in at least one workshop.

No compensation was offered or given to the Expert Panel, survey respondents, or workshop participants (except for the project team, and 2 student assistants).

KEY FINDINGS

Survey – Key takeaways from the full set of responses to the STEM Futures Survey are summarized below:

- The desired skills identified in the original framework (Figure 1) were reinforced by the respondents.
- However, comparing the skills industry requires now vs. 5-years from now, the need for the formerly top desired skills (Fig. 1) will not go

Table 1. Additional skills to framework 1.0 identified from the STEM futures survey results.

Specialized	Bioengineering; Sustainability Energy; AR/VR/Computational Media, Water Engineering; Finance; Material Science; Trade + Software skills; Industry Platforms; 5G; Wireless; Satellite Communication; Optoelectronics; Semiconductors; Social Sciences
Foundational - Work Practice Skills	**Working remotely** Managing across cultures
Foundational- Soft Skills	Mindfulness Story telling

away; but the relative demand for skills may change as new technologies emerge.

- Additional desired Specialized and Foundational Skills were suggested as outlined in Table 1.
- The importance of remote working was heightened as a direct impact of COVID-19. Several Survey respondents indicated that there is a set of skills required to efficiently work remotely that employers will demand long after the pandemic is over (i.e., efficient use of collaboration and communication tools and the ability to manage across cultures and time zones).
- The Foundational and Specialized Skills most desired by industry are the same ones that industry views as most lacking in new STEM graduate hires.

Workshops

A second significant component of this project was a series of four, 3-hr virtual Workshops. Each Workshop was designed to hold a conversion between industry experts and academic leaders around one of the research topics as outlined below[1].

- Workshop 1- Nov 10: Long-Term Impact of COVID-19 on Work/Learning/ Skills (designed to reflect on research question 1)
- Workshop 2 - Nov 17: Industry Best Practices for Skills Screening (designed to reflect on research question 2)
- Workshop 3 - Dec 8: Industry Lens on Undergraduate Education Best Practices (designed to reflect on research question 3)
- Workshop 4 - Dec 15: Micro-learning, Career Pathways and Future of Credentialing (designed to address question 4)

Each Workshop consisted of one panel. Therefore, throughout this document, Panel 1 refers to the panel held at Workshop 1, Panel 2 refers to the panel held at Workshop 2, and so on. (Total registration for Workshops 1, 2,

[1]Descriptions of the workshops are available on the ISSIP.org website, and recordings are posted ot the ISSIP YouTube channel.

3, and 4 were 45, 54, 68, and 94 respectively, and attendance was 33, 43, 54, and 80 respectively).

Workshop 1/Panel 1 - How Have Industry Perspectives on High-Demand Skills (Figure 1) Changed in the Aftermath of the COVID-19 Crisis?

The shift toward remote and distributed work had already begun several years before the COVID-19 crisis. The pandemic, however, accelerated that trend on a mega scale forcing millions of workers, particularly in STEM jobs, to shift to remote work almost overnight. Panel 1 speakers overwhelmingly emphasized that some form of "hybrid distributed workplace" (HDW) is here to stay (PwC, 2021). Because companies are experiencing more productivity and customer satisfaction, and employees more flexibility and autonomy. The shift toward HDW in the aftermath of the pandemic has increased and sped up demand for all type of Foundational Skills (Figure 1), according to the panel, including "Cognitive Flexibility (adaptability, resilience, openness to change)," "Learning how to learn new skills," "Communication," and "Leadership."

Also, for a vast portion of the workforce, this shift has brought new skills requirements. Today, these requirements primarily involve being well-versed with collaboration tools (like WebEx and Zoom) and messaging platforms (like Slack and Teams), but industry perspectives indicated that in the future AR/VR technologies are going to play an important role.

A major concern voiced is that HDW introduces a new set of workplace challenges for entry-level hires, challenges that are harder to address in a virtual environment. Recognizing, adapting, and identifying with an organization culture in the absence of water cooler conversations and spontaneous interactions, is extremely difficult. The second challenge is inclusion and equity. The aftermath of COVID-19 crisis exposed many of our social and economic inequities. Today, many employers and educational institutions need to heighten their commitment to ensure an inclusive recovery.

Undergraduate education can play an important role to address some of these challenges by preparing students, through formal and informal learning opportunities, to sensitize students to these issues and teach the Specialized Skills and Foundational Skills necessary to succeed in HDW so that when students enter the workforce, they can recognize and manage these challenges effectively.

Another important point raised by this panel was that companies are rethinking their competitive edge given the tight job market, and increasingly, they view collaboration with academia as an enabler for strengthening their talent pipeline as a competitive edge. This provides a great opportunity for those higher education institutions that are eager to forge partnerships with industry.

Finally, desired skills perceived by the panel speakers, and from the STEM Futures Survey results, as having gained importance in the HDW era ("Framework 2.0") are summarized in Figure 2.

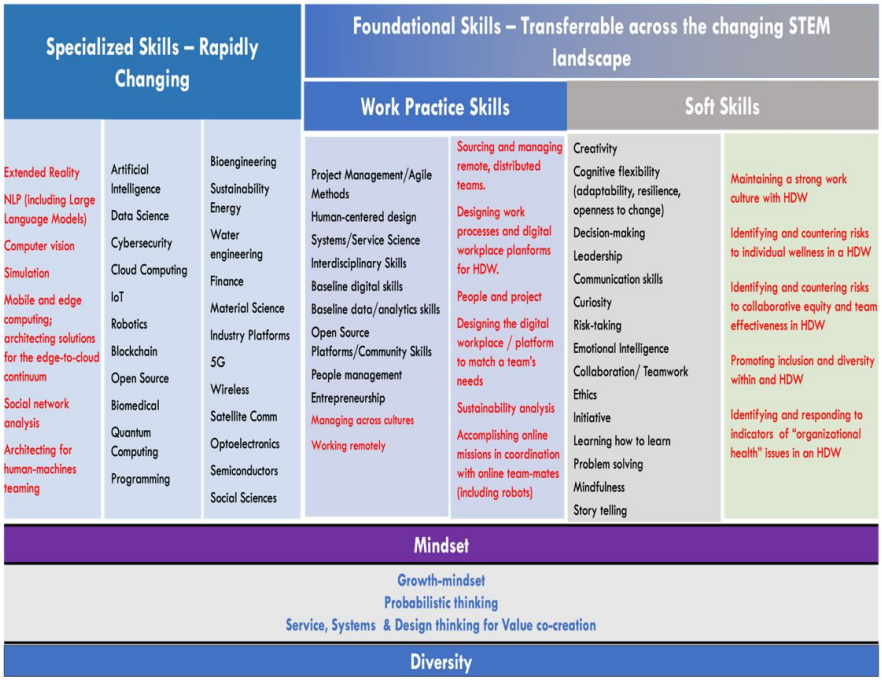


Figure 2: Framework 2.0: an industry perspective on STEM education in the aftermath of COVID-19 and the massive adoption of hybrid distributed workplace.

Workshop 2/ Panel 2 - How Are Industry Recruiters and Hiring Managers Screening STEM Graduates for Both Specialized and Foundational Skills?

Industry screening of applicants for entry-level STEM jobs is usually based on assessing Specialized Skills of being academically and experientially prepared for the job, as well as the Foundational Skills, while gauging the whole person in terms of mindset, culture, attitude etc.

Our research reinforced that there is no established practice by industry to align employers' entry-level STEM skills screening and higher education pedagogical practices. Instead, companies large and small, as well as some higher education institutions, are proactively partnering in joint practices to offer work-based learning opportunities to students and prepare them with the skills demanded in the workplace. Industry practices include on-campus college recruiting, dedicated university programs that drive joint research, co-creating assets to advance industry-relevant skills, and corporate social responsibility that donates course material and technology to higher education and trains the trainer. Some of the best practices mentioned for experience, curricula, and ecosystem development include:

Experience

- Industry-led student mentorship programs leading to better job preparedness.

- Student internship and co-op programs - Based on internal measurable employee performance, and retention rates. Some companies (e.g., Cisco) prioritize recruiting from schools with well-designed and industry-friendly co-op and internship programs (Northeastern University, and North Carolina State).

Curricula

- Industry advising and supporting courses and curriculum to increase demand relevancy.
- Industry free open courseware to integrate into college courses, bootcamps, micro credentials. (e.g., Cisco Net Academy and Infineon's open courseware).
- Industry sponsored student capstone projects (e.g., capstone classes).
- Faculty awards for student-driven industry research or course sponsorship (e.g., SAS Institute sponsoring a course in Visual Design at NC State, and IBM faculty award).
- Having a dedicated college/university program that proactively seeks partnership with higher education institutions (e.g., IBM University Program).

Ecosystem

- Nurturing/growing a pipeline of experts as student mentors or sponsors.
- Participating in associations that promote industry-academia collaboration around student work-based learning.
- Industry initiatives to strengthen hiring of underrepresented populations (e.g., recruiting from Minority Serving Institutions).
- Offering Corporate Social Responsibility programs that provide touchpoints for collaboration with academia to build innovation capacity for society at large (e.g., Cisco Networking Academy, IBM P-TECH, TCS Go IT).

Workshop 3/Panel 3 - Which University Curricula Does Industry View as Best Aligned With Their Needs? Can Attributes Be Articulated for Higher Education Pedagogy and Curricula That Industry Has Most and Least Success in Terms of Industry's Hiring, Developing, and Retaining New Graduates?

Major attributes of undergraduate institutions that our panelists perceived as having best workforce preparation practices are outlined below.

- The university/college is extremely vested in their students' academic and career success by providing students a variety of programs that offer students work-based learning experiences throughout their undergraduate programs.
- The institution has a central or departmental-level point of contact for industry outreach and communicates clearly and often to industry experts interested in collaborating with higher education.
- The most effective university industry collaborations, however, are perceived to be local and at the department level. Typically, a department

faculty or staff engages the local employers for interaction with students (through mentorship coalitions, clubs, competitions, internships, co-ops, capstone projects).
- The university builds, grows, and nurtures active industry advisory boards that provide advice to faculty and administrators, and influence curricula and pedagogies.
- The institution prioritizes its curricula around regional talent needs, before going global.
- The institution provides skill-based recognizable and stackable micro credentialing opportunities toward a degree.

The following are those higher education institutions that workshop panelists cited multiple times as demonstrating all or a subset of these best practices.

- **Northeastern University** (**NU**) multi-semester co-op program in partnership with over 3300 businesses (on a multi-year average), 93% of NU graduates are employed or enrolled in graduate school nine months after graduation.
- **North Carolina State University** (**NC State**)**, Engineering** invites industry experts as guest lecturers or adjunct professors and seeks industry advice through academic boards.
- **California Polytechnic** (**Cal Poly**) **& MIT** - both are considered by panelists as having a "learn by doing" approach. Professors play more of a facilitator role than lecturer. They also use advisory boards to evolve courses and curricula.
- **Rensselaer Polytechnic Institute** (**RPI**) offers multiyear industry-sponsored student projects (not limited to senior year).
- **San Jose State University** (**SJSU**) **School of Engineering** – professors are encouraged to proactively reach out to industry to incorporate industry interest into their curriculum as much as possible, and to identify open job opportunities for graduates to explore.
- **Hartnell College**, and **Cabrillo College**, both California community colleges, offer various programs that prepare students for the regional agriculture-based economy.

Workshop 4/Panel 4 - How Are Industry Recruiters Using Badging and Certification to Assess Job-Readiness for College Graduates?

Micro credentialing verifiable through 3rd-party digital badges[2] is a recent trend that promotes skilled-based vis-a-vis degreed-based education and is increasing becoming more important for employers, learners, and higher education leaders alike.

It is important to employers because in today's tight labor market, businesses can tap into a larger portion of the skilled, but non-degreed population (36 million Americans hold some post-secondary education that they never

[2]The Open Badges (https://openbadges.org/) defines standards for issuing, earning, and displaying open digital badges.

complete[3] Micro credentialing is also a verifiable way for learners to demonstrate commitment to life-long learning and preparedness to work in new areas. According to Strada Education (2020)[4], 68 percent of adults considering enrolling in education preferred non-degree pathways, up from 50 percent the year before (a jump considered as a direct result of the COVID-19 crisis (Gallagher and Ferrari, 2021; Strada Education Center for Consumer Insights, 2020)). Higher education institutions are slowly starting to respond to this market demand by forging partnerships with industry to offer micro credentialing and innovative learning pathways designed for student's early and rapid skills development, and for professionals' life-long upskilling. A few innovative approaches by colleges that integrate micro crediting in the program:

- **Northeastern** is the first university to turn digital badges into degree programs. The university has been working with IBM to integrate the company's in-house education programs with the university's academic credentials. IBM employees, customers, and members of the public have been using IBM-issued badge credentials toward three Northeastern professional master's degree programs—data analytics, project management, and portfolio management.
- **California Community Colleges System** (a collection of 115 community colleges serving 2.5 million students) offers micro degrees focusing on the needs of small business designed with verifiable industry recognized certifications and digital badges for "Business Information Worker" and "IT Technician – Cybersecurity."
- **Open University (UK)** offers micro credentials in Leadership and Management, Computing and Digital Technologies, Environment, Climate Change and Sustainability, Teacher Development, and Inclusive Learning (partnership with Cisco Networking Academy).

Another promising trend in colleges and universities with some promise, according to one panelist, is the badging of experiences and coursework as part of the experience of gaining a traditional degree. The advantage of this credentialing-as-you-go approach for learners is that at every stage of their undergraduate education, learners can demonstrate accomplishment in the process of their degree program. Therefore, badges can be a supplement to degrees rather than a phenomenon that threatens to replace degrees.

The panel advised academic leaders who are considering getting into the business of micro credentialing to consider using already existing processes to build stackable programs. For example, one panelist mentioned that higher education institutions can use their "prior learning assessment process[5]" to introduce an industry micro credential into an existing curriculum (Leaser et al., 2020).

[3]National Students Clearinghouse (2019), Some Colleges, No Degrees, https://nscresearchcenter.org/some-college-no-degree-2019/ (Download, Feb 15, 2022).

[4]Work and Education Research: https://cci.stradaeducation.org/public-viewpoint/

[5]This is the process by which universities use to transfer credit from another college or university.

More research is needed to study the impact of micro credentialing on the workforce and higher education.

RECOMMENDATIONS, CONCLUDING REMARKS AND FUTURE DIRECTIONS

Considering the industry perspectives gathered in this research from the Stakeholder Feedback and Workshops, the following summarizes the project's recommendations to higher education leaders:

- Consider shaping the learners' career success and life long-learning to be part of your mission.
- Consider creating incentives for faculty and administrative leaders to evangelize work-based learning and foster industry-academia collaboration to that end, by involving large and small employers in an array of student engagements including competitions, internships, co-ops, capstone projects and other experiential learning opportunities.
- Consider offering students high-demand industry micro credentials, verifiable through digital badges, that can be integrated into degree programs as stackable options.
- Leverage the "prior learning assessment process" to integrate micro credentials into existing programs.
- To offer industry-oriented micro credentials, consider starting with a well-established ecosystem (e.g., Cisco Net Academy, Google, IBM P-TECH, and Google Professional IT Certification).
- Provide options to faculty for career growth paths that emphasize teaching and practical research and are valued for tenure comparable to fundamental research.
- Consider industry collaborations not only with large enterprises, but also small and medium size businesses. And tailor at least some programs around local and regional workforce needs.
- Keep technology and tools up-to-date and aligned with industry talent needs.
- Engage students with open-source projects that are conducive to innovation.

This project also recommends that the National Science Foundation promotes academic engagement with industry as part of undergraduate education. An example would be for the Division of Undergraduate Education to sponsor Research Experiences for Undergraduates (REU) Sites where undergraduate students can participate in research projects that have industry sponsors.

By providing this industry perspective on needs and opportunities to better align higher education and entry-level STEM workforce employment, this research has aimed to inform leaders of US higher education of the changes in educational programs that industry requests, to prepare the American workforce for new high-paying STEM jobs and increase the innovation capacity in the US now and in the future.

Future Research - During the course of this study, the project team identified micro credentialing a recent trend that industry experts claim will revolutionize education. More research is needed to study the future impact of micro credentialing on the workforce and on higher education.

REFERENCES

A Subcommittee of the NSF Advisory Committee of the Education and Human Resources (2020), *STEM Education for the Future – A Visioning Report,* NSF, https://bit.ly/3gkaR5H (download, Feb 19, 2022).

D. Leaser, K. Jona, S. Gallagher (2020), Connecting Workplace Learning and Academic Credentials via Digital Badges, Volume2020, Issue189, Credentials for a New Era of Work and Learning, Wiley.

Gallagher, S., Ferrari, M. (Dec 2021), Northeastern University, https://bit.ly/3h5t1br, (download, Feb 19, 2022).

McKinsey Global Institute (2021), *The future of work after COVID-19,* McKinsey & Company (download, Feb 19, 2022).

Moghaddam Y., Kwan S., Freund L., Russell M. G. (July 2021), *A Proposed Roadmap to Close the Gap Between Undergraduate Education and STEM Employment Across Industry Sectors.* In: Leitner C., Ganz W., Satterfield D., Bassano C. (eds) Advances in the Human Side of Service Engineering. AHFE 2021. Lecture Notes in Networks and Systems, vol. 266. Springer, Cham.

PwC (March 2021), *What's next for America's workforce post-COVID-19?* (download, Feb 19, 2022).

Strada Education Center for Consumer Insights (2020), https://bit.ly/3sPiyX2 (download, Feb 19, 2022).

World Economic Forum (Sept 2020), *The Future of Jobs Report 2020* (download, Feb 19, 2022).