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State of STEM: Defining the Landscape to Determine High-Impact Pathways for the Future Workforce

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Abstract

This article attempts to address the workforce crisis with implications for economic competitiveness and national defense faced by America and the dichotomy of STEM needs and available employees. Businesses struggle to fill critical skilled roles in STEM occupations and thus suffer sluggish growth. In fact, some estimate up to 2.4 million STEM jobs go unfilled College graduates in STEM fields struggle to find jobs. STEM jobs have doubled as a proportion of all jobs since the industrial revolution. New jobs and entirely new fields are being created daily. Estimates suggest that 65 percent of children entering elementary school today will ultimately end up working in completely new job types that are not on our radar yet. More students are in college than ever before, and STEM graduates out-earn those in non-STEM fields 12-30 percent across all education levels. It seems impossible for both these narratives to be accurate. Yet, impossibly, they are both quite real. These two realities demand a greater understanding of the STEM talent ecosystem and a greater commitment to action. Both employers who have jobs to fill and job seekers are facing myriad confusing messages, options, and challenges. Considering this complexity, it is tempting to put our energy towards finding a single solution—the one program, metric, or organization that has all the answers. Since the National Science Foundation (NSF) coined the term "STEM" nearly two decades ago, we have seen an explosion in interest, investment, programs, research, and data all seeking such a solution.

Keywords
STEM, workforce, STEM Education, STEM Workforce

State of STEM:

Defining the Landscape to Determine High-Impact Pathways for the Future Workforce

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STEMconnector

Introduction

What is the state of the STEM workforce?

America is facing a workforce crisis with implications for economic competitiveness and national defense. Businesses struggle to fill critical skilled roles in STEM occupations and thus suffer sluggish growth. In fact, some estimate up to 2.4 million STEM jobs go unfilled ("The STEM Imperative," 2018). College graduates in STEM fields struggle to find jobs. Those without a postsecondary degree can barely achieve a family sustaining wage. Technology and automation are rendering human workers obsolete across industries (Korinek & Stiglitz, 2017; Autor & Salomons, 2018).

America is also on the cusp of a revolution in work, with technology fueling innovation and opportunity beyond our imaginations. STEM jobs have doubled as a proportion of all jobs since the industrial revolution. New jobs and entirely new fields are being created daily. Estimates suggest that 65 percent of children entering elementary school today will ultimately end up working in completely new job types that are not on our radar yet (Pethokoukis, 2018). Job seekers have more choice than ever before, and advanced skillsets are in demand. More students are in college than ever before, and STEM graduates out-earn those in non-STEM fields 12-30 percent across all education levels ("The STEM Imperative," 2018).

It seems impossible for both these narratives to be accurate. Yet, impossibly, they are both quite real (Xue & Larson, 2015; Kharas, 2017). These two realities demand a greater understanding of the STEM talent ecosystem and a greater commitment to action.

Both employers who have jobs to fill and job seekers are facing myriad confusing messages, options, and challenges. Considering this complexity, it is tempting to put our energy towards finding a single solution—the one program, metric, or organization that has all the answers. Since the National Science Foundation (NSF) coined the term "STEM" nearly two decades ago, we have seen an explosion in interest, investment, programs, research, and data all seeking such a solution. The field is asking questions in pursuit of this solution such as:

What letter should be added to the STEM acronym?

How many jobs will robots take from humans?

> *Box 1*
>
> **STEMconnector's definition of STEM**
> While we recognize that STEM stands for "Science, Technology, Engineering, and Math," we seek to expand our understanding of the definition beyond the acronym to include the set of knowledge, skills, and mindsets that all students and workers need to succeed in both middle- and high-skill jobs in the modern economy.

Which jobs "count" as STEM jobs?

How big is the STEM talent gap?

These questions, which may seem reasonable, have not addressed the systemic challenges. Seeking answers to these questions has led us to build systems of incentives, practice, and narrative over time that interact to create the outcomes we now see—outcomes that do not serve anyone well or fully.

"Why define a target that's always moving? Let's not spend our time defining STEM, but rather spend it collaborating and taking action that gets us to the goal we share: a more robust STEM workforce."
Justina Nixon-Saintil
Director, Corporate Social Responsibility
Verizon Foundation

These questions serve as a distraction for companies, funders, educators, policymakers, students, and job seekers. They distract from the questions that, if pursued, could lead to real transformation for business and for society. Many of the current questions—particularly those seeking to name skills or number of jobs—are also "probably unanswerable"

(Kharas, 2017).

These questions also isolate and divide at a time when we need all sectors and systems working together in coordination, focused on closing talent gaps. That daunting yet essential work is about recognizing that every student, every job seeker must be equipped with the set of knowledge, skills, and mindsets we associate with STEM.

"Creating an adaptable, STEM-ready workforce requires full participation not just of the student or job seeker, but of all those who influence their outcomes, including educators, employers, families, non-profits, and funders. Success requires an intentional and collaborative approach."
Drew Glassford
Director, Strategic Initiatives
Boy Scouts of America

Asking different questions will lead us from incremental progress to impact at scale, creating economic value and social impact.

What skills do we need to build in __all__ students, so they are ready for today's careers and prepared to adapt for those of the future?

How can we create more connected and relevant pathways through learning and working?

How can we move from discussion of diversity, equity, and inclusion in the STEM workforce to tangible results?

How can we better align sectors, respecting separate objectives while working toward common goals?

These questions embrace the complexity of the modern workforce and the STEM talent ecosystem. STEMconnector seeks to use this report as a framework to create discussion and catalyze action around these questions.

"Why *now*?" you may ask. Haven't we written enough about this topic already?

We have reached a moment in time where STEM is not set apart from the world, but rather influences every aspect of our education, work, and community life. There were no touchscreen phones in the room nearly two decades ago as the NSF met and created the term "STEM." The public education system did not serve nearly the diversity of students it does

> "STEM is about creating opportunity for businesses and for individuals to drive the innovation that will transform the world."
> Balaji Ganapathy
> Head of HR Workforce Effectiveness
> Tata Consultancy Services

today. The pace of change in technology has accelerated, and we have seen more progress over the last five years on automation and Artificial Intelligence (AI) than in the previous 50 (Manyika, 2017).

Individuals, organizations, and systems surrounding STEM must move into this new reality to solve today's challenges and embrace tomorrow's opportunities.

"The future competitiveness of the United States in an increasingly interconnected global economy depends on the nation fostering a workforce with strong capabilities and skills in STEM."- The National Academy of Sciences ("Developing a National Workforce Strategy," 2016)

In Section II, we describe the STEM ecosystem and reveal the complexity of relationships within and across sectors. This allows us, in Section III, to more fully interpret the challenges and disconnections in education and work and to reconsider the real drivers and gaps. Section IV lays out a framework for action and proposes pragmatic and effective solutions that inform organizational practice and investment.

Box 2

Key readings on the future of work
1. *A future that works: Automation, employment, and productivity.* James Manyika, Michael Chui, Medhi Miremadi, Jacques Bughin, Katy George, Paul Willmott, and Martin Dewhurst. McKinsey & Company.
2. *Digitalization and the American Workforce.* Sifan Liu, Siddharth Kulkarni, Mark Muro, and Jacob Whiton. Brookings Institution.
3. *The Future of Jobs and Jobs Training.* Janna Anderson and Lee Rainie. Pew Research Center.
4. *Navigating the future of work: Can we point business, workers, and social institutions in the same direction?* Josh Bersin, John Hagel, and Jeff Schwartz. Deloitte.
5. *How Technology Is Destroying Jobs.* David Rotman. MIT Technology Review.
6. *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.* World Economic Forum.

Box 3

Key sources of STEM data

Data is a challenge in this topic area. As the STEM talent gap is about education, work, economy, technology, and more, we must use a variety of sources to speak to those different elements of the STEM challenge when describing the STEM ecosystem.

1. **National Science Foundation (NSF):** The NSF supports research and education in science and engineering, and their National Science Board produces the annual Science & Engineering Indicators dashboard.
2. **Burning Glass:** With its artificial intelligence technology, Burning Glass analyzes hundreds of millions of job postings and real-life career transitions in order to provide insight into labor market patterns.
3. **U.S. Bureau of Labor Statistics (BLS**): As part of the U.S. Department of Labor, the BLS is the principal federal agency responsible for measuring labor market activity, working conditions, and price changes in the economy.
4. **National Center for Education Statistics (NCES**): The NCES collects and analyzes education data from pre-kindergarten through postsecondary education, including STEM-related disciplines.
5. **Pew Research Center:** The Pew Research Center polls students and employees along the STEM talent pipeline, measuring interest and retention in STEM fields as well as barriers present along the pipeline that may deter people from pursuing STEM careers, namely pay inequity and a lack of diversity.
6. **Gallup, Inc.:** Gallup conducts an annual student survey capturing student goals, engagement, and other variables, with nearly five million completes since its inception in 2009.

The STEM Ecosystem

The STEM ecosystem is the set of systems, organizations, individuals, and forces that shape the experience and outcomes of those who interact with them. The first step in unpacking the complexity of the STEM ecosystem is to define its major subsystems and their elements, connections, and functions.

This section of this report is descriptive, and the implications of this current landscape will be explored in Sections III and IV. Any given map can be applied at a hyper local level (a single community) or a national level. All of them take a human-centered design approach, which means that each sub-system map puts a person—a K-12 student, a postsecondary student, or an employee—at the center. The most proximate actors to the student or employee are the most influential in his or her pathway.

> "We believe it's critical to understand and catalyze action in state-level systems in order to achieve greater impact in the STEM talent space."
> The Honorable Regina B. Schofield
> Director, Corporate Engagement & Education
> Battelle

This set of system maps is designed as a defined starting point, though we will continue to build them out in greater detail across 2018 using a digital platform. This online, interactive platform will allow our members to access greater detail on each element of the system, providing a valuable tool to guide investments. Understanding this system in greater detail reveals how prospective solutions fit into the whole, producing more systemic and less isolated progress.

Figure 1 is a base map of the STEM ecosystem, including three main sub-systems, also known as sectors. Within each sector are different organizations and individuals who influence the overall outcome.

- K-12: Refers to education from early childhood through high school graduation.
- Postsecondary: Refers to all educational experiences beyond secondary or high school.
- Employer: Refers to the organizations that provide jobs, including those in the private sector (i.e., companies) and the public sector (i.e., government).

Figure 1 also lists forces or influences that place pressure on the sub-systems by producing embedded incentives, guidelines, and beliefs. These forces include:

- Technology: Includes both personal and organizational technologies. In a June 2015 Fortune 500 survey, 72 percent of CEOs reported that keeping up with rapidly changing technology is their number one challenge ("500 CEO Survey," 2015).
- Macroeconomy: Includes consumption, trade, immigration, unemployment, monetary policy, and others.
- Policy: Includes legislative or administrative bodies and actions at the local, state, and national levels.

- Media: Includes digital media such as social media, as well as traditional press.

Figure 1. STEM Ecosystem Base Map
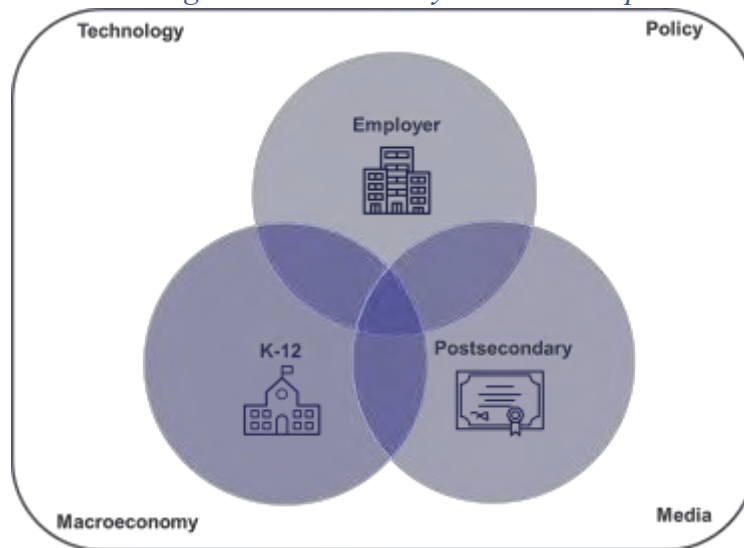
Box 4

Three technology trends influencing the STEM workforce

1. **Automation:** robots, computers, or other technologies performing physical or cognitive work activities often previously conducted by humans (Bughin, et al., 2017).

2. **Digitalization or digitization:** the diffusion and use of digital technologies and information into nearly every business across operations, assets, and worker activity. It can be considered a form of automation (Kulkarni, Muro, & Whiton, 2017).

3. **Artificial intelligence:** technology that appears to emulate human performance or intelligence by learning, appearing to understand complex content, and performing routine and non-routine tasks (Gartner, 2017; Bughin et al., 2017).

Figure 2 displays some of the issues and trends that impact the STEM ecosystem. Areas where two sub-systems come together are particularly ripe for solutions grounded in partnership across sectors. The one space where all three systems come together is for community-based cradle to career initiatives, bringing together actors across sectors to create more clear, connected, and flexible pathways through learning and into the workforce.

"We need system-wide transformation at scale —not just a one-off program—to solve our STEM talent challenge."
Al Bunshaft
Senior Vice President, Global Affairs, Americas, Dassault Systémes
President, The Dassault Systémes U.S. Foundation

*Figure 2. Relevant Issues and Trends in the STEM Ecosystem*
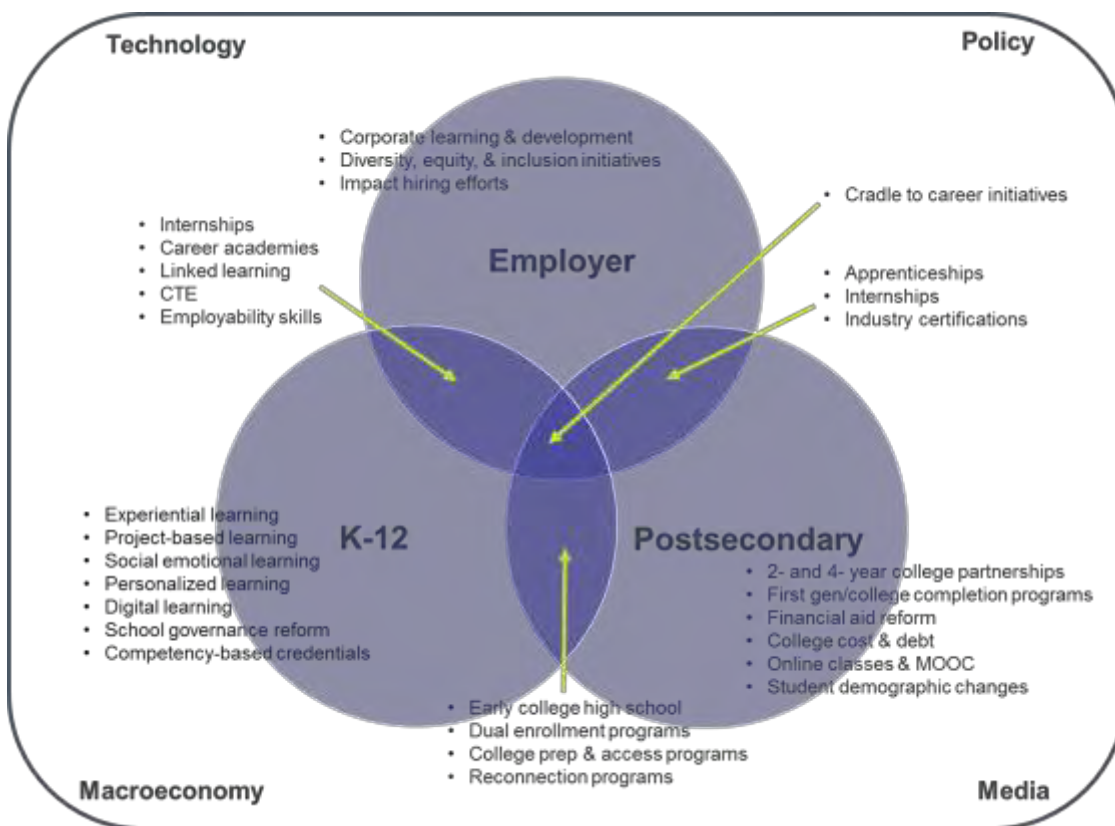
K-12

The K-12 education system is growing in scope and scale. In the fall of 2017, a total of 55.9 million students attended school from pre-kindergarten through 12th grade. Of these, 35.6 million were in prekindergarten through grade 8 and 15.1 million were in grades 9 through 12. An additional 5.2 million students attended private elementary and secondary schools ("Table 98," 2012).

These students are served by state and local systems encompassing 13,625 school districts, with over 127,000 public and private schools that employ over 3.7 million teachers ("Table 98," 2012).

"We must appreciate and harness the power of the classroom to drive impact. To do so, educators and administrators in K-12 must more fully understand how the world of work has changed."
Dr. Cindy Moss
Vice President, Global STEM Initiatives
Discovery Education

Figure 3 represents the system surrounding a single student in the K-12 system, who is influenced by both the school institution as well as home and community settings. The people/stakeholders closest to the student are the strongest influences.

Figure 3. K-12 Sub-System
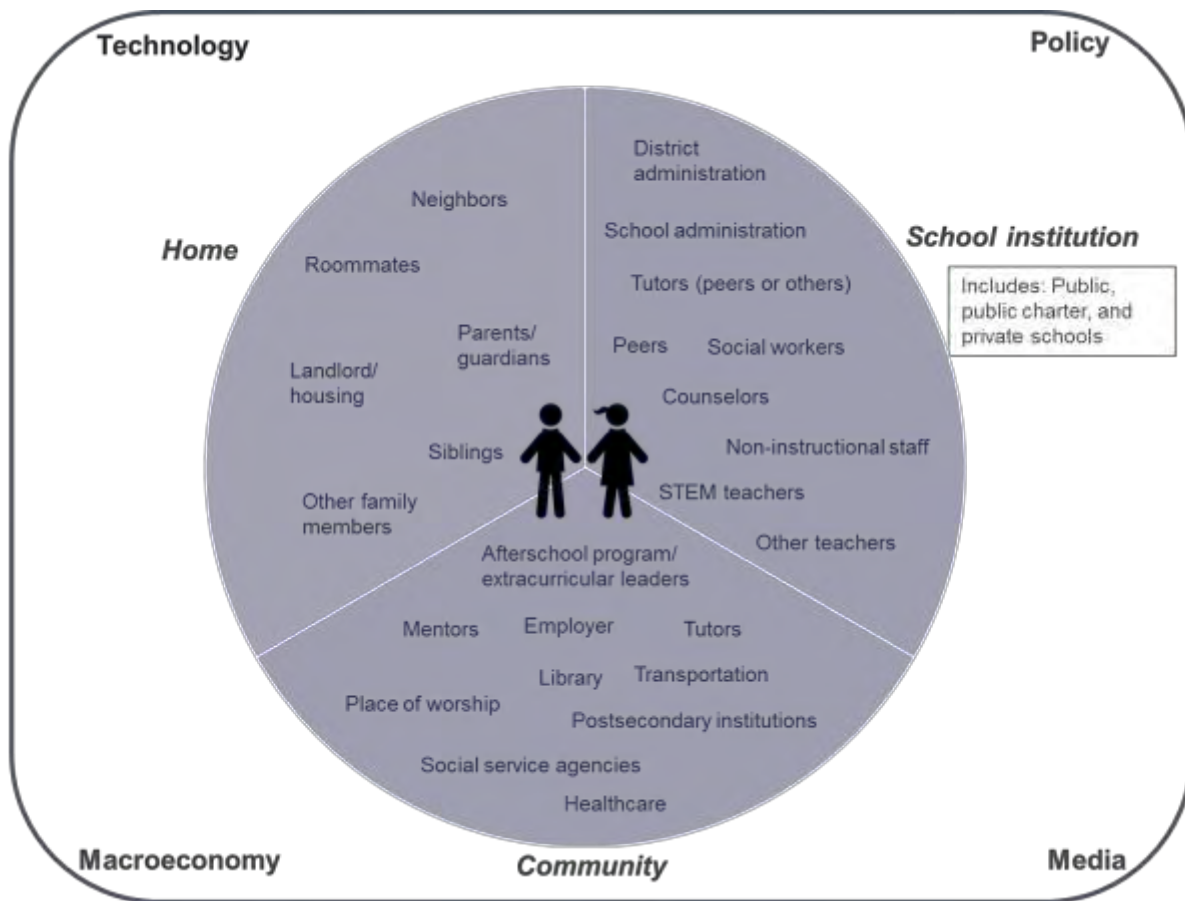
Postsecondary

The postsecondary education system comprises a plethora of different institutions, credentials, and students, as seen in Figure 4 below. The people/stakeholders closest to the student are the strongest influences.

There are over 7,000 postsecondary institutions in the U.S., educating over 20 million current students. Public, non-profit institutions enroll 70 percent of students, yet represent less than 30 percent of the total number of institutions (Columbus & Cooper, 2017).

There is no single "average" profile of a college student. Over 25 percent of all undergraduate students, or 4.8 million students, are raising dependent children (Gault, Reichlin, & Roman, 2014). Nearly 30 percent are age 25 or older ("Table 303.50," 2016). Most college students work, and 40 percent of undergraduates work at least 30 hours a week (Carnevale et al., 2015).

"Traditionally, we have determined what skills you have via the credentials you hold from a degree granting institution. While that still holds true, we're also seeing a growth of entrepreneurial organizations that can more quickly identify and teach the skills that students and job seekers need to compete for today's jobs."
Andy Smarick
Morgridge Fellow in Education Studies
American Enterprise Institute

Despite the growth in the number and type of education options, along with college access programs, there remain nearly five million young people between ages 16 and 24 who are out of school and out of work—nearly one in seven youth in that age group ("Opportunity Index," 2017).

Figure 4. Postsecondary Sub-system
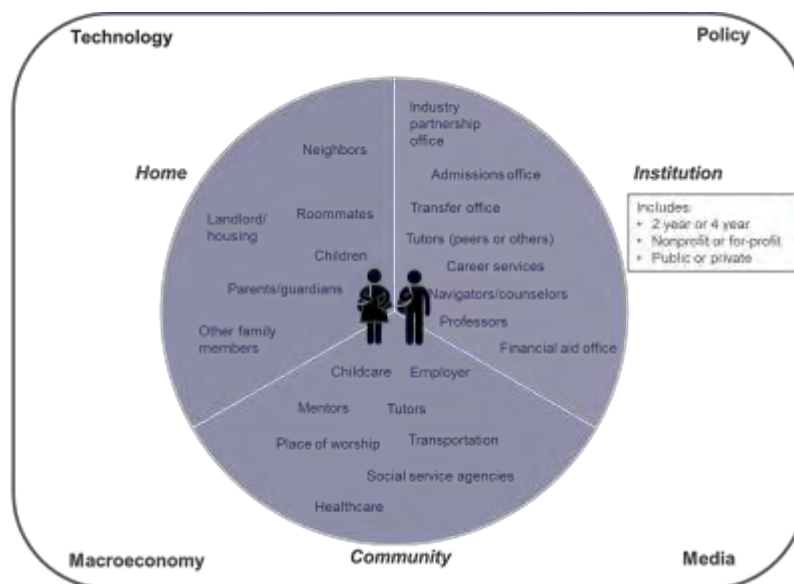
Employers

There are over 7.6 million enterprises who employ workers in the United States, with small- and medium-sized businesses (those with 500 or fewer employees) employing nearly 50 percent of the total United States workforce ("Quick Facts," 2017; "U.S. Small Business," 2016). In 2015, startup or young firms (those less than six years old) accounted for 11 percent of employment and 27 percent of jobs creation. Firms more than 25 years old accounted for 48 percent of jobs creation ("Startup Firms," 2017).

"We must ask, how are we *as companies* taking the responsibility to prepare the current and future workforce for the jobs that are just around the corner?"
Lori Beer
Chief Information Officer
J.P. Morgan Chase & Co.

New jobs will be added in the next decade in occupations that reflect the technology changes in our world (such as computer sciences), and in occupations that reflect the aging demographics: five of the 10 jobs projected to grow fastest in the next 10 years are in health care and elderly assistance (Thompson, 2017). Jobs for people with bachelor's degrees are projected to

"Employers continue to approach hiring with the same mindsets and practices, yet the job-seeking population and the nature of work have changed."
Johnny Taylor
President & CEO
Society for Human Resource Management

grow twice as fast as jobs for people with just high school degrees (Thompson, 2017). New research suggests that automation may be creating more jobs than it makes irrelevant; however, wages appear to be stagnant (Autor & Salomons, 2018).

Figure 5 represents this system of employers, including both private and public sector entities. The people/stakeholders closest to the student are the strongest influences.

Figure 5. Employer Sub-System
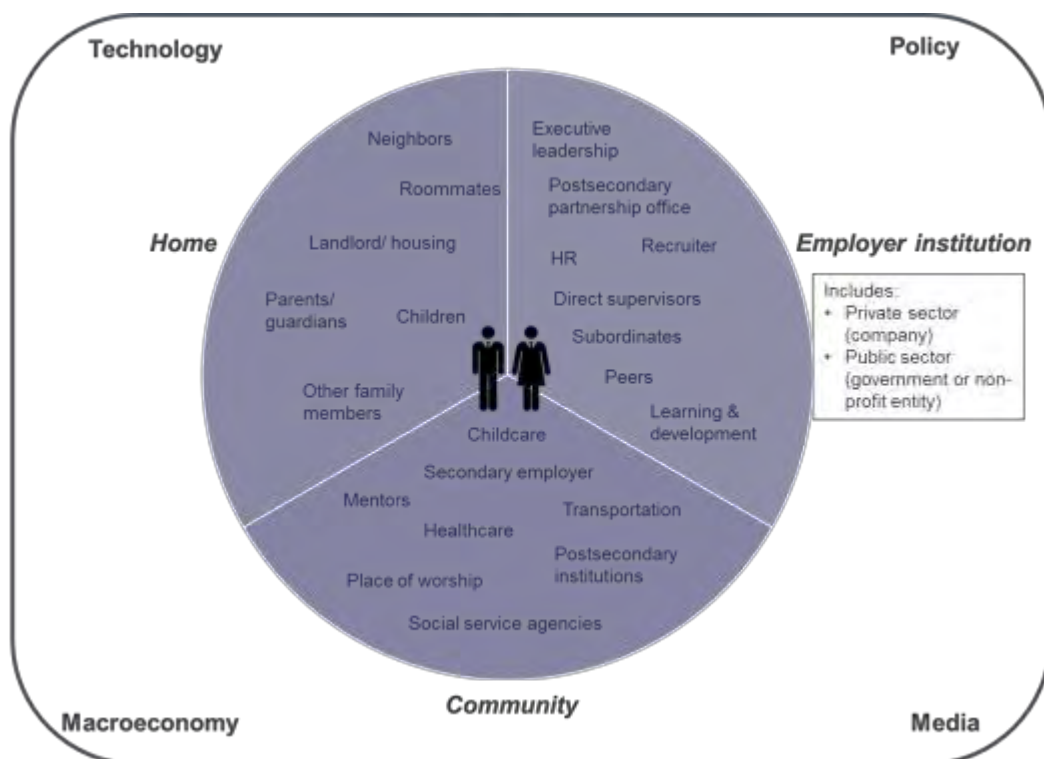
The STEM Talent Gaps

The complexity of the STEM workforce ecosystem means it is challenging to quantify the STEM jobs available today and those that will be available in the future, along with the number of workers ready and able to take on those positions. The best definition of the "surplus or shortage" of STEM workers question came from the National Science Foundation in 2016:

Close study…reveals that there is no straightforward "yes" or "no" answer to whether the United States has a surplus or shortage of STEM workers. The answer is always "it depends." It depends on which segment of the workforce is being discussed and where. It also depends on whether "enough" or "not enough STEM workers" is being understood in terms of the quantity of workers; the quality of workers in terms of education or job training; racial, ethnic or gender diversity, or some combination of these considerations ("Revisiting the STEM Workforce," 2015).

As we stated at the outset, this research is not designed to count how many STEM jobs exist, nor how many qualified workers present themselves for those jobs. Rather, we seek to describe the STEM ecosystem and name its nuances in order to create a framework for action.

Box 5

Three nuanced readings on the STEM talent gap
1. *Revisiting the STEM workforce.* National Science Board. National Science Foundation.
2. *STEM crisis or STEM surplus? Yes and yes.* Richard C. Larson and Yi Xue. Bureau of Labor Statistics.
3. *STEM.* Anthony Carnevale, Michelle Melton, and Nicole Smith. Georgetown University's Center on Education and the Workforce.

As such, we have uncovered five critical gaps in the STEM workforce and the overall workforce of the future:

1. **Fundamental Skills Gap:** industry and education have identified skills that young people need to succeed as lifelong workers and active citizens, but not enough young people are developing that foundation.

2. **Belief Gap:** young people, and adults around them, hold incorrect beliefs about the aptitude or traits young people must have to belong and thrive in STEM fields.

3. **Postsecondary Education Gap:** the new knowledge economy requires credentials beyond a high school diploma, but not enough young people are earning those credentials.

4. **Geographic Gap:** hubs of economic growth, particularly for businesses requiring STEM skills, are often far from large concentrations of qualified job seekers or far from population centers.

5. **Demographic Gap:** there is disproportionate participation in STEM jobs based on race, gender, and income, despite decades of focus on diversity and inclusion.

These gaps work together to produce the overall gap in opportunity faced by students and job seekers, as well as the companies seeking to hire them.

Fundamental Skills Gap

Over the last decade, industry and educational sectors have led efforts to identify the **fundamental skills** that young people need to succeed as lifelong workers and active citizens, but not enough young people are developing that foundation. This gap in fundamental skills includes both technical or content knowledge, as well as employability skills, and manifests itself in different forms.

Average STEM competency is insufficient for modern work

Say we take a simplistic view that STEM skills are about the fundamentals of mathematics and science. If the highest achieving students in K-12 STEM courses all pursued jobs in the traditional STEM fields that make up about five percent of all jobs, there might not be a talent gap (Carnevale, Melton, & Smith, 2011). However, those students do not all pursue those traditional fields, or even a STEM-related field at all. And many jobs today require STEM, not just those typically considered.

By this skill definition, the overall STEM competency of the *average* American K-12 student does not meet the demand for overall STEM skills in the U.S. labor market. The skills bar is higher to enter many jobs, particularly those in growth areas that pay a family-sustaining wage. This bar is likely to continue to rise as jobs grow more complex.

The challenge of K-12 STEM skill development mastery is well-documented, and researchers have pointed to many factors including teacher preparation, curriculum, and available classroom resources ("A Workshop Summary," 2016).

The new "STEM skills" are hard to build in traditional education models

"In the era of Google, we don't need people who can memorize, we need people who can think."
Dan Barstow
Education Manager for International Space Station
CASIS

Meanwhile, jobs outside of the traditional STEM space increasingly require fluency in STEM skills beyond basic mastery of mathematics. Tasks in many jobs—particularly those projected to

grow over the next decade—are non-routine. They require a higher level of cognitive skill and ability, and often involve critical thinking, complex and creative problem solving, and ability to adapt (Albanesi et al., 2013). These are the types of skills that are often developed via traditional STEM disciplines, as well as via forms of teaching and curriculum delivery that emphasize hands-on, project-based learning that is applicable to the real lives of students. While many K-12 schools and postsecondary institutions are adopting different forms of project-based, experiential, and cross-disciplinary learning, these models have not reached scale.

"A student's ability to think critically and learn in an agile manner is just as important as mastery of specific technical skills. These competencies likely will outlast today's technologies."
Eileen Yang
Senior Manager, Corporate Citizenship
Genentech

Yet young people do not gain these skills via school alone. Rather, they build such skills through experiences in their home and communities, whether formal extracurricular activities or informal interactions with family, peers, and community members. The availability and accessibility of these experiences depends as much (or more) on the income level as the interest level of both students and parents (Sawhill 2015).

Employers do not always clearly or appropriately define the skills it needs

The fundamental skills gap is driven by more than student skill preparation and mastery. Employers contribute to this gap through inadequately defining and signaling skills required for each job. The skills listed in a job description may extend beyond those actually required for the role ("Writing Effective Job Descriptions," 2009). Essentially, employers may sometimes screen out talent who could do the job but could not meet the specifications of the inaccurate job descriptions.

Belief Gap

The beliefs young people hold, as well as those beliefs held and reinforced by the adults, institutions, and systems around them, create a **belief gap** in STEM talent. These beliefs include the aptitude, personal traits, and level of achievement required to be successful in STEM fields, as well as the nature of the fields themselves. These beliefs impact everything from interest to diversion rates in STEM education and employment.

Students hold incorrect beliefs about their own STEM ability

"Many students are convinced they are not and cannot be good at STEM by the time they are in high school. As educators, we must not confirm this belief. We must instead encourage students of all ages to see themselves in STEM."

Dr. Freeman Hrabowski
President
University of Maryland, Baltimore County

About half of adults say the main reason young people do not pursue STEM degrees is because students think these subjects are too hard (Funk, Hefferon, & Kennedy, 2018). Why do young people hold these beliefs? Perhaps because their parents or other adults recall their own struggles with these subjects. Many young people believe that if they are not able to master a STEM concept (for example, 4th grade math) immediately, or at a high level of proficiency, that STEM is not for them. Teachers may confirm this belief if they lack appropriate training in math pedagogy, or if they themselves are not confident in math.

As a student progresses through school, well-meaning counselors may suggest that students with simply average performance in mathematics choose other topics to study in college. In college, entry level STEM classes often create a sense of "imposter syndrome," by which even those students who mastered STEM in high school do not believe they can succeed in STEM in college. While these beliefs may have some truth in any given circumstance, taken in aggregate, they are false. They serve to turn away potential STEM talent at every stage of education (Degol & Wang, 2013).

"Unfortunately, many times students in the 'academic middle'—'low B' and 'C' and even 'D' students—are not encouraged to consider a STEM career. They are often discouraged and overlooked by teachers, STEM programs, and even potential employers. These students are the very students that provide a great opportunity for impacting the STEM talent gap—the truth is that many are likely economically disadvantaged, balancing life issues/priorities or don't have a connection to someone in a STEM field. We need to do better here."
Kathleen Martinez
Senior Director, National Strategic Relationships
BP

Students believe only certain industries offer STEM jobs

Students may believe that only certain industries offer STEM jobs. For example, a student may think that only companies that produce consumer technology need staff with computer science skills. This leads to two challenges. One, students who are studying STEM may limit their job seeking to those few industries or companies, leading to hyper competition for those jobs. Second, students may not choose to study STEM at all if they do not think it applies to a broad array of job and industry types.

Students believe they do not belong in STEM

"Students in STEM disciplines often suffer from imposter syndrome by their first quarter in college—they feel like they don't belong. This is partly due to the challenging transition from high school coursework but becomes more acute when students don't

Beyond beliefs about skill, many young people feel they do not "belong" in STEM because of their race, ethnicity, gender, or other personal characteristics (Degol & Wang, 2013)). Parents, teachers, employers, and others reinforce this belief due to their own conscious or unconscious biases, creating a culture that neither welcomes nor values the contributions of those who are traditionally under-represented in STEM. In addition, the lack of role models, including teachers and employers, who share the same background contributes to a student or employee's general sense that people "like them" do not belong in STEM.

> see themselves [their gender, their racial identity] reflected in faculty or peers."
> Beth Broome
> Senior Advisor to the Provost & Director of STEM Strategies
> University of California, Davis

Employers hold incorrect beliefs about how academic performance and credentials relate to job success

It's not just an issue of what students believe about themselves—it's about what employers believe about them. Beyond education, companies may overlook postsecondary graduates with average GPAs given an assumption that only the "top" students can be successful.

> "Innovation is not solely within the realm of Ph.Ds. It takes ten technicians at the middle skill level to contribute to any single engineering breakthrough."
> Dr. Nicole Smith
> Chief Economist
> Georgetown University Center on Education and the Workforce

They may also believe that a certain type of credential conveys skill mastery, particularly for employability or non-content related skills. This leads some companies to require postsecondary degrees for roles that may not require the actual content knowledge of such as a degree (Bittle, Restuccia, & Taska, 2018).

Postsecondary Education Gap

The new knowledge economy requires credentials beyond a high school diploma, but not enough young people are earning those credentials, nor are they earning credentials that are relevant to industry needs. This **postsecondary education gap** is not just about the number of graduates holding a traditional STEM degree (such as engineering), but also about the type of skills needed for success, regardless of type of credential.

Not enough people hold credentials beyond high school

> "Those of us in higher education must be more willing to acknowledge that *our* job is to prepare students for *their* jobs. While it's still important

to teach students a particular subject matter, it's just as important to prepare them to be able to link that knowledge to a job."
Brian Jones
President
Strayer University

By 2020, 65 percent of all jobs in the economy will require postsecondary education and training beyond high school (Carnevale, Smith, & Strohl, 2013). By some estimates, at the current production rate of students with postsecondary education credentials, the United States will fall short by five million workers. This could be an overly optimistic estimate, as the greatest job growth in the next decade will be in occupations requiring a graduate or professional degree ("Employment Projections," 2018). This gap is even more pronounced in many STEM fields, where over 90 percent of all STEM occupations require at least some postsecondary education or training (Carnevale, Smith, & Strohl, 2010). Yet, only 35 percent of Americans hold a bachelor's degree or higher ("Educational Attainment," 2017). By numbers alone, more people need to enter and complete postsecondary education credential programs.

Figure 6. U.S. Educational Attainment, 2017, Adults 25 and older
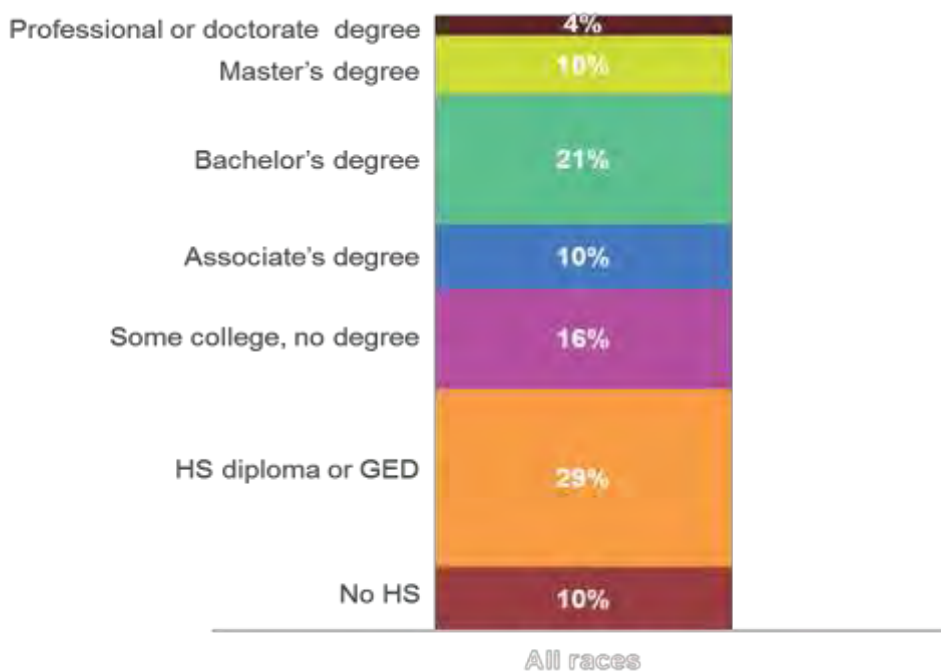
Credentials are misaligned with employer needs

The challenge is not only around sheer numbers of credential-holding job seekers. Postsecondary institutions struggle to move quickly to adjust curriculum to the rapidly evolving labor market demand. There is also a disconnect in communication and understanding between the education sector and employers. Both trends contribute to a lack of job seekers holding *appropriate* credentials—that is, credentials that fit employers' needs and translate to success in a given career (Bittle, Restuccia, & Taska, 2018).

Challenge of engaging in lifelong learning

Once on the job, some new employees require additional training either at the outset or throughout their careers, adapting to new technologies or gaining the skills needed to move along a career pathway. However, it can be difficult for employees to take time away from their full-time jobs to gain a new credential, especially when balancing family and financial priorities.

> "I think business, nonprofit, and industry leaders haven't fully tapped the potential of 2-year institutions for their STEM education needs. They are nimble and well-connected to their communities, and thus easily partner with employers."
> Mark Greenlaw
> Vice President, Strategy & Impact
> FIRST

Many employers invest in their own learning and development programs for existing employees. In fact, in the United States, approximately 50 percent of working adults in any given year are going through training, and there are as many corporate learning center universities as there are postsecondary institutions (Lynch, 2017) However, time constraints and internal value communication challenges can decrease the impact of these programs.

Geographic Gap

Access to jobs in high-growth and well-paid fields often depends on geography as much as skills, beliefs, and education. Hubs of economic growth may be far from large concentrations of qualified job seekers or they may be far from population centers, creating a **geographic gap** in STEM talent.

Not enough jobs, or not enough job seekers to fill those jobs that do exist

This gap is driven by many economic, political, and technological forces outside the control of job seekers or system leaders. Automation and globalization, for example, have displaced workers in many historically industrial areas of the upper Midwest (Casselman, 2017). The postsecondary gap has a double impact on job availability, as jobs requiring only a high school degree decline while new employers hesitate to move to those same areas of low degree attainment. In addition, changing migration habits of Americans means fewer workers are moving to find new jobs (Austin, Glaeser, & Summers, 2018).

> "We have two STEM talent challenges in more rural areas: a warm body problem—having enough folks applying for jobs, and a right body problem—having job seekers with the right skills."
> Dr. Jill Zullo
> Vice President, Bioindustrials
> Cargill

All these factors and more have led to the concentration of the fastest-growing categories of jobs in large urban areas, especially on the coasts. Figure 7 shows the proportion of workers who hold jobs in categories that are shrinking, most prominent throughout the South and Midwest (Casselman, 2017).

Figure 7. Proportion of Population Employed in Occupations Projected to Decline in the Next Decade (Casselman, 2017)

The most
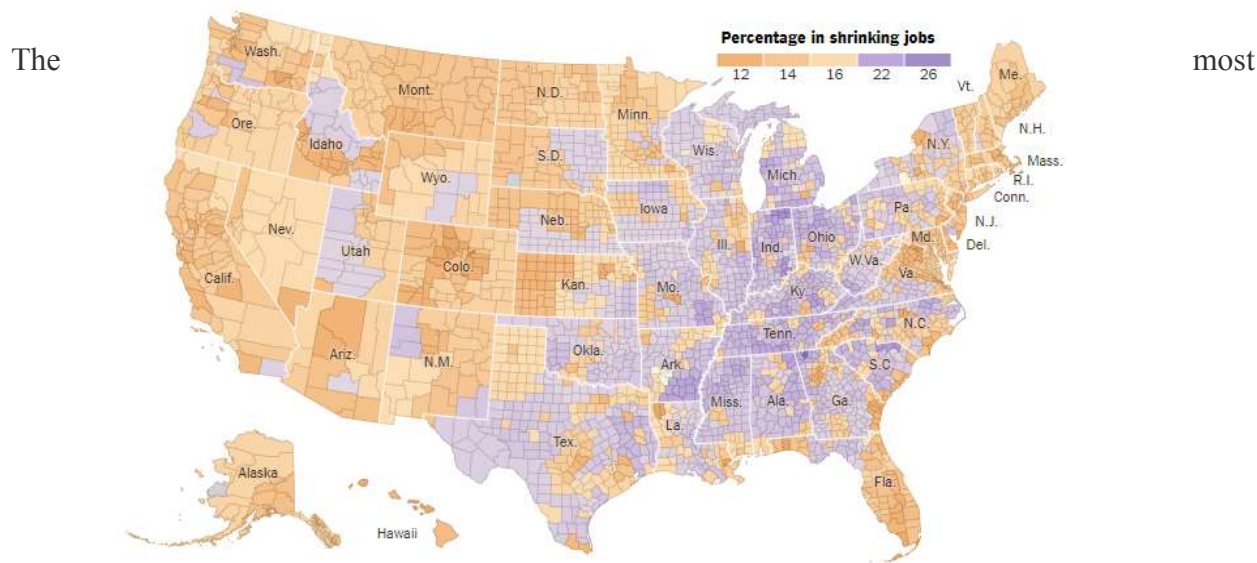
complex drivers of "shrinking occupations" are the confluence of economic and policy influences and geographic limitations (e.g., agricultural or other natural resources). In these areas, enhancing awareness of and access to postsecondary education may help mitigate some of these more intractable influences (Krupnick, 2018).

Jobs out of reach of local workforce

While some regions of the country are experiencing either a dearth of jobs or a decline in population, others have seen a tremendous growth in STEM- related jobs and companies. Those areas face a different geographic challenge in that they may have to import talent from other regions because the local populace is not equipped with the skills and knowledge to be viable candidates for these roles. In these

"As a community, we have attracted a lot of new people from other places to work in the growing STEM economy. But how can we better support the people who grew up here, who grew up down the street, to gain the skills they need to access these jobs?"
Chris Cervini
Associate Vice President, Community and Public Affairs
Austin Community College

cases, the jobs may be down the street but far out of reach of locals. This challenge is grounded in the interaction of poverty and place and occurs in part because of the lack of opportunity in certain neighborhoods and communities.

Demographic Gap

> "Equity is a key lever for closing the STEM gap, with the goal of having a STEM workforce that reflects the diversity of our customers and communities. Supporting efforts such as science encouragement programs and STEM scholarships for underrepresented and under-resourced students can help build a pipeline of diverse STEM talent. "
> Jacqueline Berry
> 3Mgives Global Communications Manager
> 3M

There is a well-documented, disproportionate participation in STEM education and careers among people of color and women, and those individuals from low-income backgrounds. This **demographic gap** remains, despite decades of focus on diversity and inclusion across race, ethnicity, gender, socioeconomic status, and other categories.

This gap will continue to present challenges as the demographic makeup of America changes. Recent studies project

Aspects of demographics that often impact STEM participation include:
- Race
- Ethnicity
- Gender
- Socioeconomic status
- English as a second language status
- Disability status

that the nation will be comprised of a majority of people of color in 2045, as the combined Hispanic, black, Asian, and multiracial population grows, and the current majority white population ages (Frey, 2018). Today, most public school students are non-white, and public schools are serving an increasing number of English-language learners ("The Condition of Education," 2016). More children in America have immigrant parents—an increase of 34 percent since 1990 (Batalova & Zong, 2017).

Nearly 29 million of today's children will live below the poverty line for at least one year before they turn 18 (Ratcliffe, 2015). Black children are three times as likely to be poor as white children. Half of students in our public schools are eligible for free or reduced-price lunch, meaning their families earn no more than 185 percent of the poverty line ("Public Elementary/Secondary School Universe Survey," 2016).

Access to resources drives achievement gaps

The STEM demographic gap is closely aligned to the achievement gap that has been the focus of education efforts for the last two decades ("School Composition," 2015). While the black-white and Hispanic-white achievement gaps have shrunk over time, the gap based on income has widened. The poorest students lag, on average, four years behind their wealthiest peers in academic performance (Garland, 2013). A student's race or income is highly predictive of academic outcome from 4th grade mathematics scores through postsecondary degree attainment.

The demographic and geographic gaps are closely linked, as neighborhood poverty continues to impact overall access to quality education, extracurricular activities, and technology in the home. Even the most motivated student will struggle if he or she attends a school without well-equipped teachers, if his or her parents do now know about or cannot afford enrichment activities, and if he or she cannot pay for college.

> "Diversity solutions in STEM fall short because we assume that merely inviting groups from underserved communities to have a seat at the table will lead them to participate—but what if they don't have a way to get to the table?"
> Gabriela A. González
> Deputy Director
> Intel Foundation

Bias and historic inequity remain embedded in our systems

Yet access to resources alone does not create the demographic gap. Increasingly, educators and employers are becoming aware of the existence of bias and discrimination, at the individual, organizational, and systemic levels. These forces are more complex, intransient, and uncomfortable than any others. Yet they will continue to impact the composition of the overall STEM talent pool, from K-12 education through postsecondary and into the workforce.

> "In addressing underrepresented communities, we need to listen more and talk less."
> Edwin Link
> National Vice President, Youth Development Operations
> Boys & Girls Clubs of America

The STEM Talent Path Forward

The five STEM talent gaps we have identified interact with each other across the STEM ecosystem—K-12, postsecondary education, and industry—and are pressured by the forces that sit outside the systems—technology, macroeconomy, policy, and media. This interaction creates an overall opportunity gap for individual students and job seekers, a workforce development challenge for educators, and a business imperative for employers.

Several operating principles emerged based on our refined understanding of both the STEM ecosystem and the STEM talent gaps. Any solution we seek must be guided by these principles or we will continue to see isolated impact, not progress at scale.

1. **Think systemically.** This requires a deeper appreciation of one's own position in the STEM ecosystem, and of the connections between elements of the system, and of the dynamic nature of complex systems. The below recommendations for action and investment should be interpreted and applied based on your understanding of your own unique role.
2. **Act in coordination and alignment.** There is neither a single solution to STEM talent outcomes, nor a single sector that can control them.
3. **Focus on the person.** Whether a student, a job seeker, or an employee, seek to be guided by the experience of the end user of your piece of the STEM ecosystem.

Path Forward for the Field

Recommendations for action and investment are divided into two distinct but equally important categories: enhancing practice within a system and creating a more enabling environment around and between those systems.

Enhance organizational and professional practice: Many field leaders and practitioners have identified effective practices to address STEM talent gaps. However, these practices are often applied inconsistently and with varying levels of rigor. More intentionality around the dose (quantity or intensity), frequency, duration, and standardization of these practices will allow them to reach their fullest expression and lead to the most positive outcomes. These practices may yield shorter term outcomes and can often be accomplished with single partnerships rather than a more expansive cross-sector collaboration.

A. **Expose students to STEM routinely**, both in and out of school settings. This exposure must begin with the earliest learning experiences and continue throughout their K-12 years, not just once, but many times and in many ways. A greater number and variety of exposure opportunities leads to stronger outcomes. Activities, programs, and people can provide such exposure. For example, out of school time

providers can embed age-appropriate STEM activities into their existing programming to provide more opportunities for students to engage with STEM.

B. **Embed experiential learning** curricula in and out of the classroom, throughout K-12, postsecondary education, and employment, to teach fundamental skills and make STEM real to students. This may include project-based and community-based learning, along with hybrid working and learning opportunities such as paid internships and apprenticeships. For example, K-12 schools can partner with local businesses to make paid internships a standard part of high school curricula for all students.

C. **Develop, translate, and provide navigation resources** and support along STEM pathways, ideally in conjunction with a strong mentoring relationship. The mentor can help coach the mentee through the key decision points and help the mentee access and interpret information. For example, postsecondary institutions can assign staff or volunteers as an advisor and mentor to meet regularly with each student, particularly those who are first generation college students, assisting with course selection and job exploration.

D. **Equip educators throughout the ecosystem** with preparation, training, and resources so they may effectively develop STEM skills in students and employees. Expand cross-sector and cross-discipline training and practice development for education (K-12 and postsecondary) and industry professionals. For example, postsecondary institutions can partner with business to offer externship programs to place faculty in business settings and business leaders in postsecondary classrooms.

E. **Evaluate aptitude, skills, and credential requirements** throughout the ecosystem. Redefine and clearly signal the types of requirements more routinely across sub-systems, and update processes for organizational decision-making accordingly. For example, employers can regularly review and update job descriptions, assessing the written description against the role needs based on input from different business units.

F. **Build a holistic set of supports and resources** around STEM learning and working pathways. Identify those personal, family, and community demands that impact success in school and work, and buffer them with programmatic and relational support. For example, K-12 institutions can partner with local nonprofit or government entities to assess student and family needs and offer referrals to support services around non-academic issues such as housing, food, and child care.

Create an enabling environment: The interconnectedness of the STEM talent gaps requires some solutions that move beyond a single professional, organization, or even system. These solutions allow best practices to come to scale and collaboration to thrive. These solutions seek to influence the forces that place pressure from *outside* each system, such as policy and media, or

to enhance connection *across* systems through clear information flows and intentional partnership. These are highly leveraged solutions but require a commitment to a longer time horizon and deeper cross-sector collaboration.

G. **Collect, analyze, and use organizational, systemic, and population level data.** Often data in the STEM space is limited to overall population level outcomes. Data on process changes, quality of practice, and system coordination can help decision-makers understand how and why the population outcomes shift. For example, postsecondary institutions can track the short, medium, and long term career path of graduates in order to use that information to shape curricula and partnerships.

H. **Align incentives** for organizations and individuals with overall STEM ecosystem talent goals. This includes professionals in education and business (e.g., teachers and HR managers), processes (e.g., testing and recruitment), and funding (e.g., university research grants). For example, employers can shift incentives for talent acquisition from activity-based metrics to impact metrics targeting business outcomes.

I. **Create, institutionalize, and target evidence-informed marketing campaigns** to different sectors within the STEM ecosystem. Changing the unclear, unproductive, and false narratives around STEM requires awareness and knowledge to change alongside practices. For example, national out of school time providers can work together to employ a social marketing campaign with age-appropriate STEM messaging delivered to students throughout their service regions. A word of caution: while shaping message and marketing is important, it is easy to choose this as a single solution or to ascribe too much influence to these forces.

J. **Connect with and/or be aware of cradle to career initiatives** in your communities and industry verticals. Many such efforts already exist and can create an amplifying effect on your investment and action. For example, employers can join a cradle to career effort in a market in which they have trouble securing local talent and share job needs and projections with education partners.

Each of these solution sets can be a powerful lever for change in STEM talent outcomes. However, the solutions are also meant to work together, just as the five STEM talent gaps work together to create the overall challenge we face. Any given solution set may impact a set of gaps, as illustrated in Figure 8.

Figure 8: Solution Sets That Address the Five STEM Talent Gaps
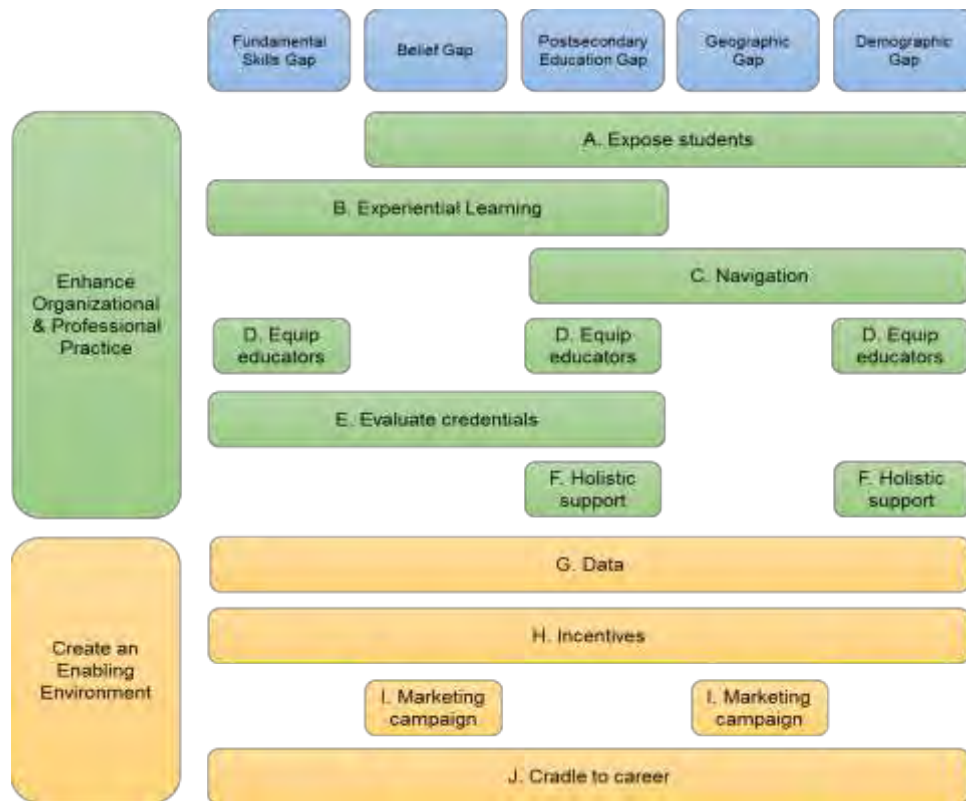
Change at scale on STEM talent challenges will only occur when we address all the gaps and begin to intentionally deploy all the solution sets. This does not mean that we must invest in every solution. Rather, it means we should take a portfolio approach across the gaps that are most pressing in our sphere of influence. We may invest deeply in a specific solution set alongside a funder who is focused on another set. No one actor need to "own" the entirety of solutions. But an investment will be much more leveraged with greater intention around the location and type of solution, and alignment with other efforts.

The choice of where to invest or how to change your own practice begins with an assessment of the challenge (or gaps) you face. Then you can move to selecting the solutions that are likely to be most impactful. This assessment process must occur regularly and should include questions about the dosage, frequency, and quality of intervention. Given the dynamic nature of work and many influences on the STEM talent ecosystem, a solution set that fits in one moment may not fit in another.

While the solution sets may appear simple, they must be deployed with a deep understanding of and appreciation for complexity of the STEM talent ecosystem and the gaps that emerge within it.

Path Forward for STEMconnector

STEMconnector will build on the research that produced this report to guide the content of our research, convenings, initiatives, and services. Our research and data will drive our decisions and be responsive to both member and market needs.

Throughout 2018, we will create a **detailed and interactive STEM ecosystem map** available via a digital interface, including specific organizations and their connections to each other. The map will further serve to identify areas for potential future collaboration.

We will also use the newly launched **Innovation Labs** as cross-sector platforms for discussion around the STEM talent gaps, to create more specific, actionable recommendations, and to apply and learn from the application of these recommendations.

In the next 18-24 months, we will produce **a series of briefs and resources** accessible to members covering other topics in the STEM talent ecosystem in greater detail. Each piece serves a different purpose or set of purposes—to more fully define a problem—to set out guiding principles for solutions, to outline solution sets, to document case studies, or to offer tools and resources.

Additional resources under consideration for 2019 include:

- STEM Strategy Resource Center: a compendium of strategy components for those investing in STEM
- Profiles of Corporate STEM Councils: a series of case studies detailing various options for their structure and function
- Global State of STEM, Country-level View: a deep dive in a single country outside the U.S. to better understand their STEM talent gaps

Conclusion

The STEM talent gap exists, though not in a manner that lends itself to easy counting and simple solutions. Rather, it is the sum and interaction of five different gaps across fundamental skills, beliefs, postsecondary education, geography, and demographics. These gaps emerge from a complex ecosystem of actors, organizations, systems, and influences.

At the heart of that complexity is an individual student, graduate, job seeker, or employee seeking to access to opportunity. The systems that surround, educate, and employ each of those individuals can accelerate and expand that opportunity by enhancing practice and building an enabling environment.

The *State of STEM* is both encouraging and challenging, full of potential and pitfalls, and calls us to move from awareness to action and, ultimately, impact.

Appendix

Methodology and Interview List

Secondary research

To produce this report, STEMconnector reviewed literature across STEM and related fields, including education and youth development, workforce development, economic mobility, technology, innovation, equity, and other disciplines. Information on these sources is captured in the endnotes and in the callout boxes.

Interviews and focus groups

STEMconnector gathered the perspectives of over 100 individuals through individual interviews, group interviews, and focus groups. All individuals interviewed touched the STEM ecosystem through a variety of functions—from executive leadership to frontline education. Individuals represent international corporations, national nonprofits, local nonprofit organizations, academia, foundations, and other organizations and institutions.

The following is a list of all individuals who participated, in alphabetical order of their organization, and then their last name.

Jacqueline Berry, 3M
Nancy Barcus, Agriculture Future of America
Andy Smarick, American Enterprise Institute
Crispin Taylor, American Society of Plant Biologists
Scott Heimlich, Amgen
Kassie Hilgert, Artsquest
Chris Cervini, Austin Community College
Abby Hollingsworth, Bank of America
Ingrid Ellerbe, Base 11
Landon Taylor, Base 11
Rob Evans, Battelle
Regina B. Schofield, Battelle
Shannon Fugate, Baum School of Art
Kevin Easterling, Black Heritage Association of the Lehigh Valley
Drew Glassford, Boy Scouts of America
Michael LoPresti, Boy Scouts of America
Edwin Link, Boys & Girls Clubs of America
Kathleen Martinez, BP
Jose Rosado Jr., Building 21
Dan Restuccia, Burning Glass Technologies
Menexia Tsoubeli, Campbell Soup Company
Jill Zullo, Cargill
Dan Barstow, CASIS
Kassie Davis, CME Group
Kathryn Nash, Cognizant

Ruthe Farmer, CS for All
Mark Hays, Dallas County Community College District
Jason Treadway, Dallas County Community College District
Al Bunshaft, Dassault Systèmes
Randolph Guschl, Delaware Foundation for Science and Mathematics Education
Tonie Leatherberry, Deloitte
Cindy Moss, Discovery Education
Suzanne Thompson, Discovery Education
Anna Watt, Discovery Education
Steve Peterson, Eaton
Bryan Contreras, ENCOURA
Melanie Goodson, ENCOURA
Mark Greenlaw, FIRST
Mark Rosenberg, Florida International University
Prashant Javkar, Ford Motor Company
Eileen Yang, Genentech
Nicole Smith, Georgetown University Center on Education and the Workforce
Chris Nowicki, Gulfstream
Jessica Katzbeck, Haven House
Sonya Smith, Howard University
Barb Bidan, Indeed.com
Gabriela González, Intel
Lori Beer, JPMorgan Chase & Co.
Dane Boyington, Learning Blade
Sheila Boyington, Learning Blade
Brendan Cotter, Lehigh and Northampton Transportation Authority
Layne Turner, Lehigh County Drug and Alcohol Services
Maggie Hadinger, Lehigh Valley Health Network
Brian Abel, Lehigh Valley Health Network
Carmen Guzman-McLaughlin, Lehigh Valley Health Network
Steven Braun, Mead Johnson Nutrition
David Neils, Mentored Pathways
Leigh Teece, Mentored Pathways
Janine Ingram, MIND Research Institute
Daphne Dorsey, Monsanto
Melissa Harper, Monsanto
Cheryl Davidson, Northwell Health
Lauren Pearson, Northwell Health
Mitzi Montoya, Oregon State University
Lori Molloy, North Penn Legal Services
Teri Haddad, PBS-39 Director of Education
Kevin O'Sullivan, PepsiCo
Deepali Palta, PepsiCo
Ignace Conic, Prudential Financial
Susan Croll, Regeneron
Angi Calkins, Regeneron

Donna Dimke, Regeneron
Potoula Gjidija, Regeneron
Michael Palis, Rutgers University-Camden
Ann Woo, Samsung
Jenny Kopach, Science Olympiad
John Loehr, Science Olympiad
Gerald Putz, Science Olympiad
Regina Stroud, Skyline College
Mark Garrett, Smithfield Foods
Alexander Alonso, Society for Human Resource Management
Johnny Taylor, Society for Human Resource Management
Kumar Garg, Society for Science and the Public
Ron Ottinger, STEM Next Opportunity Fund
Brian Jones, Strayer University
Balaji Ganapathy, Tata Consultancy Services
Lina Klebanov, Tata Consultancy Services
Lonnie Wishom, Tata Consultancy Services
Zach Levine, Teach.org
Tara Carcillo, The Clearing
Matt Davidson, The Robert D. and Billie Ray Center at Drake University
Stephanie Oppel, The Robert D. and Billie Ray Center at Drake University
Scott Raecker, The Robert D. and Billie Ray Center at Drake University
Olga Bolden-Tiller, Tuskegee University
Cara Gizzi, Underwriters Laboratories
Greg Washington, University of California, Irvine, Samueli School of Engineering
Beth Broome, University of California, Davis
Stan Elliott, University of Central Missouri
Leslie Flynn, University of Iowa
Tania Evans, University of Maryland Baltimore County
Michelle Hewitt, University of Maryland Baltimore County
Freeman Hrabowski, University of Maryland Baltimore County
Uchenna Osia, University of Maryland Baltimore County
Amanda Ross, University of Maryland Baltimore County
Greg Simmons, University of Maryland Baltimore County
Janet Marling, University of North Georgia
Marc Schulman, USA Science & Engineering Festival
Michelle Joseph, Verizon Foundation
Justina Nixon-Saintil, Verizon Foundation
Blair Bennett, Walmart
Becca Shaddox, Walmart
Lisa Raisor, Western Governors University

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