STEM^4: The power of collaboration for change

A joint document authored by Advance CTE, Association of State Supervisors of Mathematics, Council of State Science Supervisors, and International Technology and Engineering Educators Association

Background

As a nation we are falling short in preparing students for college majors or careers in the areas of science, technology, engineering, and mathematics (STEM). Too few high school graduates have the knowledge, skills, and experiences to be prepared for STEM fields. For instance, according to the National Science Board, 25% of twelfth graders achieved a level of proficient or higher in mathematics and 22% of twelfth graders achieved a level of proficient or higher on the NAEP science assessment in 2015.[1] Furthermore, there are significant racial and socioeconomic inequities that limit students' opportunities for careers or post-secondary study. Additionally, a recent survey conducted by PayScale Inc. cited that 60% of business leaders surveyed felt that recent college graduates do not possess the critical thinking and problem-solving experiences necessary for their jobs.[2] With rapidly advancing technologies, the concept of STEM careers is expanding beyond computer science and engineering. A growing number of fields impacted by technological advances, such as healthcare, telecommunications, advanced manufacturing, and the arts, are STEM careers.

The Major Issue

The future of our nation is dependent on the children in our care. In an age of continually advancing technologies and a society more global than ever before, we must do better in preparing our students to contribute to and thrive in their world. The reliance upon a high-quality, robust, and equitable STEM education system for our nation's children has never been more paramount. It has been estimated that 65% of the children entering elementary school today will ultimately end up working in completely new job types that have not yet been envisioned.[3] It is incumbent upon all stakeholders involved in STEM education to dedicate themselves, through collaborative efforts, to ensuring our children have the academic and experiential preparation necessary for them to pursue the STEM pathway of their choice that leads them toward college and career.

Acknowledging the need for change is not enough, however. Evidence indicates pervasive disparities in STEM preparedness based on race, ethnicity, language, socioeconomic status, and gender. Recent surveys of predominantly minority schools have indicated that:[4]

- **High schools with a majority African-American or Latino enrollment are less likely to offer math and science classes, especially at advanced levels.**
- **Only 38% offered calculus, compared to 50% of all high schools.**
- **Just 51%, offered physics, compared to 60% of high schools overall.**
- **Children living in poverty, on average, are four years behind in academic performance than children living at high income levels.[5]**

The most recent census projects that by 2045 the nation will become "minority white" as the combined multiracial populations grow and the current majority white population ages, indicating that these gaps are likely to increase without interventions that change the trajectory.[6]

Additionally, students' P-12 and after-school experiences should develop the skills needed to contribute to and live successfully in a global society. The World Economic Forum's Future of Jobs report cited that the top ten skills anticipated for 2020 will shift significantly from 2015.[7]

Top 10 Skills in 2015 were:

1. Complex problem solving
2. Coordinating with others
3. People management
4. Critical thinking
5. Negotiation
6. Quality control
7. Service orientation
8. Judgment and decision-making
9. Active listening
10. Creativity

Top 10 Skills in 2020 will be:

1. Complex problem solving
2. Critical thinking
3. Creativity
4. People management
5. Coordinating with others
6. Emotional intelligence
7. Judgment and decision-making
8. Service orientation
9. Negotiation
10. Cognitive flexibility

Source: Future of Jobs Report. World Economic Forum

These skills are not taught separately from content, but by strategically integrating the practices of science, technology, engineering, and mathematics as tools that students use to explain phenomenon and solve problems. To be fully prepared for college or the workforce, students' P-12 experiences must include the use of technology in authentic ways. The rate of change in technology is exponential; there has been more progress in the last five years in the areas of automation and Artificial Intelligence (AI) than in the previous fifty years.[8] Technology is not restricted to only digital technology. It is much broader and often misunderstood. Technology, in all forms, is how people modify the natural world to suit their own purposes – the collection of processes and knowledge people use to extend human abilities and to satisfy human needs and wants. These statistics create an urgent and constantly increasing need for schools to keep pace with technology offerings.

In many cases, access to resources drives achievement gaps, and oftentimes, poverty limits access: to quality education, to after-school activities and clubs, and to technology in the home. Additionally children of poverty often are negatively affected by lack of exposure to enrichment activities and/or financial access to college.[9] As a result, poverty is one of the key determinants of academic performance, and demographics are closely aligned to achievement.

Setting the Stage:

As a collaborative, we identified three main principles to drive and implement outstanding STEM education research and practices. Each principle represents a critical component of a complex system designed to ensure academic preparation and career awareness of STEM for all students, including explicit attention to STEM-specific opportunity gaps. Understanding these principles is critical for STEM stakeholders to achieve STEM preparedness.

Three Main Principles to Drive STEM Education

Principle 1

STEM education should advance the learning of each individual STEM discipline.

Principle 2

STEM education should provide logical and authentic connections between and across the individual STEM disciplines.

Principle 3

STEM education should serve as a bridge to STEM careers.

Principle 1: STEM education should advance the learning of each individual STEM discipline.

This principle allows for the integrity of learning the individual disciplinary concepts independent of integration and organic relationships.[10] The richness of the content from each discipline is delivered without changing the basic structure or purpose and emphasizing the rigor appropriate to the grade level as defined by high-quality standards (i.e., NGSS, CCSS-M, CCSS-ELA, STL, etc.). Research has demonstrated that a hands-on and student-centered learning approach in which students design solutions to authentic problems is far more effective than rote learning.[11] All students should be held to high academic expectations, and all stakeholders must work to dismantle systemic inequities and unproductive beliefs about students' abilities.

Principle 2: STEM education should provide logical and authentic connections between and across the individual STEM disciplines.

The academic disciplines of science, engineering, and mathematics contain natural, coherent connections for students at all ages starting in early childhood.[12] Technology serves as a means for highlighting these coherent connections and engaging with the creative thinking and problem solving required by authentic, real-world scenarios.[13] This integrated view of STEM education serves as a theoretical and pedagogical premise, driving the necessary knowledge and understanding to develop appropriate solutions to human issues and needs. All four disciplines work together as students engage in design challenges, laboratory experiences, and tasks that integrate the disciplinary concepts. All students must have access to appropriate technology and experiences that integrate the STEM disciplines authentically. Comprehensively, these experiences serve to support students as they elicit the relevant mathematical or scientific ideas in a technology and engineering context, connect ideas productively, and reorganize their conceptual understandings.[14]

Principle 3: STEM education should serve as a bridge to STEM careers. Student interest and confidence in STEM are strongly correlated with postsecondary success in STEM fields.[15] Ineffective STEM education rarely includes career counseling, curricular connections to business and industry, or any formal means to increase students' awareness of, interest in, and motivation to pursue STEM-related careers. Effective STEM education, on the other hand, prepares students to transition to any next step they choose, including two-year institutions, four-year institutions, military options, or direct paths into the workplace. Career advising should be a key component of a STEM education. For example, meaningful interactions with industry experts and authentic experiences within STEM workplaces can help students make connections to academic content and explore their STEM-related interests. By partnering with businesses and industries, schools can offer integrated coursework and projects that support academic as well as career and technical program standards. These types of collaborative partnerships among P-12 systems and business, industry, the arts, and higher education institutions are required to ensure all students have knowledge about and access to STEM-related post-secondary career pathways.[16]

Recommendations:

As a result of our four organizations coming together to envision integrated STEM efforts amongst ourselves, we have created a list of recommended actions that may be taken to shift toward the access to and equity in STEM preparedness that we believe to be so crucial.

Principle 1: STEM education should advance the learning of each individual STEM discipline.

Recommended Actions:

- Ensure policies, practices, and resource allocations provide access and equity for all students to a high-quality STEM education.
- Hold policymakers, schools, and educators accountable for equitable preparation of students.
- Provide all students a full range of math and science courses.[17]
- Offer high-quality science, mathematics, engineering, and Career Technical Education (CTE) programs at the secondary and post-secondary levels.
- Ensure high-quality professional learning for teachers focused on STEM content, practices and pedagogy.
- Provide access to industry experts for teachers to better understand the STEM workplace.
- Use innovative approaches to attract experienced STEM teachers to serve high-needs schools.
- Leverage federal funding (i.e., Carl D. Perkins Career and Technical Education Act of 2006 [Perkins], Every Student Succeeds Act [ESSA], Title II, Title IVa, etc.) to promote and support STEM pathways.[18]

Principle 2: STEM education should provide logical and authentic connections between and across the individual STEM disciplines.

Recommended Actions:

- Begin STEM experiences in the earliest grades possible, including birth to PK programs to provide equitable starts for children.[19]
- Engage families in STEM learning to support parental perceptions of STEM.
- Implement instructional models such as project-based/problem-based learning to master technical and academic content in context of a specific pathway.[20]
- Ensure an integrative STEM education approach in designing and delivering STEM activities, lessons, and units.
- Offer courses in engineering design and CTE to all students.
- Engage students with meaningful, STEM-focused, in-school and out-of-school experiential learning opportunities (e.g., clubs, seminars, competitions, etc.).

Principle 3: STEM education should serve as a bridge to STEM careers.

Recommended Actions:

- Establish preschool and early childhood programs to provide equitable starts for children.
- Require career counseling to help students and families have a greater understanding of careers and college majors including those that are STEM-related.
- Make technology available on an equitable basis for use in improving student learning and enhancing teacher professional development.[21]
- Provide materials that inform families about pursuing STEM courses and careers[22] and provide students opportunities to explore STEM careers through on-site visits and other extra-curricular activities.
- Create school cultures where families are welcomed to participate in their student's STEM education, and enable all students, especially underserved and underrepresented students, to be successful with STEM learning.
- Provide resources needed so all students are prepared for the post-secondary options of their choices and become STEM-literate citizens.
- Research and apply successful models[23] to challenge the belief that underserved and underrepresented students cannot learn STEM and/or pursue STEM career pathways.
- Partner with STEM businesses to provide paid internships for teachers to better understand the STEM workplace.

Final Thoughts:

This paper is the product of an organized and coordinated effort among the leadership of our respective organizations to address the challenges faced when implementing STEM education and providing access to the knowledge, skills, and career pathways necessary for all students, particularly those in underserved populations. Across our disparate work, each organization has recognized the need for systemic change in STEM policies and practices in order to serve the nations' children, close opportunity gaps, and address systemic inequities. Our shared belief, that all students can and should be prepared for STEM-focused careers or college studies, anchors our commitment to collaborate integratively in order to foster systemic change. Because we envision a truly integrated system of STEM education, we envision other STEM stakeholders sharing their expertise and joining our work towards improving the STEM education system. As organizations, we stand steadfast in the belief that this type of cohesive collaboration is necessary to ensure that all students have access to and opportunity for STEM-focused college and career experiences. It is our fervent hope that this paper, the product of our integrated efforts, will help to catalyze the necessary changes required to fuel better outcomes for our students, our society, and ultimately, ourselves.

Representatives from the following associations were integral to the development of this guidance:

Advance CTE
http://careertech.org
- *Kate Blosveren Kreamer – Deputy Executive Director*
- *Ashleigh McFadden – State Policy Manager*

Association of State Supervisors of Mathematics (ASSM)
http://statemathleaders.org
- *Joleigh Honey – Vice President for Membership*
- *Levi Patrick – Vice President for Program*

Council of State Science Supervisors (CSSS)
http://cosss.org
- *Tiffany Neill – President*
- *Doug Paulson – 3rd Year Board Member*

Council of Chief State School Officers
- *Ashley Cheung Dooley – Program Manager*

International Technology and Engineering Educators Association (ITEEA)
https://www.iteea.org
- *Steven Barbato – Executive Director and CEO*
- *Dr. Jennifer Buelin – Director, ITEEA STEM Center for Teaching and Learning*
- *Dr. Anita Deck – STEM CTL Director, Innovation, Assessment, and Research*

Next Gen Education, LLC
- *Peter McLaren – Executive Director*

Our organizations would like to thank Texas Instruments for its generous support in the creation of this document.

References

[1] National Science Board (2018, January) *Science & Engineering Indicators 2018*. Retrieved from https://www.nsf.gov/statistics/2018/nsb20181/report/sections/elementary-and-secondary-mathematics-and-science-education/highlights

[2] Straus, K. (2018, May 17) *These Are the Skills Bosses Say New College Grads Do Not Have*. Retrieved from https://www.forbes.com/sites/karstenstrauss/2016/05/17/these-are-the-skills-bosses-say-new-college-grads-do-not-have/#72ad01db5491

[3] Pethohoukis, J. (2018, January 8). Yes, AI can create more jobs than it destroys. Here's how [Web log post]. Retrieved March 22, 2018, from http://www.aei.org/publication/yes-ai-can-create-more-jobs-than-it-destroys-heres-how/

[4] Jones, C. (2018, May 22). *Latino, African-Americans have less access to math, science classes, new data show*. Retrieved on May 23, 2018 from: https://edsource.org/2018/latino-african-americans-have-less-access-to-math-science-classes-new-data-show/598083

[5] Bohmstedt, G. (2015, September 22). *School composition and the Black-White Achievement Gap*. Retrieved on April 14, 2018 from: https://nces.ed.gov/.../school_composition_and_the_bw_achievement_gap_2015.pdf

[6] Frey, W. H. (2018, March 14). *The U.S. will become "minority white" in 2045, Census projects*. Retrieved on April 14, 2018 from: https://www.brookings.edu/blog/the-avenue/2018/03/14/the-us-will-become-minority-white-in-2045-census-projects/

[7] Schwantes, M. (2017, November 24). *Research says this required job skill will trump emotional intelligence by the year 2020*. Retrieved on April 14, 2018 from: https://www.inc.com/marcel-schwantes/study-you-will-need-this-top-job-skill-to-succeed-in-age-of-robots-by-2020.html

[8] White, E. (2018, May 18). *State of STEM: Defining the landscape to determine high-impact pathways for the future workforce*. STEMConnector. Retrieved from https://www.stemconnector.com/state-stem-report/

[9] White, E. (2018, May 18). *State of STEM: Defining the landscape to determine high-impact pathways for the future workforce*. STEMConnector. Retrieved from https://www.stemconnector.com/state-stem-report/

[10] Honey, M., Pearson, G., Schweingruber, H. (2014) *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, D.C.: National Research Council

[11] Ibid.

[12] McClure, E. R., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N., & Levine, M. H. (2017, February 2). *STEM starts early: Grounding science, technology, engineering, and math education in early childhood.* Retrieved from: http://joanganzcooneycenter.org/publication/stem-starts-early/

[13] Honey, M., Pearson, G., Schweingruber, H. (2014) *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, D.C.: National Research Council

[14] Ibid.

[15] Sawchuk, S. (2018, May 22). *Is STEM oversold as a path to better jobs?* Retrieved from: https://www.edweek.org/ew/articles/2018/05/23/is-stem-oversold-as-a-path-to.html

[16] Traphagen, K., Traill, S. (2014, February). *How cross-sector collaborations are advancing STEM learning*. Retrieved from: http://www.noycefdn.org/documents/STEM_ECOSYSTEMS_REPORT_140128.pdf

[17] Sawchuk, S (2018, April 25) *High Schoolers Should Take 4 Years of Leaner, More Relevant Math, Teachers' Group Says*. Retrieved from http://blogs.edweek.org/edweek/curriculum/2018/04/high_school_math_vision_nctm.html?cmp=eml-enl-cm-news2&M=58475626&U=

[18] Klein, A. (2018, April 28) *How Can Districts and States Use ESSA to Bolster STEM and Computer Science?* [Web log post] Retrieved from: http://blogs.edweek.org/edweek/campaign-k-12/2018/04/how_can_districts_and_states_computer_science.html?cmp=eml-enl-et-news1&M=58485712&U=

[19] Maltese, A.; Tai, R. (2010) *Eyeballs in the Fridge: Sources of Early Interest in Science*. International Journal of Science Education. v32 n5, 669-685.

[20] Advance CTE (2013, December) *CTE is your STEM strategy*, Retrieved from: https://careertech.org/sites/default/files/CTEYourSTEMStrategy-FINAL.pdf

[21] Mathematical Science Board. (1997). *Toward Excellence in K-8 Mathematics*. Washington, DC: National Research Council.

[22] Harackiewicz, J (2018, May 22). *To hook students on STEM, start with their parents*. Retrieved from: https://www.edweek.org/ew/articles/2018/05/23/to-hook-students-on-stem-start-with.html?cmp=eml-enl-eu-news2&M=58500585&U=2733377

[23] Jones, C. (2018, May 22). *Latino, African-Americans have less access to math, science classes, new data show*. Retrieved on May 23, 2018 from: https://edsource.org/2018/latino-african-americans-have-less-access-to-math-science-classes-new-data-show/598083