Challenges and Digital Solutions with STEM Learning

Anne Mangahas, *University of La Verne, USA,*
Kathleen J. Tate, *American Public University System, USA,*
and Kevin Harris, *Stillman College, USA*

Abstract

Encouraging active interest while building engagement in Science, Technology, Engineering, and Math (STEM) fields in secondary and higher education is challenging for many educators. Significant barriers that pose difficulties for high school and college students in STEM learning and proposed solutions to better support their achievement are included. A focus on digital solutions is provided that has implications for supporting both K-12 schools and universities that offer increased online and hybrid learning since the emergence of Coronavirus Disease 2019 (COVID-19).

Keywords: STEM, science, math, college, higher education, barriers, digital, online, disabilities, English Language Learners (ELLs), digital divide

Desafíos y soluciones digitales en el aprendizaje CTIM

Resumen

Fomentar el interés activo mientras se desarrolla el compromiso en los campos de Ciencias, Tecnología, Ingeniería y Matemáticas (CTIM) en la educación secundaria y superior es un desafío para muchos educadores. Se incluyen las barreras significativas que plantean dificultades para los estudiantes de secundaria y universitarios en el aprendizaje de CTIM y las soluciones propuestas para apoyar mejor su logro. Se proporciona un enfoque en soluciones digitales que tiene implicaciones para apoyar tanto a las escuelas K-12 como a las universidades que ofrecen un mayor aprendizaje en línea e híbrido desde la aparición de la enfermedad del coronavirus 2019 (COVID-19).

Palabras clave: CTIM, ciencias, matemáticas, universidad, educación superior, barreras, digital, en línea, discapacidades, estudiantes del idioma inglés (ELL), brecha digital

doi: 10.18278/jolrap.8.2.3

STEM学习的挑战与数字解决方案

摘要

对许多从事中学和高等教育的教师而言，在鼓励活跃兴趣的同时还要促进参与科学、技术、工程和数学（STEM）领域一事是具有挑战性的。本文描述了为高中生和大学生的STEM学习带来困难的一系列显著障碍，并提出了更好地支持学生成绩的一系列解决方案。聚焦于数字解决方案，其对支持K-12学校和大学而言具有意义，这些机构自2019冠状病毒病（COVID-19）爆发以来提供了更多的网络学习和混合学习。

关键词：STEM，科学，数学，大学，高等教育，障碍，数字，网络，残疾，英语语言学习者（ELLs），数字鸿沟

Though Science, Technology, Engineering, and Math (STEM) continue to be at the forefront of many educational agendas, little progress has been made over the last couple of decades (De and Arguello, 2020) with including a wider variety or enough learners into programs. The National Academies of Sciences, Engineering, and Medicine (NASEM) (2016) wrote that the "very culture of STEM presents both barriers and opportunities for successful degree completion for all students" (p. 2). They point out there are many routes for students, but "institutional, state, and national education policies have not been developed to support the various pathways that students are now taking to earn a STEM degree" (p. 2). NASEM purports that students' degree progress is slowed as they are deterred from transferring due to articulation policies or lack of them. They explain that "diminishing funding from state and federal sources have led some universities to adopt the practice of charging differential tuition" (p. 2) and this may particularly affect females and underrepresented minorities. Prior to admission to two-year or four-year STEM programs, a variety of barriers exist for students and educators at a time with increased demand for STEM professionals to enter the workforce.

Trends and Needs

In their study, Ramsey, and Baethe (2013) explored aspects that promote future success in STEM careers and found that critical thinking through meaningful application of concepts determined success and continued interest of college science majors. Similarly, Arum, and Roksa (2011) studied 2,400 college students at 24 different universities over a four-year period and found that critical thinking and other skills like writing were no longer progressing during college as compared to previous generations of students. The possible causation of these findings from secondary education might be attributed to an increase in high-stakes assessments, which may reduce students' need to apply critical thinking skills through meaningful application of content. David (2011) declared that "state tests tend to rely on easy-to-score questions that measure basic skills and recall instead of higher-order thinking" (para. 3). Diminishing meaningful opportunities for students to apply the content as result of the high-stakes movement in assessment may also affect motivation in STEM learning. Sheldon and Biddle (1998) found that when rewards and sanctions were attached to test performance, students became less intrinsically motivated to learn and less likely to engage in critical thinking. They went on to say that attaching a high-stakes nature to assessments also obstructs students' paths to becoming lifelong, self-directed learners. The Center for Energy Workforce Development (CEWD) (n.d.) presents problem-solving, creativity, inquiry, engineering design-thinking, critical thinking, and collaboration as some of the essential skills needed for STEM and explains that effective STEM learning requires a combination of critical thinking skills: analyzing information, evaluating designs, reflecting on thinking, synthesizing new ideas, and proposing creative solutions. CEWD emphasizes that all those skills are essential to becoming an independent, critical thinker. Skill development is clearly crucial. Hayes (2017) shared that:

> …results from ACT-tested students who graduated in 2016 indicate that among the students who expressed interest in pursuing a STEM major or field after high school, only about one-fourth (roughly 225,000) met the ACT STEM Benchmark"… [and thus] …approaches meant to widen the STEM pipeline by drawing in students not currently interested in STEM are rendered less effective due to levels of preparation, for postsecondary education generally and STEM majors more specifically, which are even lower than those of STEM-interested students. (p.1)

Hayes (2017) added that the onus is on policymakers to ensure schools and teachers are equipped with necessary resources for students choosing STEM trajectories to "have the precollege academic preparedness to succeed in their college coursework" (p. 2) as they are not adequately prepared for postsecondary courses "necessary to join the STEM workforce" (p. 2). In addition to lack of readiness, Hayes explained that U.S. STEM occupations grew by 10.5 percent from May 2009 to May 2015, which is more than twice the rate of growth of non-STEM occupations and that "the U.S. Bureau of Labor Statistics projects that computer occupations alone will create nearly 500,000 new jobs between 2014 and 2024" (p. 1). A recent report echoes the call for increasing students' interest and skills for STEM and STEM-related careers.

(ISC)2 (2019) highlighted job shortages exceeding 500,000 in the cybersecurity field.

Randazzo (2017) made similar points:

> …lack of STEM access is a critical equity issue in education, particularly for students in urban and rural communities, where access to high-level math and science courses is often out of reach. Soon, the impact of students living in STEM deserts will not only be reflected in those students' high school and college competition rates, but will also take a toll on the country's technological superiority, its economy and national security.

While the need to increase the number of individuals from underrepresented communities in technical careers has long been recognized, it can now be viewed as a needed component to strengthening the U.S.'s ability to protect itself as cyber-attacks continue to rise. Aside from more traditional STEM occupations, the need to raise inclusivity and diversity levels in technology could translate into strengthening the country's security posture. Iversen (2019) wrote "cybersecurity education could reinforce arguments casting STEM education as a benefit to students and country alike" (para. 3). The need for students to enter college with strong STEM skills and persist through degree programs is at a critical point.

Inclusivity, Diversity, and Access

Getting diverse learners into the STEM pipeline continues to be a challenge. Tate and Tripp (2007) discussed statistics related to lower participation of girls as compared to boys in upper-level math and science classes and the outperformance of boys over girls in standardized math and science tests and that in the early 2000s, "18 to 25 percent of all scientists and 10% of engineers were women" (p. 77). More recently, the National Science Foundation (2015) highlighted that people with disabilities along with women and racial minorities are still considered underrepresented groups in STEM. Funk and Parker (2018) reported increases as well as decreases in representation of women in STEM fields and continued lack of representation of minorities. Diversity challenges and access to STEM curriculum and careers continue and extend to factors beyond gender and disability to include cultural, linguistic, and more.

Cultural Diversity

In considering how the teaching of math and science affects student motivation and how students see themselves as being valid contributors to the field, it is worthwhile to note that students observe how content is presented in the way teachers emphasize the valid contributors to the field. This ultimately influences how students see themselves *fit* within the narrative of STEM.

In recent studies, Bauer-Wolf (2019) noted that Latinx and African

American students leave the STEM fields at far higher rates than their white peers. The White House Initiative on Educational Excellence for African Americans showed that in 2012 in the area of science and engineering, only 11.2% of bachelor's degrees, 8.2% of master's degrees, and 4.1% of doctorate degrees were awarded to women of color. While women received over half of the bachelor's degrees awarded in the biological sciences, they received far fewer in the areas of computer science (17.9%), engineering (19.3%), physical sciences (39%), and mathematics (43.1%). In exploring these statistical anomalies, what is it, within the infrastructure of STEM teaching that might be drawing underrepresented student populations out of these disciplines and into other careers? According to Gholston-Key (2010), cultural diversity in content presentation is the key to engaging students of color into STEM disciplines:

> Science curricula and science classrooms have been devoid of relevant cultural inclusion or multicultural education. Many science educators believe "science is pure" and thus escapes the influences of current pedagogy, trends, and especially cultural influences. Even though science processes are generic or "culture free," if students cannot and do not identify with information that are "processing," they may internalize the notion that they cannot perform science or are not expected to process scientific information. The process of validating and/or correcting perceived notions depends on one's culture. Multicultural science or culturally inclusive science is believed to be an enhancement for students of color. (p. 1)

Scott (2018) emphasized the ongoing practice of using outdated science textbooks that primarily showcase images of white, middle-aged men and recommended that educators "represent science and scientists in a way that all students can see themselves in the field" (p. 73). Photos, art, books, texts, online resources, and articles should show breadth of science contributors in terms of people, locales, and cultures across K-12 and higher education classrooms.

Linguistic Diversity

Inclusive education considers the strengths and needs of all diverse students and should provide opportunities for English Language Learners (ELLs) to access STEM curriculum. A joint study by Lancaster and Sheffield Universities found that language proficiency influences learners' abilities to answer scientific questions. Because ELLs are still developing proficiency in their second language, the learning of new terminology in the sciences as well as inclusion of next generation science standards further increases language demands placed upon them (Lancaster University, 2019). A focus on vocabulary building for all students, especially ELLs, should be a focus during science and STEM instruction in K-16+ settings.

Neurodiversity

Friedensen (2018) wrote that "more students with a range of disabilities from impairments in mobility, intellectual disabilities, and mental health conditions are enrolling in postsecondary education institutions" (para. 1) than in previous years. The National Center for Educational Statistics (n.d.) reported that in 2011–2012, students who met American with Disabilities Act of 1990 (ADA) requirements comprised 11% of those students enrolled; and in 2015-2016, that increased to 19%. Even as these numbers rise, fewer students in this category persist to graduation relative to their peers without disabilities, and even fewer graduate with degrees in STEM (Friedensen, 2018). Thus, it is important to explore the ways in which greater inclusivity is addressed in the curriculum to support students with disabilities and encourage their participation in STEM fields.

The Digital Divide

In exploring the reasons for a decline in participation and motivation in STEM fields, it is important to consider issues related to technological access and the digital divide among low-income households and school districts. According to Brown (2018), "lack of access to technology creates a technology divide that begins at the elementary educational level and impacts students' postsecondary educational careers. A relationship exists between the use of digital media and student academic achievement" (para. 2). A lack of access perpetuates this digital divide such that in 2013, 89% of college graduates compared with 37% of non-high school graduates had high-speed Internet access at home (Zickuhr & Smith, 2013), and the Pew Research Center shared that 98% of college graduates used the Internet in 2021 compared with 79% of non-high school graduates in 2019. Numbers are increasing as gaps continue.

Beyond Internet access are issues with the availability of technology programs, such as computer science and robotics to high-need school districts due to underfunding. With increased access to these programs, there is also a concern that teachers in these schools do not have the necessary training and needed skills to provide meaningful opportunities to engage their students in applied STEM environments (Herold, 2017). With shifts in enrollments during COVID-19, funding and resources have decreased for some universities and many college students in Gupta et al.'s (n.d.) study expressed concern about diminished learning experiences without in-person classes and network-building.

COVID-19

Persistence among science-interested college students has been compromised because of the COVID-19 pandemic. Gupta et al. (2021) found in their study that nearly 50% of college student participants declared "that their academic trajectory has been greatly or moderately affected by the pandemic" (para. 2). Various concerns were shared such as fears about performance in a remote learning setting, physical displacement (e.g., moving out of dorms), and loss of opportunities such as relationships, networks, and internships. Gupta et al. (n.d.) explain their Summer 2020 alumni survey revealed that "more than 65% of program graduates were seeking or had secured internships and summer jobs in STEM fields… [and that] these employment opportunities had since been cancelled" (p. 4). College students need new pathways for connection and support to help them persist and complete their courses and programs successfully.

Proposed Solutions

As K-12 schools and higher education institutions continue to navigate offering in-person, virtual, and hybrid instruction, there are a variety of considerations for providing solutions to counter recent and emerging STEM learning barriers. These proposed solutions are applicable across different types of classrooms with a focus on online settings, and they address the skill development, resources, teaching approaches, diversity (e.g., cultural, linguistic, special needs), digital divide issues, and other college-specific challenges (e.g., networking, remote learning, etc.) for more successful STEM learning.

Skills

To provide more meaningful opportunities for students to engage higher-order critical thinking skills in STEM instruction, project-based and problem-based strategies are key. Including more relevant and authentic application activities for students to connect their learning to solving complicated scenarios across subjects is important. De and Arguella (2020) pointed out that "novel discoveries have become a cross-disciplinary process, and modern science is most active at the interface between disciplines, requiring individuals from multifaceted backgrounds with varied perspectives to solve complex problems" (p. 1). The National Science Teaching Association (NSTA) (2020) recommends interdisciplinary instruction and experiences that prompt long-term, sustained interest into adulthood" (para. 1) and drawing from A Framework for K–12 Science Education, it points out that decision making in the 21st century will require citizens to have abilities to "frame scientific questions pertinent to their interests; evaluate complex social, civic, economic, political, and personal issues; seek out relevant data and scientific argument; and communicate…understandings and arguments to others" (para. 1). This is a call for K-16+ educators to collaborate across disciplines: with other educators and experts from the community and field. Embedding STEM concepts and skills into authentic scenarios that interest students and require additional subject-area concepts and skills should better prepare them for college and beyond. Lessons should require students to collaborate and find solutions to societal problems, and example activities include creating animal habitats and homes to keep local pets warm, building strong bridge models to withstand severe climate, and planting community gardens to help with hunger challenges. These activities may then be scaled from desk-size to community-size. These problem-based scenarios require skills in STEM as well as economics, sociology, and language arts, to name a few. When students are learning at a distance, teachers and professors may use virtual meeting rooms via Zoom, Mozilla Hubs, or Adobe Connect to foster collaboration and provide materials to students through mail or other means so that students have hands-on sessions. Students/student groups do not need to engage in the exact same activities as the focus should be on skills and concepts driven by interests.

Modeling prior to group project work should help with skill building. Modeling is an option synchronously through live sessions in virtual meeting rooms, or asynchronously through pre-recorded videos that students may view and then discuss at their own pace. Using shorter presentation structures as through PechaKucha, with multimedia slides that are 20 x 20, or 20 slides in length and 20 seconds per slide, should better engage students and allow them to focus on targeted skills and concepts due to the succinct format. This type of digital tool allows for educators to teach in an engaging way and prompt uncomplicated collaboration at a distance as students of any age may discuss, plan, contribute to, and present slides as well.

Encouraging students to think creatively and providing safe environments for them to take risks in their learning promotes the belief that failing is part of the learning process. This increases the knowledge that in STEM, part of achieving success is through the process of attempting problems through multiple iterations until a solution is devised to tackle complex issues. Multiple iterations are part of the engineering design process, which parallels the process that artists follow in that "engineers must make a plan, be creative, and attend to considerations, test, and improve their original plan" (Tate et al., 2018, p. 31). Helping students identify and discuss fields and jobs where creative problem-solving, improving, and redoing are required may help K-12 and college students embrace those skills.

Diversity

Educators should begin to view students through a growth-mindset (Heggart, 2015; Prothero, 2020), leaving behind deficit thinking in working with underrepresented and/or neurodiverse groups. The goal is to see them as capable of academic achievement, just as any other student, if given the proper accommodations that allow for their success. STEM teachers should consider the ramifications of the weed-out culture that has traditionally dominated the field and explore opportunities that provide students access to the curriculum through scaffolding and support. Thompson (2021) stated that, "we know…weed-out courses do not weed out students evenly (para. 4). Thompson (2021) found that first-year STEM grades accounted for 19% of the total difference in persistence rates (para. 9) and suggests that colleges rethink grading curves and offer pass/fail courses. At the classroom level, attempts should be made to use Universal Design for Learning principles in the teaching and development of STEM curriculum to provide students with multiple instructional pathways, enabling them opportunities to both receive content and represent their learning through varied means.

To better engage students in STEM content, educators should consider ways to decolonize their syllabi. Though, Ahadi and Guerrero (2020) declared it is easier to implement syllabus decolonization within non-STEM disciplines. However, they support instructors ensuring STEM courses serve students better. Culturally inclusive science has the potential of integrating learners' cultures into the academic and social context of the science classroom aiding and supporting science learning (Baptiste & Key, 1996; Boisselle, 2016). One approach is to integrate the learning of the traditional science curriculum with the cultures of students represented in the classroom and beyond.

Student achievement is influenced by several factors including student attitudes, interests, motivation, type of curricula, relevancy of materials, and the culture of the students (Banks & Banks, 1995). The White House Initiative on Educational Excellence for African American Students (n.d.) encourages strategies that enable students of color to receive additional support through mentorship, academic support services, and growth-mindset strategies to develop resilience. Underrepresented K-12 students should be provided more meaningful opportunities to apply STEM learning through after-school programs and museum visits. Leveraging online museum visits and resources is applicable to K-16+ students and their instructors. Infusing multicultural literature, art, photography, poetry, and music to help students learn and engage in STEM skills and concepts is an exciting option for in-person, online, and hybrid classes.

English Language Learners

In developing lessons to better engage English Language Learner (ELL) populations, mindful language planning should be integrated for what students will be reading, writing, listening, and speaking about in their classroom processes and products. Teachers should survey their curricular resources to assess if any textual features might pose problems for ELLs in their classrooms. Wu et al. (2019) suggested that when bridging the gap for ELLs in science, "hybrid language affords the opportunity for students to communicate through various modes, including natural language, visual representations, mathematical expressions, and manual-technical operations" (p. 24). ELLs, various students with disabilities, and learners in general benefit from visuals —viewing and creating them—as well as interactive, hands-on lessons that include viewing key vocabulary before, during, and after a learning experience and socially constructing understandings through reading, writing, speaking, listening, journaling, dramatizing, and negotiating. "Studies have shown that language learners especially benefit from more active learning techniques (i.e., creating mental linkages of concepts) that enable them to organize information and retrieve new information they learn (Oxford, 1990)" as cited in Lee et al. (2020). For example, when studying erosion, Wu et al. (2019)

found that "students who connected their written claims with visual representations…tended to construct stronger arguments than those who did not make connections between text and visuals" (p. 24). STEM educators need to set the classroom stage for success by using effective pedagogical practices.

Lancaster University (2019) explained that the current underrepresentation of linguistically diverse learners in STEM postsecondary education needs to be addressed now and that one of the most challenging aspects is vocabulary. Insufficient vocabulary leads to lower assessment outcomes and possibly less self-esteem. Lee et al. (2020) recommend that instructors encourage ELLs to "participate in conversations, read articles, or listen to relevant media…[to help] them rehearse their language skills" (p. 29). These approaches to building vocabulary may be done independently or collaboratively in groups and set up at a distance.

Lee et al. (2020) suggest asking students to sort and organize vocabulary. They also recommend modeling the reading of texts/lab texts highlighting previously learned words while asking students to make connections, answer questions, summarize, and predict. Lee et al. (2020) explained that having students discuss lab reports prior to writing, providing models of lab reports, and allowing oral presentations in lieu of written reports are helpful approaches. They shared that assessment questions should include visuals such as illustrations and graphs. Allotting time for and using these approaches in traditional, online, and hybrid classrooms ideally yields more positive outcomes across STEM courses for ELLs and students in general who are struggling readers, less verbal-linguistic learners, or experiencing a learning disability.

Students with Special Needs

Friedensen (2018) pointed out that students with various disabilities have different outcomes when persisting in STEM fields. Referring to some research, she explained it has shown:

> …that students with autism spectrum disorder (ASD) persist in STEM fields at levels similar to peers without disabilities and may even possess some STEM-specific advantages arising from their unique cognitive processing. Similarly, the challenges presented by a classroom environment may be different for d/Deaf students or students with hearing impairments than they are for a student with a processing disability, physical disability, or ADHD. Some students have high-incident, non-apparent disabilities—that is, disabilities such as dyslexia and ADHD, which are common among college students and often cannot readily be discerned by untrained observers. (para. 5)

The implication is for higher education institutions to have supports in place for students with special needs, especially in STEM departments. Training educators is a first step in developing a strong support system. Friedensen (2018) stated that instructors are sometimes "hostile or indifferent to providing requested accommodations" (para. 8). Helping faculty members understand laws, evidence-based strategies, and disability-specific theories and practice will likely better equip them to teach students with special needs. Friedensen explained that some faculty members reported a lack of guidance with STEM-appropriate accommodations from disability services departments. Professionals in such university departments would benefit from training as well. Advances with digital tools and assistive devices help virtual classrooms become more accessible to students with disabilities. Gomez (2021/2022) presented Kurzweil 3000, Echo Smartpen, and Dragon Naturally Speaking as useful assistive technology tools.

Students with Limited Internet Access

To mitigate the effects of the digital divide, state governments and policymakers should increase funding for low-income schools to enable them access to digital tools and frameworks and enhance technological training for teachers in those districts. These initiatives serve to better support students' learning and increase their interest in STEM fields. Further, they may provide more meaningful opportunities for students in marginalized neighborhoods to learn through computer science and robotics applications, increasing access to STEM careers. Grants tend to be more widely available through STEM-related organizations for K-12 and higher education to help with funding.

K-12 school districts are increasingly putting Wi-Fi into buses for students to use when traveling to and from school, especially since the onset of the pandemic. They have also placed parked buses with Wi-Fi into lower income neighborhoods for students to connect to virtual classes. In higher education, college students have more options to access the Internet through businesses and libraries that provide it for free. Initiatives intended to address the digital divide, help college students persevere in their studies. CollegeBuys' California Connects program helped with distributing 30,000 Chromebooks and 5,000 Internet hotspots to help address the community college digital access gap (Gomez, 2020). Universities that offer STEM degrees may consider packages and incentives for students to have pre-paid Internet access to engage in online and hybrid classes, virtual networks, and online research.

Conclusion

This is the time for policy makers to make shifts that are based on the needs of society and students. Schools, universities, educational leaders, and educators need to collect and analyze data about their STEM students and programs and implement effective approaches to include all learners in ways that will their build skills, knowledge, and successful college and career pathways. Leveraging digital tools and increased resources will help diverse students persevere and persist in STEM courses and programs, and eventually in the field.

References

Ahadi, H. S., & Guerrero, L. A. (2020). Decolonizing your syllabus, an anti-racist guide for your college. https://www.asccc.org/content/decolonizing-your-syllabus-anti-racist-guide-your-college

Amrein, A. L., & Berliner, D. C. (2003). The effects of high-stakes testing on student motivation and learning. *Educational Leadership.* 32-38. https://people.wou.edu/~girodm/611/testing_and_motivation.pdf

Arum, R., & Roksa, J. (2011). *Academically adrift: Limited learning on college campuses.* University of Chicago Press.

Banks, J. A., & Banks, C. A. M. (1995). *Handbook of research on multicultural education*. Macmillan.

Baptiste, H. P., & Gholston-Key, S. (1996) Cultural inclusion: Where does your program stand? *The Science Teacher, 63*(2), 32-35.

Bauer-Wolf, J. (2019, February 26). Early departures. *Inside HigherEd*. https://www.insidehighered.com/news/2019/02/26/latinx-black-college-students-leave-stem-majors-more-white-students

Boisselle, L. N. (2016). Decolonizing science and science education in a postcolonial space (Trinidad, a developing Caribbean nation, illustrates). *SAGE Open*. https://journals.sagepub.com/doi/full/10.1177/2158244016635257

Brown, V. (2018). Technology access gap for postsecondary education: A statewide case study. In Yildez, M. N., Funk, S. S., & De Abreau, B. S. (Eds.). *Promoting global competencies through media literacy.* IGI Global.

Center for Energy Workforce Development (CEWD). (n.d.). *What are STEM skills?* https://stem.getintoenergy.com/stem-skills-list/

David, J. L. (2011). Research says: High-stakes testing narrows the curriculum. *Educational Leadership, 68*(6): 78-80.

De, S., & Arguello, G. (2020). STEM education in college: An analysis of stakeholders' recent challenges and potential solutions. *FDLA Journal, 5,* Article 9, 1-13. https://nsuworks.nova.edu/cgi/viewcontent.cgi?article=1051&context=fdla-journal/

Friedensen, R. (2018, May 23). STEM climate for students with disabilities. *High-*

er Education Today. https://www.higheredtoday.org/2018/05/23/stem-climate-students-disabilities/#:~:text=STEM%20fields%20do%20not%20have,do%20proactively%20rather%20than%20reactively

Funk, C., & Parker, K. (2018, January 9). Women and men in STEM often at odds over workplace equity. 1. Diversity in the STEM workforce varies widely across jobs. *Pew Research Center*. https://www.pewresearch.org/social-trends/2018/01/09/diversity-in-the-stem-workforce-varies-widely-across-jobs/

Gholston-Key, S. (2003). Enhancing the science interest of African-American students using cultural inclusion. In Hines, S. M., Kincheloe, J. L., & Steinberg, S. R. (Eds.). *Multicultural science education: Theory, practice, and promise.* Lang Publishing Company.

Gholston-Key, S. (2010). Diversity in science education. *Research Into Practice Science*. 1-4. https://dokumen.tips/documents/diversity-in-science-education.html

Gomez, B. (2020, July 7). *California Community Colleges memorandum.* https://cvc.edu/wpcontent/uploads/2020/07/COVID19_Systemwide_Technology_Resources_DII_20_02.pdf

Gomez, C. R. (2021/2022). Removing barriers with assistive technology. *Journal of Online Learning Research and Practice, 8*(2), 57-62.

Gupta, P., Chaffee, R., Hammerness, K., MacPherson, A., & Podkul, T. (2021, May 26). RAPID: Supports and challenges in an educational crisis: The impact of the COVID-19 pandemic on youth STEM pathways. *The Center for Advancement of Informal Science Education*. https://www.informalscience.org/news-views/rapid-supports-and-challenges-educational-crisis-impact-covid-19-pandemic-youth-stem-pathways

Gupta, P., Chaffee, R., Hammerness, K., MacPherson, A., & Podkul, T. (n.d.). Supports and challenges in an educational crisis: The impact of the COVID-19 pandemic on youth STEM pathways. NSF rapid working paper: Mid project report on emerging findings. NSF Grant No. 2033515. *American Museum of Natural History with SRI International.* https://drive.google.com/file/d/1WaD6NXeArANhJKDYE5oehyqoVcuB1R2m/view

Hayes, S. (2017, May). Preparation matters most in STEM. *ACT Research and Policy Issue Brief.* https://www.act.org/content/dam/act/unsecured/documents/R1647-preparation-matters-in-stem-2017-05.pdf

Heggart, K. (2015, February 4). Developing a growth mindset in teachers and staff. *Edutopia.* https://www.edutopia.org/discussion/developing-growth-mindset-teachers-and-staff

Herold, B. (2017). Poor students face digital divide in how teachers learn to use tech. *Education Week*. https://www.edweek.org/ew/articles/2017/06/14/poor-students-face-digital-divide-in-teacher-technology-training.html

(ISC)2. (2019). Strategies for building and growing strong cybersecurity teams. *(ISC)2 Cybersecurity workforce study, 2019.* https://www.isc2.org/-/media/ISC2/Research/2019-Cybersecurity-Workforce-Study/ISC2-Cybersecurity-Workforce-Study-2019.ashx?la=en&hash=1827084508A24DD75C60655E243EAC59ECDD4482

Iversen, E. (2019, October 8). *How to see cybersecurity as a STEM field.* https://start-engineering.com/start-engineering-now/2019/10/8/how-to-see-cybersecurity-as-a-stem-field

Lancaster University. (2019, October 31). Study addresses one of the most challenging problems in educational policy and practice. *Phys.org*. https://phys.org/news/2019-10-problems-policy.html

Lee, E. N., Orgill, M. K., & Kardash, C. A. (2020). Supporting English language learners in college science classrooms: Insights from chemistry students. *Multicultural Education,* 25-32. https://files.eric.ed.gov/fulltext/EJ1280512.pdf

National Academies of Sciences, Engineering, and Medicine. (2016). *Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support students' diverse pathways.* The National Academies Press. https://doi.org/10.17226/21739

National Center for Statistics. (n.d.). *Fast facts: Students with disabilities.* https://nces.ed.gov/fastfacts/display.asp?id=60

National Science Foundation. (2015, January 30). Women, minorities, and persons with disabilities in science and engineering: 2015. Special Reports. NSF 15-311

National Science Teaching Association. (2020, February). *Position statement: STEM education teaching and learning.* https://www.nsta.org/nstas-official-positions/stem-education-teaching-and-learning

Prothero, A. (2020, September 15). Carol Dweck on nurturing students' growth mindsets through protest and pandemic. *Education Week*. https://www.edweek.

org/education/carol-dweck-on-nurturing-students-growth-mindsets-through-protest-and-pandemic/2020/09

Ramsey, K., & Baethe, B. (2013). The keys to future STEM careers: Basic skills, critical thinking, and ethics. *Delta Kappa Gamma Bulletin. 80*(1): 26-33.

Randazzo, M. (2017, May 10). Students shouldn't live in STEM deserts. *U.S. News.* https://www.usnews.com/opinion/knowledge-bank/articles/2017-05-10/the-us-must-address-disparities-in-access-to-stem-education

Scott, C. (2018). The scientist showcase: A tool for highlighting diverse scientists in the elementary classroom. *Science & Children, 55*(5), 73-77.

Sheldon, K. M., & Biddle, B. J. (1998). Standards, accountability, and school reform: Perils and pitfalls. *Teachers College Record, 100*(1), 164-180.

Tate, K. J., & Tripp, L. O. (2007). Hidden bias: A study exploring the preparing of white preservice teachers to teach science to black, rural elementary and middle school girls. *Journal of the Research Association of Minority Professors, 9*(1), 76-86.

Tate, K., Messina, D., Warnecke, B., Doyle, C., DePriter, T., & Brillhart, D. (2018) Marvelous metals matter! (A STEAM lesson for fifth graders incorporates the Engineering Design Process). *Science and Children, 55*(5), 27-34.

Thompson, M. E. (2021, July 26). Who's getting pulled in weed-out courses for STEM majors? *Brookings.* https://www.brookings.edu/blog/brown-center-chalkboard/2021/07/26/whos-getting-pulled-in-weed-out-courses-for-stem-majors/

White House Initiative on Educational Excellence for African Americans. (n.d.). *Fact Sheet: Supporting science, technology, and mathematics (STEM) success among African American students.* https://sites.ed.gov/whblackeducation/files/2016/09/STEM-Fact-Sheet-9.22.16.pdf

Wu, S. C., Silveus, A., Vasquez, S, Biffi, D., Silva, C., & Weinburgh, M. (2019). Supporting ELLs' use of hybrid language and argumentation during science instruction. *Journal of Science Teacher Education*, *30*(1), 24-43.

Zickuhr, K., & Smith, A. (2013) Home broadband. *Pew Research Center*. https://www.issuelab.org/resources/15698/15698.pdf

Dr. Anne Mangahas is Assistant Professor at the University of La Verne in the LaFetra College of Education. She has served in the field of education for over 20 years at the secondary and collegiate levels. Anne was a research scientist at the University of Southern California (USC)'s Keck School of Medicine at the Institute for Genetic Medicine and worked on numerous federal and institutional grants, including a $6,000,000 dollar Title III HSI grant awarded by the U.S. Department of Education and the National Science Foundation to promote the recruitment, retention, and advancement of diverse student populations in pursuit of their degree aspirations in STEM. She served as a teaching fellow and university supervisor for the CalTeach program at the University of California Irvine and as project lead with 100kin10, which seeks to bolster STEM education pipelines for students and teachers.

Dr. Mangahas has worked extensively with diversity, equity, and inclusivity initiatives and in support of faculty development efforts with organizations like Branch Alliance for Educator Diversity and received grants to develop diversity initiatives and programs. With her passion in education and her advocacy for student success, her goal is to prepare students for career-ready pathways and achievement of their academic and professional goals and to support faculty in their various functions.

Anne earned a BS in Biology and an MA in Philosophy from Biola University, an MS in Biochemistry from the University of Southern California, an EdD in Educational Leadership from Azusa Pacific University, and a STEM leadership certificate from a joint endeavor between NASA Endeavor and Columbia University.

Dr. Kathleen J. Tate is Professor and Department Chair of Teaching in the School of Arts, Humanities, and Education at American Public University System. She has over 25 years of experience in the field of education as a special education teacher in a bilingual, Title I elementary school; researcher; professor; university administrator; consultant; and children's STEM book author. She has held tenure track positions at Auburn University and the University of West Georgia and has consulted for numerous online universities over the past 17 years in master's and doctoral programs.

Dr. Tate has served as a reviewer and lead co-editor for varied scholarly, peer reviewed journals and is currently the Editor-in-Chief of The Journal of Online Learning Research and Practice, formerly known as Internet Learning journal. Her articles have been published in Youth Theatre Journal, Science and Children, Social Studies Research and Practice, and Teacher Education and Practice, to name a few. She has received more than $35,000 in internal and external grants in the areas of science and technology.

Kathleen serves on the Curriculum Advisory Board for the Institute for Humane Education. Her primary research interests include humane education, mixed methods research, underserved/ underrepresented populations, arts-based and multimodal teaching and learning, and integrated/thematic instruction with a focus on Science, Technology, Engineering, Arts, and Math.

Dr. Tate received a BA in Soviet & East European Studies with a minor in Economics and MEd in Special Education from the University of Texas and a PhD in Elementary Education from Florida State University. Kathleen has lifetime Texas teaching certificates in Elementary 1st-8th, PreK-12th Special Education, and 1st-8th Theatre Arts; and completed graduate coursework for Visual Impairment Certification PreK-12th. She studied Russian, Polish, Czech, French, and Latin as an undergraduate, and braille as a graduate student at the University of Texas.

Dr. Kevin Harris is Associate Professor in the Department of Computational and Information Sciences at Stillman College and part-time faculty member in the School of STEM at American Public University System. Kevin has more than 25 years of experience in the information technology field, having held industry positions ranging from Systems Analyst to Chief Information Officer. He developed cross functional teams implementing solutions to effectively address business challenges through innovation and security. He has taught across disciplines including business, cybersecurity, computer science, and computer networking, and has a particular interest in information security and computer forensics.

Dr. Harris' mission is to ensure benefits of education and technology advancements can be embraced by all. He believes inclusivity in the technology sector is critical from a moral standpoint and with the goal of increasing the workforce pipeline. Kevin supports diversification by serving as Board Chair for Nashville General Hospital Congregational Health and Educational Network, supporting technology outreach with the Urban League of Middle Tennessee, and acting as President of the MidSouth Cyversity Chapter. He has supported diverse student populations at various types of institutions including community colleges, Historically Black Colleges and Universities, and private and online institutions.

He is passionate about implementing ways to bridge the digital divide, especially among underserved populations. His consulting and research interests include minorities/women in technology, cyberbullying prevention, information security, and business consultation/training.

Kevin completed a DBA in Business Administration at Argosy University and an MS in Computer Management & Information Systems at Southern Illinois University Edwardsville.