Shifting Courses

Achieving Equity in High School STEM

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100Kin10 is a network of the nation's top academic institutions, nonprofits, foundations, companies, and government agencies that is working to collaboratively develop and implement solutions to the STEM teacher shortage. 100Kin10 first launched in 2011 with the audacious goal of recruiting 100,000 excellent STEM teachers in 10 years. Not only are we on track to achieve that goal, we also are tackling the underlying causes of why it's so hard to get and keep great STEM teachers in the first place. 100Kin10 will be celebrating our 10-year anniversary — and the achievement of our 100,000 teacher goal — in 2021, and we look forward to strengthening our work to address systemic challenges in STEM teaching and learning for years to come.

Thank you so much to our strategic thought partner Dell Technologies for their collaboration and generous support in this research, which we hope will catalyze action and inspiration to transform equitable STEM education for high school students across the United States.

We are so grateful to our Brain Trust, including dedicated members of the 100Kin10 Teacher Forum, who offered invaluable expertise and insights through interviews, reflection, and generosity of time and energy: Jessica Anderson, Elizabeth Babcock, Carly Baldwin, Sasha Ban, Dipak Basu, Gillian Bayne, Gregory Borman, Kim Boutwell, Ingrid Buntschuh, Peg Cagle, Kassie Davis, Susan Dawson, Michael Diaz, Carol Fletcher, Sara Harmon, Amy Hoffmaster, Sarah Jenevein, Lauren Jones-Kaplan, Anne Kornahrens, Ben Koo, Earl Legleiter, Megan Leider, Chris Link, Vanessa Lujan, Lizzie McDermott, Anne Moore, Melissa Moritz, Jeanne Norris, Julie Olson, Sarah Pedemonte, Tana Peterman, Debi Pfitzenmaier, Laura Pomerance, Amy Roediger, Sharon Sherman, Jessica Silverman, Gay Stewart, Rebecca Theobald, Fred Uy, Susan Wally, Gideon Weinstein.

Special thanks to Kerri Kerr from Sage Education Advisors who significantly contributed to the research and development of this report, and to Ellie Goldberg for crucial research support.

We are privileged to share and reflect on the contributions of these leaders and many others who have truly made this report possible — and acknowledge any mistakes or gaps as our own.

Finally, we thank you, the reader and future do-er, for joining us at the launching pad of this work. As you've already noticed, we've chosen a digital format for this report that enables us to keep it a "living" document, and you'll see invitations throughout for you to share your perspective, insights, and knowledge to deepen the work. We are eager for you to join us in shepherding the starting points offered here into action.

Thank you!

→

Dell Technologies is proud to partner with 100Kin10 to support its work to increase STEM equity in high schools. STEM skills are among the most critical to thriving in today's workforce, yet course offerings in many high schools are not reflective of this. With growing concerns about the digital divide, compounded by the impacts of the pandemic and widespread racial inequity, we need to continue to push for access to workforce-relevant courses that engage and connect with girls and students of color to increase their aspirations for and success in STEM. This report represents a roadmap for change, both in meeting the challenges of this unprecedented moment and preparing all students for success in the future workforce.

JEREMY FORD
VICE PRESIDENT, GIVING & SOCIAL INNOVATION
DELL TECHNOLOGIES

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Introduction

Back in the fall of 2019, 100Kin10 chose to focus on **increasing the range and quality of STEM courses in high school** as one of our strategic priorities. We aimed to think about the experiences of students of color, who face particular barriers to **personally-relevant and career-connected** courses that build on students' unique perspectives, capture imaginations, and effectively prepare for success in STEM. Once the decision was made, we were thrilled to dig into our research process and learn from members of our Brain Trust and other experts about how to make high school STEM courses more relevant, career-connected, and equitable.

Then, the COVID-19 virus arrived in the United States and with it, uncertainty and new urgencies. At the time of this report's launch, our nation is in the midst of a months-long pandemic that has upended post-secondary and preK-12 education systems across the country. We've seen states take tentative steps toward reopening, with some successes and many challenges, revealing that pre-pandemic life will not resume any time soon, if ever. We are navigating fundamental changes in our day-to-day reality, our world, and our expectations of what is possible.

When we started to prepare this report in the spring of 2020, teachers, students, administrators, and parents were already intensely grappling with the impacts of the COVID-19 pandemic on our **education system**: weighing the decision of whether or not to open schools; implementing widespread staggered, physically distanced, and/or remote learning solutions; facing the reality that tens of thousands of students hadn't engaged in any way during the sudden shift to remote learning in the previous spring — and the reality that those students and nearly all other children were going to begin a new school year not only with learning losses, but with new and deepened social and emotional needs, as well.

Why are STEM teaching and learning so crucial?
The United States — and the planet Earth — needs to prioritize science, technology, engineering, and math (STEM) education now. Our most pressing challenges — from climate change, to healthcare, to economic growth — and our most potent opportunities require problem-solving skills rooted in STEM. Ten of the top 14 fastest-growing industries require some kind of STEM training.

To produce big ideas and solve big challenges, students in the U.S. need excellent STEM education and learning opportunities. And with millions of students encountering most of their formal education in schools, we know that teachers are the cornerstone of our education system. Teachers support and inspire young learners every day; they produce doctors, engineers, architects, inventors, entrepreneurs, and, of course educators; they power the possible and empower future generations to imagine and achieve what now seems impossible. We need great STEM teachers.

Yet many STEM teachers aren't receiving the essential preparation, resources, and encouragement to do their jobs effectively. In fact, we face a great shortage of qualified STEM teachers nationwide. Our network of STEM education advocates and experts has grown from 28 partners to 300+ organizations, and transcends party lines, sectors, and generations. In an ever-polarized country, STEM education is one of the few nonpartisan, multi-sector, urgent issues of our time.

> The pandemic has not changed the need for STEM education — if anything, it illustrates how important strong STEM skills are for everyone.

States and districts face similar challenges, including unprecedented budget cuts and expectations to do more than ever before (redesign the school day and the curriculum, center trauma-informed education, keep people safe from a very contagious virus), under more scrutiny and with fewer available resources.

Meanwhile, the **economy** is experiencing a downturn unlike any since the Great Depression, with layoffs happening across sectors and states struggling with historic deficits. Economists predict that the shift toward automation will accelerate, and whole sectors might never return to pre-pandemic levels of employment.[1] What job growth there is will be increasingly bifurcated, with opportunity at the top, in knowledge-rich sectors in which STEM skills predominate, and at the bottom, in low-level service roles that do not offer family-supporting wages. We've seen that the pandemic has not changed the need for STEM education — if anything, it illustrates how incredibly important strong STEM skills and understanding are for everyone, and most especially for those entering the workforce.

The impacts from the COVID-19 pandemic touch all educators and families across the country, but not equally. The pandemic presents a close-up lens for understanding how **systemic racism is designed to create harmful outcomes for people of color, especially Black, Latinx, and Indigenous people, who disproportionately experience the impacts of COVID-19**. Compared to white people, people of color experience higher rates of infection, hospitalizations, and death due to COVID-19. Due to systemic inequities undergirding the U.S. economy, communities of color face significant economic fallout, with a higher risk of unemployment, greater housing instability, and a predicted slower financial recovery.[2][3][4]

It is against this backdrop of persevering amidst the coronavirus pandemic that people across the country have reignited demands for racial justice now. We are demanding racial equity in the systems that govern our day-to-day ability to learn, thrive, and survive; we are demanding that the killing of Black people by police, and brutal responses to indignation and pain at the loss of Black lives, must end.

We're focused on charting a path forward for concrete change that will impact generations of high school STEM educators and learners, beyond the immediate challenges we're facing today. But to take on such work at this particular moment — one of renewed movement and uprising for racial justice, a global pandemic, and economic crisis — **we must do so with a clear understanding of the systemic inequities that are embedded in our society, including those deeply rooted in our education system.**

This report, and the work it is intended to catalyze, invites us to look at one of the highest-leverage challenges underlying the STEM teacher shortage — the range and quality of personally-relevant, career-connected STEM courses in high school — with an explicit anti-racist emphasis and contextualized by what we know about the COVID-19 pandemic's impacts thus far.

We know that change — especially change that seeks to uproot larger systemic issues and address pressing, current challenges — will be neither easy nor simple. But we believe it is our responsibility to work together to achieve this change.

Systemic racism is not new. It is not a sudden wound we need to fix with a band-aid, or retrofit our existing work in order to address. It has been core to the design of our education system since the beginning of teaching and learning in the United States. No set of research and recommendations for change can gloss over that systemic racism drives persistent educational inequities. **For decades education-centered work in the U.S. has, in service of eradicating "achievement gaps," developed reforms at the edges of practices and systems that were never intended to achieve equality.** We must look honestly at ourselves and ask: Should we be surprised that "achievement gaps" have narrowed so little over this time, or that college graduation rates of Black and Latinx youth have barely budged?[5] Should we be surprised that schools with majority students of color rarely offer the full range of basic STEM courses, let alone the innovative and cutting-edge courses offered in higher-income communities? And why do most teenagers experience their high school learning as disconnected from and irrelevant to their aspirations and dreams — so much so that, to take action on the climate crisis, the best thing they could do was walk out of school?

About the Grand Challenges and our bet on the catalysts

Our work at 100Kin10 began by responding to the call for 100,000 new STEM teachers in America's classrooms and subsequently grew to include the creation of the **Grand Challenges** map, an unprecedented map of the 100+ underlying causes of why it's so hard to get and keep great STEM teachers in the first place. Based on the Grand Challenges map, we then identified **the most influential root causes** — **catalysts** — **that, if solved, would generate a positive domino-like effect across the entire system of STEM teaching and learning.** Recognizing the catalysts as the most strategic levers for change, 100Kin10 is mobilizing our network to address them. To date we have taken on catalysts related to teachers' work environment, supporting elementary teachers to successfully teach math, and, with this report, **increasing the range and quality of high school STEM courses.**

We can't afford to keep ignoring oppressive norms and policies that have historically and systematically limited students of color in their ability to succeed in the present and the future. At 100Kin10, we also know that we have to do work of our own to ensure that our organization and our network is persistently growing in our ability and choice to center our anti-racist

commitment. We have an enormous opportunity in front of us to make STEM learning more equitable, and it demands us to change.

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THE CHANGE WE SEEK

We want to see school districts across the country increase the range and quality of STEM courses in high school, with an emphasis on personal relevance and career connection. While there are many approaches to achieving this goal, at 100Kin10 we've developed a Networked Impact approach over the past nine years, which brings the nation's top academic institutions, nonprofits, foundations, companies, and government agencies together to work collaboratively to develop and implement solutions to the shared challenges in STEM education.

In the case of increasing personally-relevant and career-connected STEM courses in high school, we aim to support and **build the capacity of place-based systems of education to work collaboratively** to develop and implement solutions to this shared challenge while centering racial equity. Specifically, we want to ensure that teachers, school districts, universities and teacher-prep programs, professional development organizations, science-rich institutions, and workforce development organizations are all **working in lock-step** to change the way they do day-to-day business such that all high school students are offered and successfully complete a range of high-quality STEM courses.

As we increase the number of personally-relevant and career-connected STEM courses in high school, we believe it will have positive ripples across the entire ecosystem of STEM teaching and learning. We know that more people will choose to teach STEM, and more STEM teachers will remain in the profession, if they are prepared to teach courses that are high-quality and real-world-relevant. And at the same time, more students will experience the kind of STEM learning that grabs their interest, connects them to what matters, and inspires them to pursue careers in STEM. This in turn will have a profound impact not only on their lives, but on our economy and our nation as a whole. **Join us!**

LET'S BRING THIS WORK TO LIFE — TOGETHER

This report is intended to lay a foundation for coordinated, collaborative action among 100Kin10 partners, our allies, and beyond. It is presented as a "living" document and designed to serve as a launching pad for ongoing work. As our collective work grows in the coming weeks, months, and years, we expect to augment this report with new insights and actionable ideas.

We value your perspective and partnership! As you read this report, we invite you to consider: How do the challenges and opportunities outlined in the report intersect with your work? How we might work together to drive meaningful, sustainable change? We invite you to get involved by taking one of the following steps

TAKE ACTION BY CLICKING BELOW ↓

Build on our offerings from your unique perspective + Help us fill in the gaps

- What in the report resonates with your work, and how does it intersect?
- What knowledge and insights do you have as a result of your work and/or lived experience?
- What perspectives would you like to see further represented in this report?
- Are there additional challenges that are core impediments to this work? What are they?

Email us to share your insights and additions

Identify resources, promising practices, and model programs

- Who is making change and tackling this challenge, who isn't already mentioned in this report? *(This could be you/your organization!)*
  - → *We are crowdsourcing insights and collecting them in our* ***Resources Hub****, which is available to our network, allies, and the field at large.*

Contribute to the **Resources Hub**

Take on challenges by working with a cross-disciplinary community

- Interested in coming together in community with partners around a particular challenge in this report? Let us know which challenge intersects with your work, and what you envision you might accomplish together.

Reach out to connect and work with others

Share out what sparks

- Who in your organization, professional network, or local community needs to learn about this report?
- What ideas from this report can you share with others to make progress on one or more of our levers of change?

Forward this report to a colleague

Share on social media & tag us @100Kin10

Increasing the Range and Quality of STEM Courses in High School

Our research for this report was guided by three questions:

- ➔ **Why are there not more high-quality, personally-relevant and career-connected high school STEM courses?**
- ➔ **What are the particular barriers for students of color?**
- ➔ **What are the critical levers for change?**

Keeping these questions in mind, we delved into the existing research and conducted in-depth interviews with more than 20 experts from across the field. Through this process, we uncovered **11 distinct challenges** underlying this problem, organized within **three critical levers for change**, which you'll find on the next page.

The list of challenges is not meant to be exhaustive, but rather offer a picture of some of the primary factors contributing to the status quo. As our collective understanding grows, so will this report, with new insights, actionable ideas, and additional resources that can provide support and inspiration as we move forward.

Through our research, we also identified organizations and model programs that are charting the path forward, and you will see their work featured throughout **in light blue boxes**, and more examples in our crowdsourced **Resources Hub**.

Let's dig in!

Ensure High School STEM Coursework is Relevant and Applicable to a 21st Century Context

Challenge 1:	**Current STEM courses are not engaging for most youth, beginning in the early years through HS**
Challenge 2:	**STEM courses fail to recognize the experiences and contributions of people of color**
Challenge 3:	**Meaningful connections to the world of work are limited**
Challenge 4:	**Conventional ideas about STEM education dominate high-school curriculum**

Support More Teachers to Facilitate Active and Applied STEM Learning

Challenge 5:	**Adding new STEM courses that are personally-relevant and career-connected is an additional burden on a STEM teacher workforce that is already facing a shortage of teachers**
Challenge 6:	**Current teacher training and professional learning programs do not build the knowledge and capacity needed to effectively deliver personally-relevant, career-connected STEM courses**
Challenge 7:	**Quality, vetted curricular materials and formative assessments are needed to support personally-relevant, career-connected STEM courses**

Create Systems That Ensure Equitable STEM Teaching and Learning

Challenge 8:	**Significant additional funding is needed to develop and implement personally-relevant, career-connected STEM courses**
Challenge 9:	**School structures do not support equitable access to quality STEM courses**
Challenge 10:	**Siloing Career and Technical Education (CTE) from other STEM courses creates a barrier to access**
Challenge 11:	**Tracking and bias in STEM opportunities limit access for students of color**

↖ CLICK ON A CHALLENGE TO SKIP AHEAD TO IT

Ensure High School STEM Coursework is Relevant and Applicable to a 21st Century Context

In order to provide students with more high-quality STEM courses in high school, there must be **a shared understanding of what relevant, applicable, high-quality STEM learning entails**. The past 10 years have seen much progress in redefining STEM education and advancing ideas about the importance of applied STEM learning experiences. Still, many offerings hold tight to more rote practices, failing to engage and excite students from their earliest experiences through high school.

There is mounting evidence that when coursework is relevant to students' lives and passions, students from all backgrounds succeed. But the courses offered in high schools rarely connect to students' interests or provide the bedrock skills and knowledge to propel them into growing STEM careers in climate, health, technology, and other increasingly essential sectors that provide the secure and sustainable ability to provide for families. Students and employers alike are concerned that current STEM schooling isn't leading to jobs that will support them in the future.

With a lack of connection to the world of work, students largely do not have meaningful, applied learning experiences as part of their high school STEM coursework. Black, Latinx, and Indigenous students in particular are faced with STEM content that fails to recognize their own lived experiences, and STEM curricula and materials reinforce the value of white intellectual and historical contributions and frameworks while perpetuating harmful stereotypes about — or minimizing or omitting entirely — the knowledge and history of STEM leaders of color. This neglects significant opportunities to inspire students of color to pursue STEM careers through encountering and identifying with STEM leaders of color with similar experiences. As a field, we must evolve our definition of quality learning to engage and excite students of color through hands-on courses that connect to personal lived experiences and reflect what is known about the science of learning in a 21st century context, offer clear connections to applied career settings, and actively transform "traditional" notions that continue to disproportionately privilege white STEM histories and mindsets.

Challenge 1:	**Current STEM courses are not engaging for most youth, beginning in the early years through high school**

Many high school STEM courses are not engaging or interesting for students, both in the way they are taught and the content they cover. In fact, the experts we interviewed consistently described the majority of today's traditional STEM courses as presenting the same academic and abstract curriculum in place for decades, offering this content using conventional pedagogical techniques

that fail to engage students. As one expert noted, STEM courses and instruction need to change in order to "engage students in figuring out the science, rather than tell them about the science."

Failure to capture student interest and deeply engage students in learning has a negative effect both on students' overall academic outcomes and on their interest in STEM. According to the High School Survey of Student Engagement, students as a whole express a desire for "work that connects to what they want to do with their lives after high school."[6] In particular, lack of relevance is associated with significantly higher dropout rates seen for Black and Latinx youth.[7] In the same survey, almost half of students who said they have considered dropping out noted that a key factor was not seeing value in the schoolwork they were being asked to do, while 81% of dropouts reported "more real world learning" might have influenced them to stay in school.[8] In contrast, research shows that high school STEM experiences that are engaging and applied increase both interest in STEM and the odds of pursuing a STEM major, particularly for women and Black students. These experiences are described as those that work to capture the curiosity of students, inspire them to maintain excitement, and prepare them for further STEM learning.[9]

One strategy associated with increased student engagement in personally-relevant, applied STEM courses is project-based learning. Project-based learning is a teaching method where students learn by investigating an authentic, personally meaningful, and complex question over an extended period of time. Students gain knowledge and skills while engaging in higher-order thinking and maintain agency over their project and how they will carry it out.[10] [11] Opportunities to engage in project-based learning can make school more meaningful and engaging for students, promote deeper learning, and build the skills needed for success in 21st century careers. **Research demonstrates that project-based learning is associated with increased student beliefs in both their science and math abilities, motivation to learn science, and interest in pursuing a STEM career.**[12] Students of color and students from low-income households in particular can benefit from engaging in projects that authentically speak to students' lives, cultures, and identities, cultivating a sense of self-empowerment. They also benefit when given an opportunity to practice leadership over their learning and making an impact on their community or a broader real-world problem, and such opportunities disrupt normative ideas about who is able to and worthy of making an impact (i.e. white people, people with access to wealth).[13] In fact, project-based learning is seen by some as a way of advancing racial equity[14] through its focus on "intellectual challenge and accomplishment, authenticity, public product collaboration, project management, and reflection."[15]

> "Research shows that high school STEM experiences that are engaging and applied increase both interest in STEM and the odds of pursuing a STEM major, particularly for women and Black students."

Yet, project-based learning is less frequently offered in schools that primarily serve students of color. This is due to factors such as the prominence of traditional instructional methods and a focus on literacy and math in the era of test-based accountability systems, as well as historically held and long-standing racist beliefs about which students are perceived to be "ready" for project-based learning experiences[16] and how those perception map onto racial identities and experiences. In response to accountability pressures, schools primarily serving students of color and students from low-income households focused disproportionately on test prep and limited curricular options, while more advantaged schools under less pressure offered a wider and richer range of courses and instructional approaches.[17] As a result, instructional methods that seemed on face value to be less traditional, such as project-based or interdisciplinary learning, were seen as too risky in schools where great emphasis was placed on closing "achievement gaps" on state assessments.[18]

While the focus of this report is on high school courses, it is worth noting that students' experiences with STEM courses in earlier grades, in particular course quality and relevance, impact their motivation, interest, and demand for further STEM courses before and during high school. Bottia et al. (2018) found that the formal and informal STEM-related learning experiences students had prior to entering high school were even more important for later STEM success in college than the experiences students had while in high school.[19] Other research has shown that the "key factor predicting STEM career interest at the end of high school was interest at the start of high school."[20] For these early experiences, **personal relevance and quality of courses was found to be key, as students need awareness of career options and experiences that help them see and feel what it means to "do" STEM work in order to increase their motivation to take additional STEM courses.** Yet, elementary teachers in particular are not provided with enough high-quality training in STEM instruction and content, making it less likely they will have the knowledge and skill to provide higher quality and more engaging experiences to younger students.[21] Further, the greater prioritization of math and English language arts, tied to state assessments and accountability pressures, serves to limit the time and focus on STEM in the elementary grades.

The likelihood of students of color receiving high quality, engaging STEM experiences early in their education is even less. Research shows schools serving largely students of color and students from low-income households face greater challenges overall with fewer resources and less experienced teachers.[22] These challenges occur at every level of schooling and impact access to quality STEM experiences throughout a student's career. Moreover, limited access early in schooling has the further impact of restricting opportunities for more advanced learning for students of color. Research shows that inequitable access to quality early childhood opportunities for Black and Latinx children can in turn affect the way educators view student readiness for advanced learning opportunities.[23]

STEM courses and curricular materials that are designed explicitly with student engagement in mind do exist at all grade levels. One example is **Project Lead The Way**'s PreK-12 pathways in computer science, engineering, and biomedical science, which utilize hands-on activities and projects to engage students as they solve real-world problems. Similarly, **mySci**'s standards-aligned K-8 curriculum is centered around solving real-world problems through experiential learning and critical thinking. It provides teachers with the instructional strategies, learning materials, training, and ongoing support they need to effectively implement the curriculum. Yet, far too many STEM teachers do not have

access to these resources or teach in schools that utilize traditional course materials that fail to engage students with relevant and career-connected content.

PROJECT LEAD THE WAY

PreK-12 pathways in computer science, engineering, and biomedical science, utilizing hands-on activities to engage students

Project Lead The Way (PLTW) is a nonprofit organization focused on empowering students and transforming the teaching experience for PreK-12 students and teachers across the United States.

PLTW creates engaging classroom environments and empowers students to develop and apply in-demand, transportable skills by exploring real-world challenges. Through hands-on activities, projects, and problems, students not only learn technical skills, but also learn to solve real-world problems, think critically and creatively, communicate, and collaborate.

For example, PLTW's biomedical science unit puts students in the shoes of professionals to investigate topics like human medicine, genetics, physiology, and public health. Students work with others on a team to explore current pressing medical challenges and find solutions.

PLTW also provides teachers with the training, resources, and support they need to engage students.

Content adapted from PLTW's website

We are gathering examples of courses, curricular materials, and programs designed with student engagement in mind in our **Resources Hub**. We're also crowdsourcing input from readers! Add your own insights and examples to the Hub using this form.

Challenge 2: **STEM courses fail to recognize the experiences and contributions of people of color**

Historically, science education has largely focused on the work of white men, presenting their views, language, approaches, and accomplishments as the prevailing and solely accepted standard — while minimizing the contributions of STEM leaders of color. Described as the "omission of scientific histories, theories, contributions, and ways of being and knowing of historically non-dominant students of color in Western schooling", this narrow view serves to create an incorrect and harmful definition of who does science, why they do it, and what their efforts have added to our collective knowledge.[24] [25] Researchers have noted that the views and norms found in the current language of STEM may be at odds with those found among women and students of color, and this disconnect can prevent women and students of color from identifying with STEM education and careers.[26]

Research shows the negative impact on Black students and other students of color when a curriculum does not recognize, respect, and include the intellectual and historical contributions of Black culture and communities. "In the majority of textbooks, African Americans' struggles and contributions are minimalized, portrayed as blatant stereotypes, or confined to a few roles that are acceptable to mainstream white society. This absence (or destructive presence) begins in elementary and continues throughout a Black student's schooling."[27] The predominant focus of current STEM curriculum on the work and perspectives of white men, while omitting the histories and accomplishments of STEM leaders of color, presents a major impediment to attracting students of color to STEM courses and fields and providing them with greater access to personally relevant educational experiences. Bringing our definitions of STEM into the 21st century

necessitates both updating existing courses and creating new courses that centers learning on what matters to young people of color right now. How can we make STEM learning relevant to personal experiences and interests, and irresistible to pursue, from the classroom to career?

One program actively working to connect the cultural and social lives of students of color to STEM classrooms is **Science Genius**, which utilizes the power of hip-hop music and culture to cultivate passion and enthusiasm for science education. Students in Science Genius programs create science-themed songs independently and collaboratively, writing raps that focus on what they're learning in their science classrooms. **BSCS Science Learning** recently co-developed and published a high school unit about COVID-19 and how the virus is transmitted, as well as the impacts of the pandemic on communities, especially communities of color.

BSCS SCIENCE LEARNING

Transforming science teaching and learning through research-driven innovation, and with the belief that science education should advance the work of social and environmental justice

BSCS Science Learning works to transform science education nationwide through instructional materials development, teacher professional learning, leadership development, and research. Their work impacts the system at all levels (state, district, school and classroom) and has a core commitment to equity and social justice. They envision equitable access to high quality science education opportunities informed by diverse perspectives that prepare learners to understand and take on social and environmental injustices in their personal, professional, and civic lives.

BSCS has numerous offerings for educator development and for classroom instruction in their Educator Resource Center, including resources that are geared towards personal relevance for students and teachers of color.

Recently, they published a high school unit on public health and equity (which curriculum developers are currently testing), focused on the question: "How can we slow the spread of the COVID-19 virus to protect our communities?" This 15-class period unit was developed with partnership from epidemiologists, public health experts, equity and antiracist education experts, and social-emotional learning experts to create a course offering that explores immediate, present-day challenges impacting students of color and their communities.

The unit is developed for inquiry-based learning, and includes learning goals such as understanding virus transmission, understanding the disproportionate impacts on communities and influencing policies and practices, and development of social emotional competencies like self awareness and social awareness.

Content adapted from the BSCS Science Learning website

Challenge 3: **Meaningful connections to the world of work are limited**

Many common perceptions of STEM, and existing STEM pathways and courses, lack clear and strong connections to the world of work. For too many students, high school experiences fail to help them see how academic, in-school learning connects to real-world career opportunities. They also do not provide students with enough opportunities to develop the 21st century skills needed for today's workforce, such as the ability to work collaboratively, think deeply and analytically about a problem, communicate effectively, and take information and techniques learned in one context and adapt them to a new and unfamiliar problem or situation. In order to help students make these connections and develop these skills, **STEM courses must explicitly address the relevance of content to the real-world, as well as provide students with opportunities to learn and practice skills both in school and in workforce-related contexts.**

One way to provide meaningful workforce connections and training is through work-based learning experiences. Research shows **the benefits of work-based learning for students, as a model for "connecting academic learning to work preparation, enhancing positive student attitudes, academic motivation and goal articulation for school and career, and equipping young people with both academic and non-cognitive work readiness skills for the transition from high school into meaningful work and life."**[28] Studies of work-based learning at the K-12 level have shown several benefits for students. For example, students that participated in internship programs were more likely to enter the field they explored in their internship and earned higher wages than those that did not.[29]

Yet, high-quality work-based learning experiences are not often available, particularly for students of color. The cost and complexity of providing quality work-based learning experiences is high. They require strong partnerships between schools and industry, as well as significant, dedicated resources.[30] Given the financial and other challenges that schools serving students of color and students from low-income households face, it is less likely that these schools will have resources to offer work-based learning. Further, work-based learning experiences are often extracurricular, yet research shows there is a paucity of extracurricular experiences for too many of these students. Trends over the past 20 years have seen participation rates in outside-of-school activities drop dramatically and remain low for students from low-income households.[31]

> "At this moment of economic upheaval, we need well-planned, sustainable, and equitable youth apprenticeship programs that give students an on-ramp to career success."

The challenge faced in providing work-based learning experiences in a time of virtual learning and shuttered or reduced industry is even more significant. And yet, in the era of the COVID-19 virus, we need work-based learning experiences and youth apprenticeships even more, given the role they play in long-term workforce development. "At this moment of economic upheaval, we need well-planned, sustainable, and equitable youth apprenticeship programs that give students an on-ramp to career success."[32]

One organization working to provide strong workforce experiences and connections to students is **Citizen Schools.** Citizen Schools believes that schools and communities can work together to help students develop the skills needed to be successful in the 21st century job market through hands-on learning experiences and connections with career mentors. Their programs partner science teachers with community volunteers to promote project-based, real-world connected STEM learning during the school day, as well as provide hands-on STEM education and maker-centered learning opportunities for students and semester long apprenticeships taught by volunteers.

CITIZEN SCHOOLS

Schools and communities working together to help students develop the skills needed to be successful in the 21st century job market

Citizen Schools believes that schools and communities can work together to help students develop relevant, job-ready skills through hands-on learning experiences and connections with career mentors. Through this work, students are positioned as producers and problem solvers, develop key social emotional and 21st century skills and competencies, and build their networks.

Their programs partner science teachers with community volunteers to promote project-based, real-world connected STEM learning during the school day, as well as provide hands-on STEM education and maker-centered learning opportunities for students. They also offer semester-long apprenticeships taught by volunteers.

Their Catalyst model empowers science teachers, in partnership with volunteers from the community, to deliver high-quality, project-based STEM learning experiences during the traditional school day. The Expanded Learning Time model partners with schools to provide academic support, high school and college pathway programming, and semester long apprenticeships taught by volunteers. And through a network of coalition partners, their Makers + Mentors Network connects STEM mentors with nonprofit organizations and schools to offer hands-on STEM education and maker-centered learning opportunities for students.

Content adapted from the Citizen Schools website

Check out other examples of programs making meaningful connections to the working world in our **Resources Hub**. We hope you'll contribute more examples using this form, too!

Challenge 4: **Conventional ideas about STEM education dominate high-school curriculum**

Conventional notions of how to define STEM as a discipline, and what quality STEM learning experiences entail, play a large role in directing the range and types of STEM courses available to students. They also influence the extent to which resources are dedicated to providing increased access and quality of STEM learning experiences. **While there is strong evidence for the benefits of applied STEM courses, the experts we interviewed overwhelmingly felt that traditional definitions of STEM still permeate the field.** The "college-track" scope and sequence is still the gold standard that is prized by many colleges, and the idea that "pure science is best" for all students remains at the heart of the vast majority of high school course pathways.

> "Applied STEM includes gaining knowledge of the world of work, and viewpoints and skills such as ethics, leadership, and collaboration, which are increasingly important in the 21st century job market."

These ideas have led to curricular and instructional choices that are better suited for the small number of students who may become mathematicians or scientists, while neglecting to engage or prepare students for the much larger set of future careers that utilize STEM knowledge in interdisciplinary and applied ways. As one university faculty member who prepares future math teachers noted, "Our teaching now is geared towards the minority of students. We are teaching pure math to the 98% of people who *shouldn't* be learning pure math because it's not interesting or useful for them and their future careers. It needs to be applied." Similarly, a leader at a statewide nonprofit that advances excellence, innovation, and equity in STEM education said, "Our science folks hold on to science as the holy grail." In practice, **the viewpoint that favors "pure" rather than applied (or real-world relevant) math and science serves to perpetuate traditional course structures and offerings, rather than allow for multiple entry points into STEM learning and the creation of new STEM modules and course pathways.** It also leads to a limited view of how content converges across disciplines and limited ownership for bringing that content together into integrated and/or applied courses and learning experiences.

Redefining quality STEM learning involves both the content that is taught, including connections between content, as well as how STEM courses are taught. With regards to content, traditional ideas view STEM as a sequence of individual courses aligned to the four named disciplines, with great focus on math and science and relatively little to no opportunities within technology or engineering. Broader definitions view STEM as a "meta-discipline" that integrates content and experiences across disciplines. Proponents of STEM as a meta-discipline describe STEM education as "not simply a new name for the traditional approach to teaching

science and mathematics. Nor is it just the grafting of 'technology' and 'engineering' layers onto standard science and math curricula. Instead, STEM is an approach to teaching that is larger than its constituent parts."[33]

Regarding how STEM courses are taught, today's traditional courses are often procedural and abstract in nature and involve tasks such as observation, identification, computation, and documentation. Newer conceptions of applied STEM courses argue they should be taught using an integrated, applied, problem-based approach, where courses are taught through hands-on and engaging methods, are more skills-based with a focus on real-world problems, and make clear the relationships between STEM concepts.[34] Going beyond coursework, **applied STEM learning experiences include gaining knowledge of the world of work, and viewpoints and skills such as ethics, leadership, and collaboration, which are increasingly important in the 21st century job market.** Such applied learning also includes projects and activities that make direct connections to careers for students both inside and outside of the school context.

Much work has been done in the past 10 years to develop new, improved approaches to K-12 science education. These efforts have sought to articulate common, high-quality science standards that include both scientific and engineering knowledge and practices, as well as cross-cutting ideas that bridge disciplines and introduce the meaningful application of knowledge. In 2011 the National Research Council released the ***Framework for K-12 Science Education***,[35] and in 2013 the **Next Generation Science Standards (NGSS)** were released based on the *Framework* and designed to prepare students for success in college and in 21st century careers. Twenty states and the District of Columbia have adopted the NGSS standards, while 24 states have developed their own standards based on the *Framework*'s recommendations.[36]

Yet, even with these **significant efforts to redefine quality science education, experts from all levels of the K-12 education system report much progress is still needed to shift mindsets around the importance of applied STEM learning and to expand science education to include greater relevance and career connections for students.** Many continue to believe that all students should study pure science and math in a fixed or linear sequence, eschewing countering ideas about the value of more flexible learning pathways with integrated and applied content. Importantly, offering greater access to applied STEM courses does not mean students should not also have the opportunity to take traditional math and science courses. Valuing applied STEM translates to offering a wider set of options and opportunities to students, as well as utilizing instructional methods that provide authentic connections to real-world problems and to the workforce.

A **growing number of STEM programs** are being developed that articulate definitions of quality STEM education that are project-based, personally-relevant, and career-connected. One example is **DSST Public Schools' STEM program**. **The Global STEM Alliance STEM Education Framework** provides another example of a new definition of quality STEM learning experiences. The Framework describes 26 features of quality STEM education across three essential areas: Core Competencies, Instructional Design, and Implementation, and is intended to be used by anyone engaged in STEM education to help guide the development and evaluation of high-quality instructional programs and materials.

DSST PUBLIC SCHOOLS

An open enrollment network of STEM charter schools in the Denver metro region, with a mission to eliminate educational inequity and prepare all students for success in college and the 21st century

Going beyond the traditional courses students take in science and math, DSST Public Schools' STEM program empowers students to explore and better understand themselves and the world around them.

The program first provides students with a foundation in reading and writing in STEM, computational thinking, and design thinking. Students then take a discipline-specific approach, delving deeply into one of four fields of STEM (Engineering, BioScience, Computer Science, or Entrepreneurship). Students also develop 21st century skills through related structures such as senior projects and internships.

The program focuses on supporting students to develop their identity as agents of change, and to imagine pursuing STEM in college and/or their careers.

To date, 100 percent of DSST graduates have earned acceptance into college or university.

Content adapted from the DSST Public Schools website

Read more about DSST Public Schools and other examples of programs challenging conventional ideas about STEM in our **Resources Hub**, and use this form to contribute additional examples.

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Support More Teachers to Facilitate Active and Applied STEM Learning

Providing greater access to applied and relevant STEM courses requires a greater number of sufficiently trained teachers, as well as the materials and other supports those teachers need to deliver engaging, project-based, and career-connected learning experiences. In addition to a national shortage of qualified STEM teachers in general and STEM teachers of color in particular, **current teacher training and professional learning rarely support teachers to effectively teach in career-connected, project-based ways**, nor do they build adequate knowledge and capacity to teach STEM courses which feel personally-relevant to students of color. Moreover, curricular resources and other materials needed to support applied STEM courses are not readily available for all teachers. Providing teachers with the training and support they need is a necessary foundation for any effort to increase student access to quality STEM courses, and to attract and retain more engaged, committed teachers — including more teachers of color — who are interested in facilitating applied STEM learning.

Challenge 5:	**Adding new STEM courses that are personally-relevant and career-connected is an additional burden on a STEM teacher workforce that is already facing a shortage of teachers**

The STEM teacher workforce, and in particular the number of teachers available and trained to deliver personally-relevant and career-connected courses, is a significant factor contributing to the current lack of access for many high school students. Uniformly, a lack of qualified teachers for STEM courses, particularly advanced courses, was named by expert stakeholders we interviewed at all levels of the system as a critical challenge for schools. This is an even greater challenge in schools serving students from low-income households and communities of color. "One reason schools struggle to provide access to STEM courses is a shortage of effective STEM educators. More than half of U.S. public school districts, including more than 90 percent of districts serving large populations of African-American and Latin[x] students, report difficulties recruiting and retaining certified, knowledgeable STEM teachers."[37]

One factor influencing the availability of teachers for applied, career-connected courses is limitations of current licensure and training systems. In some cases, preparation and licensure pathways do not yet exist for STEM-related fields. For example, as of 2019, 39 states had a computer science teacher certification pathway, yet only 19 states had approved preservice teacher preparation programs in computer science at institutions of higher education.[38] Further, confusion and in some cases extra burden related to licensure is placed on teachers who seek to teach courses related to multiple STEM fields, given available course offerings in their school. **While Career and Technical Education**

(CTE) pathways do currently offer many career-connected courses, licensure requirements for CTE teachers are usually different from those of other secondary teachers and serve to restrict teachers' ability to teach courses out of the specific CTE pathway. For example, the Illinois Career and Technical Educator License requires teachers to have a minimum of 2,000 hours of experience outside of education in the area to be taught and restricts teachers to only the specified area of endorsement.[39]

Moreover, schools serving largely students of color often have newer, less experienced teachers, magnifying both the shortage of qualified teachers and challenge of increasing access to applied STEM courses for the existing teacher workforce. Research shows teacher attrition is significantly higher in schools primarily serving students from low-income households and students of color, leading to a concentration of less experienced teachers in these schools.[40] High rates of teacher turnover have a significant negative impact on student learning, particularly for students of color.[41] Not only do teachers in these schools face greater stress and lower job satisfaction,[42] but they earn significantly less than teachers in districts serving fewer students from low-income households and students of color.[43] Given these factors, attracting and retaining enough qualified teachers to teach applied and/or advanced STEM courses, particularly in schools serving largely students of color, is a significant barrier to access to these courses.

Unfortunately, the COVID-19 pandemic stands to exacerbate the teacher shortage significantly, particularly for schools serving students of color. Experts currently predict that at least 320,000 of the nation's 3.5 million public school teachers will lose their jobs as a result of the pandemic's economic fallout, and that layoffs are more likely to occur in schools serving higher proportions of students from low-income households and students of color.[44]

Further, civil rights advocates worry that progress made in recent years to hire more teachers of color will be lost given traditional last-in-first-out policies guiding layoffs.[45] Even with the potential of additional government-funded pandemic relief for education, the impact of the teacher workforce will be significant.

"Experts currently predict that at least 320,000 of the nation's 3.5 million public school teachers will lose their jobs as a result of the pandemic's economic fallout, and that layoffs are more likely to occur in schools primarily serving students from low-income households and students of color."

Despite these very real challenges, there are programs that are creating innovative ways to attract, train, and retain STEM teachers. For example, the **UTeach** teacher preparation program, currently at 44 universities across the country, partners education and science departments to allow undergraduate students majoring in STEM fields to earn secondary teaching certification without adding cost or time to their degrees. To date, UTeach has trained over 5,200 teachers. **Math For America** and the **Knowles Teacher Initiative** are two examples of fellowships for math and science teachers that support the ongoing development and retention of STEM teachers. Through these fellowships, participants gain a community of colleagues as well as professional learning and leadership opportunities. And 100Kin10's Project Team on **Diversifying the STEM Teacher Pipeline** has brought together members from six stakeholder organizations to support a more diversified STEM teacher workforce through identifying and sharing resources and strategies.

Challenge 6:

Current teacher training and professional learning programs do not build the knowledge and capacity needed to effectively deliver personally-relevant, career-connected STEM courses

Our research and interviews with experts consistently demonstrate that today's teachers, and the teacher preparation faculty preparing them, largely have not been exposed to training that supports teaching applied STEM content, nor have they been taught in a way that models **instructional strategies such as project-based learning**. A recent report by the National Academies of Sciences, Engineering, and Medicine examined changing expectations for the K-12 teacher workforce. It noted the challenges faced by teacher development programs — both preservice and in-service — to successfully prepare and support teachers to engage students in "deeper learning" experiences that encompass both deep understanding of core content along with opportunities to analyze and make meaning, make connections, solve problems, and adapt learning to new situations.[46]

In fact, experts in teacher preparation note that preservice teacher prep programs are still focused on training teachers to be the "sage on the stage" rather than training them to be facilitators who guide students to solve challenges and ask questions. Yet, 100Kin10 partners across the country report that there are increasing demands on teachers to become "educational curators".[47] As expectations for teachers shift, so must the training and support provided by teacher preparation and professional learning programs.

Similarly, longstanding expectations for teachers to be content experts in all subjects serve to limit the teacher workforce, particularly for advanced STEM courses. These beliefs often translate to teachers needing to be content experts in traditional science fields such as chemistry and physics, as well as potentially engineering, computer science, and other fields. Interviews with experts revealed that common expectations for teachers to be highly skilled in multiple and/or specialized fields serves to reduce the pool of teachers eligible to teach STEM courses.

Beyond teacher preparation, the existing professional learning opportunities available to teachers by and large are not aligned with applied STEM courses. The typical teacher spends 89 hours each year in professional learning activities — either directed by their district or self-guided.[48] Yet, these hours do not provide the training and support needed to prepare teachers to effectively deliver the content or instructional methods required for applied

STEM courses. Experts noted further that **there is a need for more high-quality professional development paired with specific applied STEM curriculum and resources so that teachers learn in the context of the curriculum they will actually teach.**

All of these factors demonstrate the need for new ways of training and supporting teachers to enable them to effectively deliver high quality STEM courses. This is even more important in schools serving large proportions of students of color, which as noted earlier, are more likely to have teachers with less experience and preparation. Therefore, robust professional learning opportunities tied to teaching applied STEM courses are needed to support the ongoing learning and development of STEM teachers serving students of color.

Many of the programs highlighted thus far include a professional learning component for STEM teachers to build the knowledge and capacity needed to effectively deliver career-connected, personally-relevant STEM courses. And importantly, many include a teacher learning component aligned with their curriculum or other materials. For example, Project Lead The Way and mySci both provide teachers with the training and support they need to effectively engage students and implement their model, serving as a one stop shop providing teachers with everything they need to be successful. **Bay Area Biotechnology Education Consortium (BABEC)** is another example: they empower teachers through providing curricula and full equipment kits for hands-on labs (and since the start of the COVID-19 pandemic, for online lessons as well). While UTeach is currently partnered with 44 universities, change is needed at more teacher preparation programs to ensure the majority of STEM teachers receive the training needed to effectively deliver applied STEM courses.

BAY AREA BIOTECHNOLOGY EDUCATION CONSORTIUM (BABEC)

A community nonprofit founded by high school science teachers in 1996 to increase access and equity in science education

The Bay Area Biotechnology Education Consortium (BABEC) helps students develop an interest in science, consider science as a career, and become scientifically literate citizens through a combination of teacher professional development and highly leveraged, portable biotech supplies and equipment.

BABEC is guided by an equity-based philosophy that a high quality science education is a necessity for all students, regardless of academic achievement, socioeconomic status, or English language proficiency. Students of diverse backgrounds gain critical laboratory skills and exposure to life science careers through a substantive program that combines basic bioscience hands-on skills, PCR, fluorescent protein, forensic, industry-based internships, guest speakers from the industry and independent research.

A key goal of the program is to give students the skills and confidence needed to pursue additional education and enter the life science technical workforce. BABEC achieves its goals through developing strong collaborations with teachers and districts; providing a relevant curriculum and technical support, producing cost effective access to educational biotechnology supplies and equipment, and cultivating a strong regional network of educators and community partners.

Content adapted from the BABEC website

Find additional exemplar programs and initiatives in our **Resources Hub** – and contribute more to our list via this form.

Views that teachers can be science motivators, mentors, and facilitators, working to lead students through challenge-based learning experiences and ask questions to push their own learning, are reshaping expectations of teacher knowledge and expanding the teacher pool. For example, programs like the **Orchard Foundation's Workplace Experience Exchange** program help prepare teachers to be facilitators of learning by matching practicing STEM teachers with regional STEM leaders in industry and academia for professional development.

Challenge 7:

Quality, vetted curricular materials and formative assessments are needed to support personally-relevant, career-connected STEM courses

Teachers need high-quality, vetted curricular materials with embedded formative assessments designed for applied STEM courses. Yet, many teachers and professional learning experts report that existing curricular resources for high school courses that go beyond traditional STEM offerings have not been designed or organized in a way that is useful. Instead they prove to be too overwhelming for teachers who have to sift through options and craft their own curriculum.[49] Given research linking project-based learning with greater student interest, self-efficacy, and intrinsic motivation to pursue STEM,[50] the implications for curriculum developers are to build or expand upon materials to create coherent and teacher-friendly STEM resources that include applied instructional methods such as project-based learning.

The need for better materials applies to both new and traditional courses. Traditional and/or discipline-specific courses require revamped materials that are more personally meaningful and career relevant. In addition, new courses are needed that integrate content across disciplines, use applied and project-based methods, and connect to students' interests and future careers. These new courses require a full suite of instructional materials and aligned assessments.

In our interviews, high school teachers consistently reported they lack access to the materials needed to offer applied STEM courses, either because to their knowledge the course does not exist in publicly available form or where it may exist they cannot access it given limited resources. This leaves teachers with the added job of having to create their own materials, either for new courses or to upgrade existing. Yet, today's teachers do not have the time or training to design courses and write curriculum for applied STEM courses given the overwhelming demands and day-to-day requirements of the job.

Further, as noted earlier, existing STEM curricular materials do not include and value the racial identities of students of color and the contributions of scientists of color. Yet, minor revisions to learning objectives or inclusion of limited culturally relevant content is not enough. Instead, existing and new STEM curricula must be reframed to also center the experiences of Black, Latinx, and Indigenous youth.[51] "Instructional materials must match and augment the images used to make cultural diversity visible in STEM. That is, it is important to move away from superficial representations of diversity to more culturally and socially relevant activities that promote students' engagement, agency, and social responsibility."[52]

Much work is currently happening to develop curriculum and other materials to support quality STEM courses. **OpenSciEd.org** is developing freely available science instructional materials aligned to the Next Generation Science Standards. Materials are being designed for use with low-cost, standard laboratory equipment

and materials, making them readily usable for teachers and schools without the need for additional dollars. LabXchange also provides free curricular materials through its online platform, where users can find and create high-quality content to create flexible STEM learning pathways. Another example, the **New Jersey Center for Teaching and Learning**, provides a fully integrated set of materials and approach including curriculum, instructional methods, and a new sequence for teaching STEM subjects.

Curriculum and other instructional supports are needed even more in a time of remote or blended online/in-person learning. STEM courses, more than most others, are impacted by the challenge of remote learning given the prevalence of hands-on learning experiences and need for laboratories and other specialized materials. In fact, **today's context of distance learning is challenging prevailing beliefs that STEM courses require hands-on learning components and therefore cannot be delivered fully or in large part online.** This is prompting new thinking about the tradeoffs seen by offering fully online STEM learning experiences when considering the potential negative consequences on student access and learning. Much sharing and learning about effective strategies to meet these requirements is needed in the coming weeks and months.

LABxCHANGE

A free online platform offering virtual simulations developed by experts in science education and online learning

Remote learning poses an added challenge to STEM subjects that traditionally rely on equipment and materials that cannot be found at home. Tools like **LabXchange,** an online platform with numerous science education simulations and resources, create opportunities to give more students the hands-on and high-quality science learning experiences they deserve.

LabXchange empowers educators to create personally- and career-relevant learning pathways for their students, especially for students of color.

The world of science is both complex and diverse, and is enriched by the interactions of many people across many fields. Too often, though, students are shown or told an impoverished version of science that only speaks to one perspective — for example, that a drug is developed entirely in a silo by a bench scientist — or that reenforces problematic stereotypes about who a scientist is and what they look like.

This isn't merely a sad fact about the state of education in many places, but a huge problem. With tools that foster individual curiosity and growth, LabXchange supports the inclusion of all voices in the conversation of science.

LabXchange allows educators to remix and share content to support differentiated, personalized learning that engages, inspires, and empowers their students. The content library contains high-quality digital resources from universities and scientific organizations worldwide — including interactive lab simulations, videos, assessments, narratives, and more. Educators can combine this content with their own materials to create customized learning pathways. As well as facilitating content creation and remixing, LabXchange connects learners, educators and researchers through social features such as private classes, discussion forums, and the ability to mentor or be mentored. By providing tools that foster hybrid learning, LabXchange allows users to engage in design, iteration, and problem-solving, while supporting individual exploration.

Many young people who are interested in science are also interested in the law, or communications, or finance, or or data analysis, or a range of other fields, and often don't realize the huge opportunity that exists for them to combine their interests across the scientific sector. LabXchange highlights the intersections within scientific disciplines and across adjacent fields, facilitating a multitude of entry points and celebrating every student's unique perspective and interests.

LabXchange's offerings, approach, and mission embody a commitment to inclusive, equitable access.

LabXchange believes that students deserve equal opportunity to experience, pursue, and succeed in science. Increasing equity within the sciences requires the creation of more effective and engaging resources to prepare for future research experiences and careers. It also requires a supportive environment that allows for the sharing of diverse perspectives, which reaffirm that everyone belongs in the sciences, no matter their gender, cultural or socioeconomic background, or any other marker of identity.

Access to the scientific community increases a sense of connectedness and enhances persistence in science, but student researchers often lack substantive opportunities to connect with peers and mentors — especially those who share similar backgrounds. This not only denies students the excitement of belonging to a community engaged in common challenges and approaches, but also increases the risk of isolation and alienation.

LabXchange, and the content created, curated, and shared there, allows students, scholars, and teachers to share their stories and engage with the lived experiences of others, while simultaneously learning about fundamental concepts and techniques. Combined, these resources and interactions help create and sustain a supportive, intergenerational community that allows all learners to find their path in science.

LabXchange has been adapting its offerings and accelerating impact since the start of the COVID-19 pandemic.

In the face of the coronavirus pandemic and the need for social distancing, how can the largest number of individuals continue to provide meaningful science education to their students and children? They need to access high quality content that can be customized to teach what they want; they need to integrate that material with assessments that drive active learning and skills development; they need to track learner performance; they may need to bring several learners together in an online class. All of these needs are traditionally met in a school classroom or in an online course developed by an institution. Now, society needs all of these capabilities to be open and free if we are to sustain effective education at scale during the pandemic. LabXchange provides all of these fundamental capabilities to anyone with an internet connection, and for free.

Since March 2020, demand for high-quality, free distance learning resources has skyrocketed across the US and worldwide, among secondary and undergraduate educators alike. With over a million visits to the LabXchange platform in that time, the LabXchange team has accelerated efforts to meet global demand by creating and curating new content, developing new features to meet the increasing needs for digital teaching and collaboration tools, and offering new professional development opportunities.

LabXchange now offers expanded assessment capabilities and progress tracking, and to facilitate collaboration and the sharing of ideas in an online space, global discussion forums are scheduled to launch later this month. And to support educators with varying degrees of familiarity with remote teaching, they built new tutorial materials and offered several virtual webinar series to provide professional development - in particular, around using virtual lab simulations. Based on user surveys, their resources — especially the suite of virtual lab simulations and interactives — have proved to be an invaluable resource for instructors and learners adjusting to these uncertain times.

100Kin10 is excited to partner with the Amgen Foundation and Harvard University to spread awareness of LabXchange.

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Create Systems That Ensure Equitable STEM Teaching and Learning

Each of the challenges we've identified and described so far represents a specific impediment to ensuring that all students, and especially Black, Latinx, and Indigenous students, experience personally meaningful, career-relevant STEM courses. But they all sit within a broader education system that has perpetuated greater inequity and harmful outcomes for people of color. **We need systemic and cultural change to address practices considered "inherent" to our education system if we want to erode the current barriers that students of color face in accessing relevant, excellent, career-connected STEM education and opportunities beyond school.** Foundationally, additional funding is needed to support the widespread implementation of personally-relevant and career-connected STEM courses. Schools structures must also change to allow the time and space for teachers to create and students to take applied or advanced STEM electives. And importantly, barriers to access inherent in our existing system must be removed, such as the intentional siloing of Career and Technical Education (CTE) from other STEM courses and the tracking of Black, Latinx, and Indigenous students into lower quality and/or less advanced STEM courses, harmfully narrowing pathways early in their educational experience, and limiting opportunities for their interest in STEM to blossom.

Challenge 8: Significant additional funding is needed to develop and implement personally-relevant, career-connected STEM courses

Research shows that providing access to a wider range of high-quality STEM courses requires significant resources and capacity on the part of teachers, schools, and districts and charter management organizations (CMOs), from providing needed laboratory equipment and other materials to hiring teachers. Yet schools often lack the appropriate materials and resources to implement courses that provide students with applied, career-connected and relevant experiences.[53] And as these courses are often electives, funding for them can be even more sparse. The need for funding to design and provide material resources required for personally-relevant, career-connected STEM courses remains a challenge during the COVID-19 pandemic, even with an uncertain future of in-person learning.

Going far beyond the funds needed for textbooks and materials, schools serving students of color face chronic and long standing underfunding, impacting a wide range of factors that drive the overall quality of students' educational experiences. "Resource inequities caused by funding gaps in school districts that serve large populations of students of color have a profound effect on the educational opportunities districts and schools are able to provide."[54] **As recently as 2018, research showed that districts**

serving the largest concentrations of Black, Latinx, and Indigenous students "received about $1,800, or 13 percent, less per student in state and local funding than districts serving the fewest students of color."[55]

Lack of funding influences myriad factors required to implement career-connected and relevant STEM courses, such as teacher pay and access to high quality teachers, supports for teacher ongoing professional learning, availability of student supports, and curriculum and other instructional resources. Fundamentally this means that schools serving Black, Latinx, and Indigenous students are not equipped to afford the changes needed to implement quality STEM learning experiences and will remain so. When the field embraces new mindsets about the need for applied STEM courses, richer schools will have the resources to implement these changes, whereas poorer schools, which serve primarily Black, Latinx, and Indigenous students, will not.

According to a **recent report published by the Council of Chief State School Officers**, the Every Student Succeeds Act (ESSA) allows for increased funding and the use of federal funds to support STEM, resulting in several examples of states implementing STEM-focused policies and programs to strengthen education equity, career readiness, and CTE curriculum. For example, the Mississippi State Board of Education directed funding for the **K-8 STEM Initiative Enhancement Project Grant** to support school-based implementation of STEM, technology upgrades, and educator training. Arkansas, North Dakota, Oklahoma, and Wyoming have all made significant investments in computer science education. State-level investments mark progress, yet much more funding is needed to ensure the systemic changes required to increase access to quality STEM courses for all students are made.[56]

Even with promising activity in some states to prioritize funding for STEM, this discussion of financial resources needed to enable high-quality STEM courses must also acknowledge today's reality. The COVID-19 pandemic is severely impacting nearly every aspect of the K-12 education system, with the economic fallout resulting in massive cuts to district budgets due to losses in state income and sales tax revenue as well as teacher layoffs. For example, Georgia recently announced a cut of $950 million from its K-12 education budget while Nevada's legislature is debating a cut of nearly 25 percent of its education budget. While uncertainty about additional Congressional bailouts looms, fiscal experts predict districts overall will see a $555 billion loss of revenue, amounting to 25 percent, over the next two to three years. Additionally, **at least 320,000, or nearly 10 percent, of the nation's public school teachers are predicted to lose their jobs.**[57] Experts note the economic impact on schools will be greatest in districts serving largely students of color and students from low-income households given their heavier reliance on state funding. The implications then are a recession leading to even wider inequities between rich and poor districts.[58]

The financial impacts of the COVID-19 pandemic have not only surfaced efforts to reduce education budgets and decrease staff but also to simultaneously add new expenses. Districts and teachers have been forced to adapt course materials and training programs to a remote/blended environment, a task requiring significant financial and other resources. Districts offering any in-person learning options must provide additional supplies, such as masks, partitions, and hand washing stations. And, staff or other services are needed for things like frequent cleaning and implementing other recommendations for making schools safe for teachers and students.

> While uncertainty about additional Congressional bailouts looms, fiscal experts predict districts overall will see a $555 billion loss of revenue, amounting to 25 percent, over the next two to three years. Additionally, at least 320,000, or nearly 10 percent, of the nation's public school teachers are predicted to lose their jobs.

Challenge 9: **School structures do not support equitable access to quality STEM courses**

Several aspects of traditional high school structures contribute to the lack of available, high-quality STEM courses, namely school schedules, size, and context. First, traditional high school schedules leave little room for electives once all graduation requirements are accounted for. High school graduation requirements in most states require two or three pure science courses. **Because applied STEM courses, and advanced STEM courses such as AP Biology, Chemistry, and Physics, are often considered electives, limitations in student schedules mean these courses may be deprioritized and ultimately reduced in offering.** Similarly, common beliefs that deprioritize STEM in favor of literacy and math (with math not seen as integrated within a broader STEM framing) also serve to reduce focus and effort on increasing access to high quality STEM courses. Both of these factors make it difficult to push for expanding access to a wider range of STEM courses with district/CMO and state leaders who see little opportunity or reason for students to go beyond the required number of courses. And, for students of color and students from low-income households, the limitations of school schedules are further exacerbated by a greater focus on test-based accountability systems and the subsequent narrowing of course offerings in an effort to raise test scores.[59]

School size and context also play a role in limiting the availability of STEM courses. Fewer science electives and AP courses are usually available in smaller high schools as a function of demand, scheduling, budget, and teacher availability. Rural schools often see similar limitations in course offerings and course taking, again as a function of factors such as school size, teacher availability,

and/or access to broadband to take advantage of virtual and technology-based platforms.[60]

The impact of school structures is even greater for students of color and students from low-income households. Research documents **inequities in the opportunities that students of color have to take advanced courses, and/or the prerequisites needed to reach them.** Public high schools serving a high-poverty student population have been found to provide fewer academic offerings to support students in their preparation for college.[61] For example, in 2018 a quarter of high schools with the highest percentage of Black and Latinx students did not offer Algebra II, a prerequisite for many higher-level STEM courses, and third of these schools did not offer chemistry.[62] Among high schools with majority Black and Latinx students, only 38% offer calculus.[63] The **disproportionate representation of Black and Latinx students in STEM courses is seen at all levels of K-12 education, and is seen in particular in gateway courses in middle school that set students on a pathway for more advanced high school courses, such as 8th grade algebra, as well as in enrollment in AP courses while in high school.** Recent research demonstrated this is caused in part because schools that serve largely Black and Latinx students have fewer available seats in advanced classes as schools that serve fewer Black and Latinx students.[64]While traditional school structures often limit access to a wider range of STEM classes, STEM-focused schools, networks of schools, and within-school academies have become more prevalent in recent years. **These schools and programs focus heavily on STEM subjects and the integration across them, while also largely value and prioritize a project-based, problem-centered pedagogy and strong workforce connections and experiences for students.** Examples include **Harmony Public Schools**, a system of 57 public charter schools in Texas, and the **Edward M. Kennedy Academy for Health Careers**, a college preparatory and vocational high school in Boston where students explore careers in the health professions and related fields. Partnerships with local hospitals and community health care providers bring career-focused experiential learning opportunities to Kennedy's students. Kennedy serves a student population that is 96 percent students of color and achieves a 98 percent four-year graduation rate.

> "In 2018, a quarter of high schools with the highest percentage of Black and Latinx students did not offer Algebra II, a prerequisite for many higher-level STEM courses, and third of these schools did not offer chemistry."

HARMONY PUBLIC SCHOOLS

A 57-school charter system in Texas focusing on rigorous, career-ready STEM education

Harmony Public Schools is a system of 57 Texas public charter schools that provides rigorous, high-quality education focused on STEM.

Harmony provides PreK-12 students from historically marginalized communities the opportunity to excel through project-based learning where they learn the skills necessary to become a contributing global citizen.

Harmony opened its first school in Houston, Texas in 2000 and has grown to 58 campuses serving over 34,000 students across the state. Their curriculum heavily emphasizes STEM education to prepare students for college success and equip them with highly sought-after job skills for their future careers.

100 percent of Harmony's students have been accepted to college, and a higher percentage of graduates choose a STEM major in college than state or national averages.

Content adapted from the Harmony Public Schools website

In our **Resources Hub**, we're sharing more examples of schools and initiatives transforming school structures with an equity commitment. Contribute to our knowledge base by using this form!

These schools and others like them are redefining what a high-quality STEM-focused education can look like, particularly for Black, Latinx, and Indigenous students. However, effective STEM-focused schools that serve largely students of color are few and far between. And while STEM schools and within-school academies are demonstrating ways to structure schools with an emphasis on high-quality STEM classes, we also recognize the need for school structures that provide greater access to these courses for students within traditional high school models.

School schedules will likely limit opportunities for applied STEM electives even more in the time of COVID. As of this writing, school districts around the country are creating plans for re-opening schools for the 2020-21 school year. Many of these plans currently include full or partial online learning and in the cases where in-person school is being contemplated, rotating schedules or staggered attendance times will likely be needed given safety guidelines. In many cases this translates to a sharper focus on ensuring students at least receive instruction in core subjects, such as English language arts and math, and leaves districts with little time and capacity to provide electives.

Challenge 10: Siloing Career and Technical Education from other STEM courses creates a barrier to access

There are deeply ingrained perspectives that STEM is different from, and in many views more rigorous than, Career and Technical Education (CTE) pathways — which silo these learning opportunities and ultimately limit student access to high-quality, relevant STEM learning. Historically, many schools tracked students of color and students from low-income households into technical education programs as an extension of Jim Crow-era segregation, leading to lower-paying "dead-end" jobs.[65] Many continue to see CTE pathways as low rigor, "blue collar" courses for non-college going students, while traditional science and math courses are seen as more rigorous and geared towards college-bound students. Yet, the types of personally-relevant and career-connected learning experiences made possible within high-quality CTE pathways could serve to greatly increase access to high-quality STEM courses, particularly

with **stronger connections and coordination between curriculum and teachers**. Existing mindsets make it difficult to combine these two pathways and build bridges for students that enable them to benefit from both CTE and traditional course pathways.

The siloing of CTE and other applied courses and pathways from pure science and math courses also provides a structural impediment to increasing access to more students. Many schools operate CTE pathways on totally separate tracks from pure science courses, requiring students to select one path or the other and not allowing for flexible movement between paths or for students to take courses from both. Similarly, this structural separation is replicated at the school, district/CMO, and state levels with different teachers and leaders serving the two paths with little to no communication and coordination occurring.

Students of color and students from low-income households enrolled in urban schools may have even less access to quality CTE programs than their suburban and rural counterparts, despite evidence of the benefits of these programs. CTE programs are often typecast and more likely to be associated with rural and suburban schools than urban schools. Similarly, many urban education leaders under pressure to improve state test results often overlook CTE programs. However, research shows that **students engaged in CTE programs are less likely to drop out of school and realize improved academic and social outcomes.** For example, studies have shown that taking CTE courses along with academic classes minimizes the risk of students dropping out of high school. Similarly, Latinx youth who participated in career academies demonstrated increased confidence, engagement, and an increase in overall achievement and motivation. Quality CTE programs have also been shown to effectively prepare students not only for postsecondary education but also for a range of career opportunities given their hands-on, project-based instructional methods and career-connected content.[66]

District policies that silo CTE courses contribute to this challenge. However, revising policies that require math and science courses which teach a traditional set of core content, to instead embed CTE approaches, can help to break down these barriers. Converting required courses to a CTE lens — for example, revamping a required 9th grade biology course to a CTE curriculum — can ensure all students receive career-connected content and **formalize relationships between CTE and academic courses**.

> “Studies have shown that taking CTE courses along with academic classes minimizes the risk of students dropping out of high school.”

Challenge 11: **Tracking and bias in STEM opportunities limit access for students of color**

Many schools continue to track students into narrow pathways — for their math and science courses and/or to a CTE pathway — early in their careers, in some cases in elementary grades, and use data such as middle school math performance to determine high school course options. The experts we interviewed consistently noted how this **early tracking puts students on paths that they cannot easily change in the future, therefore locking students out of opportunities to take advanced courses.** Research has shown that early tracking in turn impacts later high school course taking as well as high school performance, college performance, and the likelihood students will graduate from college with a STEM degree.[67] For example, prior to a recent policy change, a California district placed incoming 9th grade students in either biology or agriculture based on students' 8th grade math scores. Once on this pathway there was no way to switch to the other, so students placed in agriculture were locked out of the rest of the science pathway.

Tracking plays a large role in limiting access to advanced STEM courses for students of color. Research has long documented that **judgment of students' academic ability and subsequent placement in tracks or ability-grouped classes follows race and social class differences.**[68] Recent research has also demonstrated Black and Latinx students are often denied access to limited seats in advanced courses, particularly in racially diverse schools.[69] Undeniably, while tracking continues to occur based on race, students of color will receive less access to quality STEM learning experiences from early in their educational career through their time in high school. Because they receive less preparation and engaging experiences early on, they are in turn less prepared and less interested in STEM as they age. Bottia et al. (2015) noted, "Particular attention should be given to underrepresented subgroups of students to increase their chances to follow STEM pathways. Doing so will require a serious evaluation and redesign of tracking practices to eliminate their correlation with students' racial and SES backgrounds, including offering honors courses for all students."[70]

Furthermore, educators' and administrators' racial bias is a persistent factor in limiting access to advanced course opportunities for students of color. Without interrogating such biases, there are harmful impacts for Black and Latinx students (and particularly for high-achieving students), who are regularly denied opportunities to participate in advanced courses due to low expectations held by teachers.[71] For example, research has shown that teachers often underestimate the academic abilities of Black, Latinx, and Indigenous students in math, believing that the course they are teaching is more difficult for students of color than it is for white students. Teachers' lower expectations are in turn linked with Black and Latinx students having lower academic expectations for themselves as well as lower grades,[72] churning the systemic cycle of racism experienced by students of color (and additionally impacting students' sense of self-worth and confidence to succeed academically). "Educator bias is one of the biggest barriers for Black and Latin[x] students, [which is] when school leadership overly rely on the recommendations of teachers and counselors whose judgments may be shaped by implicit or explicit racial bias."[73] These racial biases also show up in assessment and grading practices, both teacher-written and those developed by test publishers.[74] "Testing materials can undermine diversity, reinforce stereotypical roles, and devalue racial and cultural differences. And because teachers are not

immune to racial bias, those biases can show up in their grading practices."[75]

> "When teachers act from implicit racial biases and hold lower expectations for students of color, those biases can show up in their assessment practices, which in turn create harmful impacts for Black and Latinx students' grades and self-confidence to succeed academically."

Policies governing practices such as student course selection can have unintended consequences on limiting STEM course access and course taking by students of color. For example, while traditional opt-in policies for course enrollment can reduce student uptake and magnify the impact of implicit racial bias, **academic acceleration policies like that passed recently by the Washington state legislature** automatically enroll students in the next advanced course. As a result of this change, the demographics of student enrollment in those courses has changed and will continue to change, and there is a shift in the default thinking that not all students may be capable of continuing on an advanced STEM path. Since implementing this policy, Tacoma Public Schools has seen the percentage of historically marginalized students in advanced classes rise from 19.5 percent to 60 percent.[76] Another recent example of policy guidance comes from the New York Equity Coalition and State Department of Education, who have **partnered to create guidance for school districts** on how to improve equitable access to advanced coursework. Across the country, more policies are needed to support students of color to pursue advanced STEM courses and disrupt the structurally inequitable practices currently baked-in to our STEM education ecosystems.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS (NCTM)

Resource guides and guidance focused on examining and changing policies and practices impacting inequitable mathematics education

NCTM's Catalyzing Change series offers resource guides, guidance, webinars, and publications to support critical conversations and decision-making around inequitable policies and practices in mathematics education at every level.

One resource in particular identifies and addresses the challenges inherent to existing high school mathematics, focusing on how to ensure that each and every student has the mathematics experiences necessary to increase their opportunities for personal and professional success.

In particular, attention is paid to the need to end tracking of students and teachers and ensure school and district policies support access for all high school students, regardless of gender, race, class, or ethnicity.

Content adapted from NCTM's website

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Research Sources

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