

National Science Foundation
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A SUBCOMMITTEE OF THE ADVISORY COMMITTEE
OF THE EDUCATION & HUMAN RESOURCES DIRECTORATE

STEM

EDUCATION FOR THE FUTURE

A VISIONING REPORT





The logo features the word "STEM" in large, bold, blue letters. Each letter is filled with a white icon: 'S' contains a flask with bubbles, 'T' contains a circuit board, 'E' contains a gear, and 'M' contains a rocket. Below "STEM" are the words "EDUCATION" and "FOR THE FUTURE" in a bold, grey, sans-serif font, stacked on two lines.

STEM
EDUCATION
FOR THE FUTURE

A VISIONING REPORT
MAY 2020



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“All citizens can contribute to our nation’s progress and vibrancy. To be prepared for the STEM careers of the future, all learners must have an equitable opportunity to acquire foundational STEM knowledge. The STEM Education of the Future brings together our advanced understanding of how people learn with modern technology to create more personalized learning experiences, to inspire learning, and to foster creativity from an early age. It will unleash and harness the curiosity of young people and adult learners across the United States, cultivating a culture of innovation and inquiry, and ensuring our nation remains the global leader in science and technology discovery and competitiveness.”

A **VISION STATEMENT** FOR STEM EDUCATION OF THE FUTURE



PREFACE

Rapid technological advancements and societal changes are our daily reality. While the future of work, the economy, and society is uncertain, one thing is not: To maintain the nation's leadership in science and technology discovery, we must create an approach to science, technology, engineering, and math (STEM) education that prepares and advances the U.S. for this future.

Experts agree that science, technology, engineering and math will drive new innovations across disciplines, making use of computational power to accelerate discoveries and finding creative ways to work across disciplinary silos to solve big challenges. To remain competitive going forward, our nation must continue to design and build a thriving innovation economy, supported by a citizenry that is invested in the STEM enterprise. To succeed, the nation must invest in new research and innovation infrastructures that include all people, regardless of their background.

HOW DO WE ACHIEVE THIS VISION?

We instill creativity, innovation, and a passion for STEM from an early age, and we maintain that engagement and enthusiasm throughout their lives. Doing so will unleash an innovation culture, teaching learners of all ages to take risks, be creative, and problem-solve.

Today, we are far from this goal. Many Americans are entering the workforce without a basic grasp of STEM facts and approaches. Equally worrisome, amid the stagnant or dipping numbers of U.S.-born STEM workers, there is a critical lack of women, people with disabilities and African Americans, Hispanic Americans, and Native Americans who remain underrepresented in STEM. This underrepresentation is especially evident in several strategic areas critical for U.S. progress and security, including computer science, mathematics, and engineering.

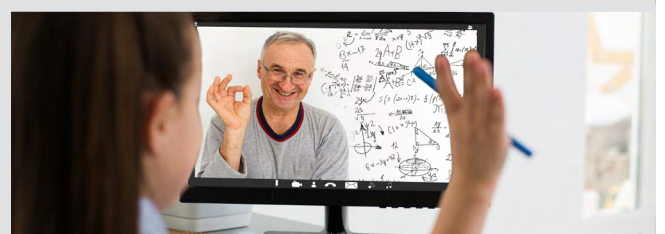
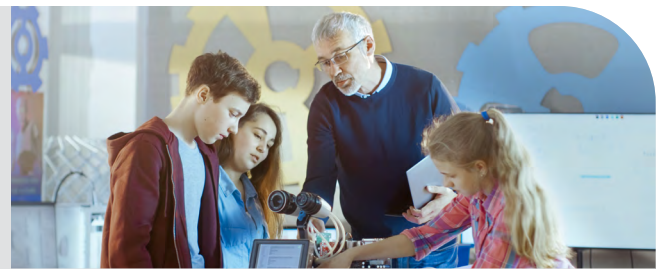
We are in dire need of STEM role models and leaders for the future. By 2060,¹ Black and Hispanic youth will comprise nearly half of all U.S. school-age children. However, STEM faculty from these backgrounds are currently scarce, and trends among the number of domestic students who pursue advanced research degrees in STEM disciplines—particularly computer science, mathematics, and engineering—provide

little hope for the necessary progress toward increasing diversity, inclusion, and equity of the STEM and STEM-education workforce.

This workforce representation gap is a threat, but it's also an opportunity for the American STEM education enterprise.

To maximize the opportunity, we must consider the entire education ecosystem so that children of all backgrounds, race, ethnicity, gender, religion and income levels can learn the wonders and possibilities of STEM and maintain that interest and passion throughout their lives.

Whether or not they become scientists or engineers, all Americans should have the access, opportunity, encouragement, and tools to participate in the innovation economy, and to succeed amid technological progress and change. Likewise, it is vital to ensure that the American workforce is upskilled to thrive in a future influenced and transformed by technology.



Achieving the goals of lifelong STEM learning, equitable access to sustained success, and a strong American workforce will require answering key questions, including but not limited to:

- How can we incentivize higher education institutions to implement necessary change toward these goals, including adopting practices we know work?
- How can technology be used as a pedagogical tool and be a democratizing force?
- What non-traditional pathways are students taking to acquire skills, competencies, and credentials? How do these new pathways challenge higher education as we know it?
- How do people best learn STEM concepts at different life stages? How do different contexts, including where people live, affect learning? And how do we optimize content delivery to improve outcomes?

With these questions in mind, and with the goal that all Americans can become partners in the innovation economy, the STEM Education of the Future Subcommittee embarked on a journey² to understand how others have answered similar questions, to better assess what is possible, and to set a clear path for making STEM Education of the Future the cornerstone of progress and prosperity for the nation.





PRIORITIES, CHALLENGES & ACTIONS

Before creating a vision for the STEM Education of the Future, it is vital to understand the present. What are the challenges we face in current STEM education? What is working, and where are we falling short? What are our priorities now, and how can we shape them to strengthen our future?

The Subcommittee explored current examples of innovation in STEM Education, gathered information from individual experts and students, and looked for inspiration from NSF's 10 Big Ideas for Future Investment and the NSB's Vision 2030. From this work, the Subcommittee identified three priorities for a STEM Education of the Future that will ensure learners understand and are prepared for 21st century STEM knowledge and STEM careers:

- **Priority One**

All learners at all stages of their educational pathways must have access to and opportunities to choose STEM careers and contribute to the innovation economy.

- **Priority Two**

We must build an ethical workforce with future-proof skills.

- **Priority Three**

We must ensure that the appropriate technological innovations make it into learning spaces, whether face-to-face classrooms or not, guided by educators who understand how modern technology can affect learning, and how to use technology to enhance context and enrich learning experiences for students.

The STEM enterprise faces major challenges within each of these three priority areas. In this section, the Subcommittee identifies seven major challenges and provides action recommendations for how the STEM Education of the Future can address each of them.



PRIORITY I

All learners at all stages of their educational pathways must have access to and opportunities to choose STEM careers and contribute to the innovation economy.

CHALLENGE 1

Access to high-quality STEM education is uneven across the nation's geography and institutions.

- **Too often, learners' zip codes and income levels are the determining factor for the quality of their STEM education, and the future of the learner.**
- **Too many under-resourced rural and urban institutions struggle to provide high-quality STEM education.**
- **The high cost of higher education is a deterrent for many learners.**

CHALLENGE 1 | ACTIONS

Create opportunities for all students to receive an accessible and high-quality STEM education and help them foster a love and curiosity for science and mathematics from an early age.

- We must challenge our beliefs about the STEM education system and look for structural changes that make it both cost-accessible and sustainable.
- We must help citizens to pursue the STEM career of their choice through the mechanisms and paths that best suit them.
- We must train and incentivize STEM educators to provide learners with rewarding STEM experiences.
- Instruction should be informed by factors, context and challenges in both the local community and in the global state of affairs and STEM enterprise.
- Culturally relevant and context appropriate learning experiences, coupled with modern technologies, are particularly important in rural, underserved, or under-resourced communities where access to STEM experiences can be more limited.

CHALLENGE 2

The persistent and complex dynamics of bias in STEM.

- Despite considerable progress, the STEM enterprise still suffers from biases, which create unwelcoming and hostile environments for underrepresented racial and ethnic groups, people with disabilities, women and other groups.

CHALLENGE 2 | ACTIONS

More research is needed to determine the most effective access, equity, and inclusion interventions to promote change.

- We must increase the number of faculty role models from underrepresented groups in STEM classrooms, from pre-K to graduate school.
- We must mitigate historical and current stereotypes by increasing the numbers of high-achieving STEM professionals from underrepresented groups in industry, academia, and government and improving the visibility of these role models.
- It is crucial that today's students represent all dimensions of America's diverse society to facilitate equity and inclusion, because today's students will become tomorrow's STEM faculty, workforce and innovators.
- We must improve our understanding of the mechanisms by which bias, both implicit and explicit, and aggressions, both micro- and macro-, impact STEM student success from an early age, including the psychology and sociology of impostor syndrome and stereotype threat.³ Additionally, we must actively strive to address these barriers to student success and promote student resilience.



CHALLENGE 3

The pathways to attain an undergraduate degree and/or the competencies required for a STEM job are changing. Some of these shifts have the potential to challenge common academic structures.

- **The population of learners is continuing to shift from full-time STEM students to working adult learners.**
- **Today's academic structure was designed with traditional students in mind and it is not optimal for the growing number of students who are starting their postsecondary education at an older age, or for the majority of undergraduate students who opt to start at community colleges instead of a four-year university.**
- **Skills that will be needed in the future are to be earned by all learners above and beyond traditional STEM content.**
- **In some areas of the economy, industry credentialing is disrupting existing education models by replacing the need for diplomas to more competency-based skills and credentialing.**

CHALLENGE 3 | ACTIONS

Regardless of their educational pathway, students need to acquire core 21st century competencies, including the ability to adapt and be flexible, to work collaboratively, learn independently, and be lifelong learners.

- STEM education must consider the new ways that companies seek to fulfill the STEM jobs of the future, and more clearly understand the implications of these changes on how learners need to prepare.
- We need to understand how foundational STEM concepts, computational thinking, and systems thinking are best learned.
- We must understand how to instill flexibility, creativity, teamwork, problem solving, and communication skills.
- We must examine the current academic structures and see if they best respond to the needs of current and future students.

CHALLENGE 4

STEM education must be adaptable to all phases of life and be tailored to the changing ways learners may process and engage information across their lifespan.

- More adults will require re-tooling and upskilling to continue their participation in the workforce of the future.

CHALLENGE 4 | ACTIONS

Educators need to understand how people learn from Pre-K through adulthood.

- We must gain greater knowledge about how factors beyond age influence learning, including the impact of local communities and learning environments.
- We need to understand how learners' self-actualization and cognitive abilities at each life stage affect learning.



CHALLENGE 5

A lack of diversity of thought and of human capital in U.S. STEM graduate programs hinders the nation's ability to maintain its position as a global leader in 21st Century innovation.

- **STEM research is still largely siloed, because graduate education and research do not always reward convergent or transdisciplinary approaches. However, evidence shows creativity and innovation in STEM require researchers to navigate across disciplinary boundaries and to take risks.**
- **Access to quality graduate education for all groups does not occur evenly across all STEM disciplines. Diversity exists in some fields at the graduate school level, but women, people with disabilities, and other groups are grossly underrepresented in others.⁴ Most doctoral students in computer science and engineering are international students with temporary student visas, for example, and enrollment of American students in those programs has been static or declining.⁵**

CHALLENGE 5 | ACTIONS

Graduate education should enable students to acquire core 21st century research competencies, including the ability to be creative, to solve meaningful research problems, to work across disciplinary boundaries, and to collaborate with diverse teams.

- Some research problems can only be solved by transcending STEM boundaries across disciplines, and we must reward researchers who endeavor to tackle these tough problems by engaging across disciplines.
- To accelerate impactful discovery, we must understand the mechanisms and environments that groom successful researchers and innovators.
- Mentoring and education of graduate students, whether at the master's or doctoral level, should enable a positive and safe environment, which allows all students to explore different pathways and personalize their career outcomes.

There must be opportunities and incentives for domestic students to pursue research careers in areas of national strategic importance.

- Efforts to attract American youth to research careers in certain STEM fields are crucial. We must understand and address the factors (e.g., financial aid, academic preparation, and availability of appropriate mentorship) that deter undergraduate American students from pursuing master's and doctoral programs in strategic fields.
- Graduate education should create opportunities for students to receive an accessible and high-quality graduate STEM education and address systemic bias that reduce access for underrepresented groups

PRIORITY II

It is imperative to build an ethical workforce with future-proof skills.

CHALLENGE 1

Advances in 21st century technologies present ethical issues and require new creative thinking.

- As technologies develop, STEM workers and researchers must be able to recognize both their potential benefits and technological threats to society.
- As workplaces become more automated, capabilities that include creativity and complex problem solving become more critical than manual skills or memorized content.

CHALLENGE 1 | ACTIONS

STEM education must prepare our workforce to innovate and work with modern technologies, and also to consider their societal effects.

- It is critical to develop STEM learners' ability and willingness to acknowledge and resolve ethical issues in their work.
- The STEM education system needs to define what foundational knowledge all students need, as well as shift its emphasis from memorization of scientific facts, formulas, and definitions to understanding concepts in context and be ready to use available computational power to accomplish tasks.. This clearer definition and shift in emphasis will strengthen traits such as creativity and problem solving.



PRIORITY III

We must ensure that the appropriate technological innovations make it into learning spaces, whether face-to-face classrooms or not, guided by educators who understand how modern technology can affect learning, and how to use technology to enhance context and enrich learning experiences for students.

CHALLENGE 1

We need to understand how virtual distance learning environments affect cognition and learning.

- **Learners at all levels, including graduate students, are not always located in the same physical space, and this trend is only increasing.⁶ Virtual and distance learning present new opportunities and new challenges.**

CHALLENGE 1 | ACTIONS

Research is needed to build a deeper understanding of the possibilities of virtual and hybrid distance learning environments, from how they affect the development of skills and abilities, to the pedagogies and curriculum that work best.

- Research priorities must include exploring how new educational technological infrastructures affect student outcomes, as well as their impact on structural factors such as cost, access to quality education, faculty retention, and growth of the STEM research enterprise.
- Research needs to accelerate development, testing, and understanding of technologies that facilitate and reward remote experiential learning, such as learning that traditionally happens in laboratories and field work.



STEM

3 LESSONS FOR THE FUTURE

FROM THE SUBCOMMITTEE'S INTERACTIONS WITH STEM EDUCATION INNOVATORS

As part of its work, the STEM Education of the Future Subcommittee interviewed innovators from educational institutions that have already adopted promising pedagogies. The Subcommittee examined those pedagogies that support a deeper exploration of STEM-related concepts in context, including those enabled by project-based inquiry for all students.

Institutions examined include:

- High Tech High
- Station¹
- Minerva Schools
- Olin College of Engineering
- Harvey Mudd College
- Arizona State University
- Worcester Polytechnic Institute

Notably, these innovators, which span learning contexts from K-12 through graduate school, deploy surprisingly similar strategies that may be broadly implemented to improve STEM education.

LESSON I

Learning environments are student-centered, project-based, and personalized.

These institutions have developed innovative instructional models that create learner-centered and project-based STEM learning environments. Students have opportunities to direct their own learning and demonstrate STEM knowledge by undertaking complex projects. Such practices are grounded in contemporary understanding of how people learn. They also use evidence-based teaching strategies, such as complex instruction,⁷ inquiry-based learning,⁸ and culturally responsive pedagogies.⁹

LEARNER-CENTERED

In this approach, the learner is at the center of all planning and actions. Learning environments intentionally build communities of practice between students and faculty, recognizing that learning is a social act that includes guidance and mentoring. The innovators the Subcommittee examined strive to create rewarding interactions that enhance learning for all. They mitigate the mindset that STEM disciplines are difficult and appropriate for only some to pursue. All groups, including women, low-income, first-generation, and other underserved student groups, enter learning environments that are culturally and linguistically relevant to them, and that are engaging and welcoming.

PROJECT-BASED

Project-based learning allows students to acquire knowledge and skills, to practice inquiry across multiple disciplines, and to make meaningful connections across STEM disciplines, medicine, the social and behavioral sciences, and the humanities. Project-based learning often focuses on real-world problems that can have significant social impact across society. A common thread

among these innovators, from K-12 to graduate school, is the participation of their students in meaningful projects that require STEM concepts. This participation varied from projects in single courses to capstone projects that span the entire curriculum.

The innovators also changed their assessment and grading practices to align with this emphasis on project-based learning. As a result, learning becomes driven by students' motivation and their demonstrated capacity to learn, rather than mastery of specific STEM content alone, or by high-stakes examinations that determine course grades. From performance-based assessments with rubrics that help students develop competencies over time, to evaluations based on portfolios of student work, the innovators offer many opportunities for students to complete complex, technology-based projects with a variety of approaches to evaluations and grades.

PERSONALIZED

The innovators strongly feature self-directed learning. At some of these institutions, students start with a project of personal interest and decide how to acquire the knowledge needed to solve the problem, whether enrolling in classes, seeking mentoring, or accessing information through other means. Several innovators have eliminated practices that sort students into groups based on background or prior knowledge. Differences in foundational knowledge are instead mitigated individually through faculty mentoring or other strategies, allowing students to engage in self-directed learning based on individual preferences and pacing in a personalized way.

LESSON II

Equity and inclusion are foundational principles.

These innovators share a conviction that they are responsible for enabling all learners to succeed. The goal of their institutions, from administrators to faculty and staff, is to make each student feel welcomed and a part of the community. Equity and inclusion are embedded in the entire educational process.

EQUITY

These innovators have focused on models designed to enable all learners to build competencies over time, rather than more traditional models that seek to “weed out the weak.” As a result, learners are finding unprecedented success as measured by meaningful metrics, such as the percentage of students who attend college, succeed in college, graduate from college, enter professional or technical jobs, or attend graduate school.

INCLUSION

The Subcommittee also examined issues of inclusion within these innovators’ institutions. It spoke with scholars who study bias and examined how stereotypes can threaten students’ performance, regardless of intellectual capacity (i.e. stereotype threat). Additionally, STEM students from underrepresented groups shared eye-opening testimony about their experiences in highly competitive and ground-breaking STEM programs. From these conversations,¹⁰ it is evident that simply adopting pedagogical innovations won’t ensure equitable participation in STEM.

Instead, institutions must address two important threats:

1. Unwelcoming, non-inclusive institutional environments created by administrators, faculty, and non-marginalized students that expect underrepresented students to fail.
2. The negative self-evaluation that marginalized students unconsciously make of themselves affecting cognitive performance (stereotype threat) and social and behavioral well-being (impostor syndrome) regardless of intellectual capacity.

In sum, increasing diversity and broadening participation in STEM cannot be viewed or addressed as an independent problem; instead, creating greater diversity and participation should be designed into the educational ecosystem. Every learning environment, tool, classroom, syllabus, instructor, and intervention must consider, from the beginning, how to serve all students. Only then will learners of all ages and backgrounds have equitable opportunities to participate in the STEM enterprise.



LESSON III

Technology holds promise for creating equitable learning environments, but it also alters the skills we need in the future, and changes what and how we teach.

The promise of modern technology to facilitate how people learn STEM and change inequalities in the education enterprise is captured by Fullan and Langorothy¹¹ in the following quote:

“...digital access makes it possible for students to apply their solutions to real-world problems with authentic audiences well beyond the boundaries of their schools. This is the real potential of technology to affect learning – not to facilitate the delivery and consumption of knowledge, but to enable students to use their knowledge in the world.”

The potential of technology to promote access, equity, and inclusion is inspiring. Members of the Subcommittee sought to understand trends, learning tools, and environments that technology might offer today and in the future. It explored where high-tech companies think artificial intelligence and automation will go, and the competencies and skills that learners will need over the next decades.

In particular, the promise of technology was explored in two arenas:

1. Preparing learners of all ages to work actively with technology and other contemporary tools of science and mathematics, as technology will continuously change the nature of work and STEM.
2. Technology’s promise to provide tools to improve research, teaching, and learning.

In spite of its considerable promise, technology also poses challenges and threats. Educators, learners, and researchers must examine the biological, psychological, societal, and ethical implications of technological advances. New theories and models of cognition and learning are needed to fully harness technology’s benefits to humankind. Where once the outsourcing of jobs to computers was a major threat, now it is a given that everyone must be able to fully leverage the computational power offered by new technologies. At the same time, we must be discerning about how technologies, particularly

those applied in computational and data intensive endeavors, influence how we engage with the world and with each other. Technology can also inadvertently exacerbate the digital equity gap that continues to exist in under-resourced communities throughout the U.S.^{12, 13}

In the future, there will be a demand for humans to do work that machines cannot do or cannot do as well as humans can. Being able to think critically, reason probabilistically, and exercise

logical, discerning judgement will be some of the most important human competencies. We must cultivate these qualities in young people and “re-tool” adult learners to master them as well. How we harness cognitive and emotional mechanisms to infuse an attitude of self-motivation and self-actualization, in young people and adults, will be the key to our ability to adapt to the new jobs of the future.





A VISION FOR STEM EDUCATION OF THE FUTURE

Through an examination of STEM innovators and the current education landscape, together with an assessment of future challenges and opportunities, the Subcommittee has worked to identify the principles and priorities that must define a STEM Education of the Future. Rather than provide detailed and specific recommendations, the Subcommittee has outlined these important 21st century considerations for the NSF community to weigh in shaping forward-looking strategies. The Subcommittee concludes that research, policies, and practices that elevate these essential qualities will ensure a strong STEM Education of the Future—one that allows all Americans to participate in a vital human endeavor, and ensures that our nation will remain a global leader and innovator.



The STEM Education of the Future will harness technology in ways that provide equitable access to all learners and ensure that all learners thrive. Skillful instruction aided by technological advances can overcome structural barriers such as cost, distance, opportunity, socioeconomic background, or prior STEM preparation, and allow all STEM learners to overcome stereotypes and biases with the support of their learning communities.

Well-prepared educators and mentors will use evidence-based methods, pedagogies and technologies that are informed by research on how people learn in different contexts and across their lifespans. Wherever appropriate, all new technologies, including those powered by artificial intelligence, will be used in formal and informal settings in tailored ways to ensure learners acquire competencies and STEM knowledge.

In this equitable, learner-centered environment, all learning pathways will be aligned to learners' interests and include proven, experiential activities in both physical and digital ways (for example, virtual labs and online classes). Connections to relevant, real-life problems, including those in students' communities, will be what drive STEM learning. Teachers will focus on providing knowledge and experiences, such as problem solving, ethics, and decision making, that will be needed in future work contexts and jobs. These connections to real experiences will demonstrate the tangible benefits of STEM education and empower learners to own their education and become the agents of their own futures.

The STEM Education of the Future will enable learners to participate effectively in the STEM enterprise of today, and tomorrow. In a future where STEM knowledge and technology rapidly evolve, STEM learning will not merely be about mastering a stable knowledge base. Instead, learners must be skilled at lifelong learning and adapt with ease to the changing world. From reflection to metacognition to thinking in convergent, dynamic, and computational ways about complex problems, lifelong learners will need to adapt to tomorrow's challenges, and contribute to the nation's health, safety, and success in the future.



A VISION ALIGNED WITH THE NSB & NSF

BOLD | VISIONARY | PROACTIVE | URGENT | NIMBLE

The watchwords **bold**, **visionary**, **proactive**, **urgent**, and **nimble** are the common threads that run through the Subcommittee's vision for the STEM Education of the Future. They also fit the NSF's 10 Big Ideas for Future Investment and the National Science Board's priorities, being united in a sense of urgency for creating a STEM-educated workforce that is not merely aware of STEM concepts and principles from an early age but is also creative and innovative.

It is imperative that the Directorate for Education and Human Resources (EHR) and the agency think boldly, nimbly, and for the long term. The Subcommittee emphasizes that the nation must be proactive and nimble in addressing the urgent challenges of today and those in the years ahead.

THE NATIONAL SCIENCE BOARD'S VISION 2030

As the NSB points out in Vision 2030, the increased globalization of science and engineering research presents both an opportunity and a pressing concern. There is an enormous need to grow a domestic STEM workforce in an era when science and technology permeate the economy. Current trends and demographic shifts in our national science and engineering indicators are not promising: Our nation's youth lack interest in research STEM careers, and progress is slow in reversing dangerous trends in low numbers of women, people with disabilities, and other underrepresented groups in the innovation ecosystem.

In other words, the U.S. is at risk of surrendering its global leadership in technological innovation. Urgent actions and long-term investments are needed in STEM Education and Workforce Development Research to establish an educational infrastructure that is modern and attracts, retains, and develops the diverse STEM talent that the United States needs for the future.

NSF'S 10 BIG IDEAS

NSF's initiative to define the cutting-edge research agendas and processes that will push forward the frontiers of U.S. research and provide

innovative approaches to solving some of the most pressing problems the world faces, as well as lead to discoveries not yet known, is known as The 10 Big Ideas. These capitalize on NSF's investment in fundamental STEM research, which is the basis for discovery, invention, and innovation, and ensures that future generations can reap their benefits. This STEM Education of the Future document builds on many of the concepts present in the Big Ideas.

EHR'S STEM EDUCATION OF THE FUTURE

Development of talent to reach these goals is of utmost importance for the NSB, NSF, and EHR — for the next decade and beyond. This ambitious visioning document points the way forward, through funding STEM education innovations **from pre-K through post-doctoral experiences:**

- It aligns with NSF's 10 Big Ideas for Future Investment, in recognizing **the need for convergent-, computational-, systems-, and critical-thinking for the future STEM enterprise.**
- It aligns with NSF's 10 Big Ideas in its call for **equity and inclusion of all learners in the STEM enterprise (NSF INCLUDES),¹⁴** and its focus on the importance of **the convergence of disciplinary knowledge, tools, methods, and approaches (Growing Convergence Research).¹⁵**
- Further, it echoes The Future of Work at the Human-Technology Frontier¹⁶ and the Harnessing the Data Revolution¹⁷ Big Ideas in its call for **the use of technology and data to shape learning environments and pedagogies for learners of all ages.**
- In sum, the STEM Education of the Future aligns with the Big Ideas' emphasis on the importance of **providing learners across their lifespan with the opportunity to develop competencies and knowledge.**

In conclusion, STEM Education of the Future, NSB's Vision 2030, and NSF's 10 Big Ideas are aligned in their bold, visionary, proactive, and urgent calls to make the changes needed to STEM education today, so that the United States can remain the global technological and innovation leader of tomorrow.

FOOTNOTES

PAGE 8¹ William Frey, “The US Will Become ‘Minority White’ in 2045, Census Projects: Youthful minorities are the engine of future growth,” (Washington, D.C.: Brookings Institution, The Avenue, 2018)

PAGE 9² **Note:** The subcommittee started this work in the Spring of 2018. At the time of this report’s approval in the Spring of 2020, the world and the Nation are facing an unprecedented health, social, and economic emergency with the SARS-CoV-2 pandemic, which is dramatically impacting all realms of life. The unprecedented move by the majority of educational institutions to online learning to comply with social distancing measures is shaking all educational structures as we know them. This new reality is revealing both the fragility and the resilience of institutions, and putting enormous pressures on faculty, researchers, administrators, and students. A discussion about issues of access, technology, pedagogy, and appropriate faculty training in a future STEM education ecosystem where things will never be the same is now more relevant. Thus, this unsettling new reality has made the contents of this report even more pertinent and urgent than before.

PAGE 14³ Stereotype threat is the unconscious decrease in performance of people for which a societal stereotype predicts they are less capable. For example, women underperform on math tests in situations in which they are consciously or unconsciously made aware of their gender.

PAGE 16⁴ <https://www.nsf.gov/statistics/2018/nsb20181/report/sections/higher-education-in-science-and-engineering/graduate-education-enrollment-and-degrees-in-the-united-states>

PAGE 16⁵ **Note:** As we improve graduate education, we must continue to recognize the benefits of international experiences for students and continue to attract the best and brightest foreign-born scientists. Foreign scientists, international exchanges and collaborations are critically important in the progress of the American scientific enterprise.

PAGE 19⁶ As of March 2020, the public health-related social and physical distancing measures implemented in the wake of the SARS-CoV-2 pandemic have brought to light significant vulnerabilities in the American education system. American students and educational institutions have had to improvise, enhance, and develop remote learning plans across the country and for all ages.

PAGE 22⁷ Complex Instruction is an approach to small groupwork that promotes equitable interactions and learning, particularly effective in classroom settings where students bring multiple abilities and a range of community/cultural diversity.

- PAGE 22**⁸ Inquiry-based learning uses different evidence-based pedagogies to engage students by building knowledge through exploration, experience, and discussion. Instead of memorizing facts and material, students learn by doing.
- PAGE 22**⁹ Culturally responsive pedagogy is a learner-centered approach to teaching that nurtures the learners' unique cultural strengths to promote achievement and a sense of belonging and well-being about the student's cultural place in the world.
- PAGE 23**¹⁰ The subcommittee thanks Dr. Claude Steele, Stanford University for an open dialog about stereotype threat, Dr. Maria Klawe, President of Harvey Mudd College for an honest appreciation of leadership challenges of inclusion policies and Mr. Antonio Perez, an engineering junior at Olin College of Engineering for sharing his experience as an underrepresented student in a highly innovative STEM program.
- PAGE 24**¹¹ Fullan, M. & Langworthy, M. (2014) *A Rich Seam: How New Pedagogies Find Deep Learning*, London: Pearson.
- PAGE 25**¹² ...re, R; Vitale, D.; Stainoga, N. (2018), *The Digital Divide and Educational Equity*, ACT Research & Center for Equity in Learning, August Access online: <https://www.act.org/content/dam/act/unsecured/documents/R1698-digital-divide-2018-08.pdf>
- PAGE 25**¹³ Lee, Nicol Turner (2020) *What the coronavirus reveals about the digital divide between schools and communities*, Brookings Institute, March. <https://www.brookings.edu/blog/techtank/2020/03/17/what-the-coronavirus-reveals-about-the-digital-divide-between-schools-and-communities/>
- PAGE 29**¹⁴ https://www.nsf.gov/news/special_reports/big_ideas/includes.jsp
- PAGE 29**¹⁵ https://www.nsf.gov/news/special_reports/big_ideas/convergent.jsp
- PAGE 29**¹⁶ https://www.nsf.gov/news/special_reports/big_ideas/human_tech.jsp
- PAGE 29**¹⁷ https://www.nsf.gov/news/special_reports/big_ideas/harnessing.jsp

REFERENCES

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