SRI International®

Mid-Scale Research Infrastructure for STEM Education Research

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Contents

Introduction

In 2016, the National Science Foundation (NSF) unveiled a set of "Big Ideas," 10 bold, long-term research and process ideas that identify areas for future investment at the frontiers of science and engineering. One of those big ideas, the NSF Mid-scale Research Infrastructure Program (Mid-scale RI 1 & 2), supports the implementation of projects that comprise any combination of equipment, instrumentation, and computational hardware and software, as well as the necessary commissioning and human capital in support of their implementation. The total cost for Mid-scale RI-1 projects ranges from $6 million up to $20 million, and mid-scale RI-2 projects can range from $20 million up to $70 million. The Mid-scale Research Infrastructure Big Idea aims to transform scientific and engineering (S&E) research fields and STEM (Science, Technology, Engineering, Math) education research fields by investing in new capabilities, while simultaneously training early-career researchers in the development, design, and construction of cutting-edge infrastructure.

Mid-scale research infrastructure is a new funding area for NSF and for the Directorate for Education and Human Resources (EHR). Some S&E fields have well documented ideas for mid-scale research projects – microscopes, robotic equipment, computation power, and lasers. In contrast, mid-scale research infrastructure needs for STEM education are less well known. Possible categories of infrastructure may include laboratories and observational systems; instrumentation; platforms and computational and analytical systems; data availability and repositories; policies and practices around data security, privacy, and confidentiality; and social infrastructure such as networks, dissemination channels and organizations. To advance understanding of what research infrastructure encompasses in STEM education and begin to identify high priority investments, NSF awarded a grant to SRI International, a non-profit research institute, to convene key researchers and stakeholders around this topic. SRI's approach entails framing the pressing issues and opportunities for advancement in STEM education, and then identifying impediments and facilitators to progress that may point to the need for new research infrastructure.

Workshops

SRI hosted a series of four virtual workshops over the second half of 2020 to help the STEM education community develop a vision and set of priorities for the mid-scale infrastructure needed to support research. Specifically, these workshops brought together STEM education experts and stakeholders to: (1) gather and exchange ideas on how mid-scale research infrastructure applies to STEM education, (2) identify gaps and opportunities, and (3) develop a community around this topic and initiate new collaborations.

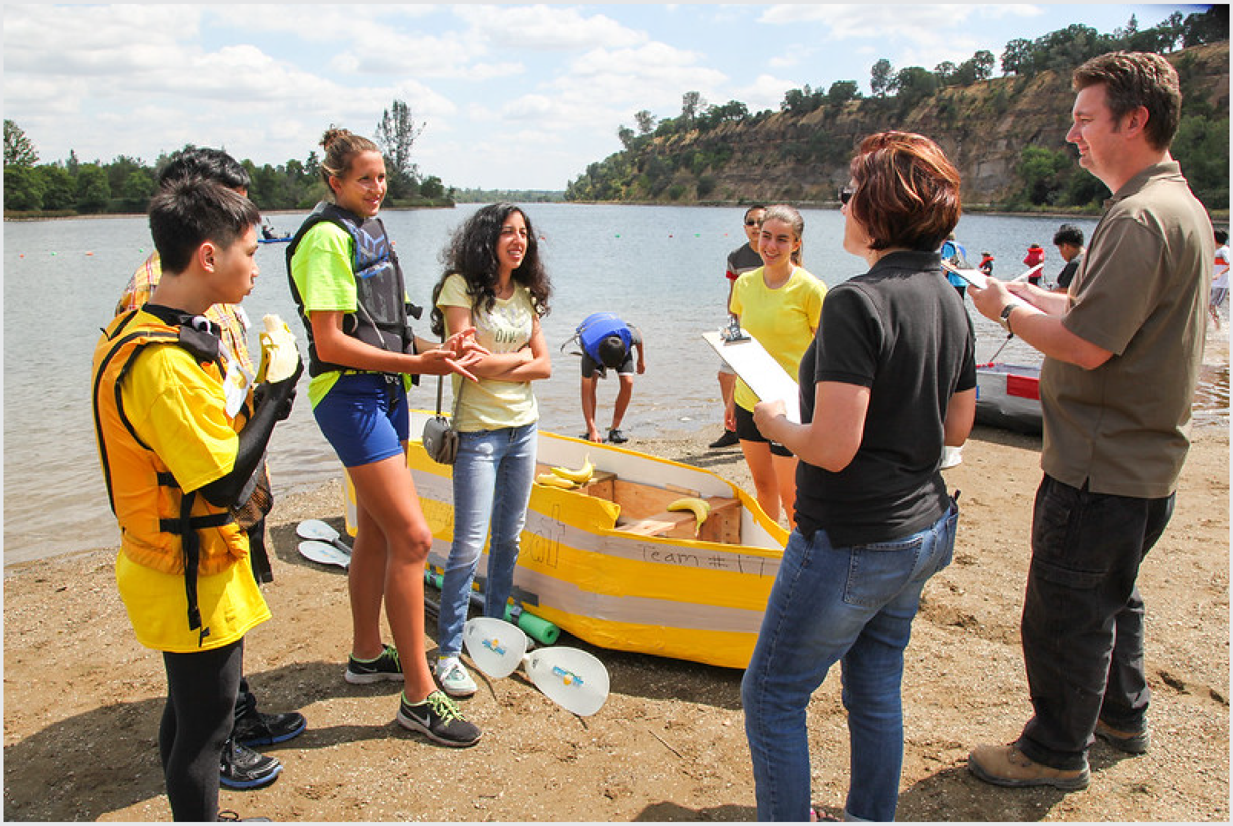
Workshop Discussion Topics

1. What students need to learn, taking into account the cross-disciplinary skills and knowledge needed for future STEM careers and engaged citizenry.

2. Technological advances to enhance student learning, engagement and achievement, including research and applications involving artificial intelligence, virtual reality, and biometric data

3. How diverse students advance through STEM pathways and issues of equity and inclusion

4. Research infrastructure for undergraduate STEM education



Preface

This report summarizes the main themes from the four workshops. These views do not necessarily represent those of SRI or of all participants. For the most part, issues that arose with no associated infrastructure ideas were not included. Full workshop summaries can be found in the appendix.

Curriculum and Instructional Reform

Workshop participants identified a need for instructional and curriculum reform to provide more enriching educational experiences and to better prepare students for the 21st century workplace. Education practitioners have only been able to artificially connect classroom instruction to the "real world," which has resulted in a general lack of authenticity in student learning experiences. Experts should develop flexible learning environments that enable students to pursue their own pathways and attain the disciplinary knowledge and skills needed to achieve their goals. Curriculum should be centered around students' experiences rather than organizational structures.

Participants described a potentially expanded role for technology in the future of STEM learning. Advances in technology can provide the scaffolding for more authentic forms of collaborative learning. Technology will help to eliminate the physical barriers posed by classroom walls and facilitate "anytime, anywhere" learning, including opportunities for collaboration with students outside of one's own classroom, school, or district. Educators can leverage technology to scale projects and expand student access to effective academic interventions, like personalized learning systems, automatic feedback, tailored performance assessments, and educational gaming. Technology can also support teacher training programs and initiatives through teaching simulations (also known as digital puppeteering), in addition to nonessential learning, such as classroom management, to streamline classroom instruction.

STEM curricula should be focused on improving STEM competencies among all students. The workforce currently faces an excess of demand for certain STEM competencies, not an under-supply of STEM workers. There is a disconnect between curricula and the reality of the workforce, such that even non-STEM workers are required to have technical and analytical skills to succeed. For example, educators should better incorporate development of data science skills for students who do not necessarily plan to join the STEM workforce. Teacher training infrastructure could connect educators with the skills and technologies they need to keep their curricula up-to-date and relevant for learners and businesses. Researchers and educators should explore the use of blockchain technology to award credentials and verify competencies while breaking down barriers for unconventional students.

Equity and Dimensions of Student Experience

The path to equity in STEM education has always been challenging, and the pandemic has further exacerbated opportunity and achievement gaps between underserved students and their peers. This is the case not only for minoritized communities, but rural populations as well. Low-income, transient students often move across administrative boundaries to access services, and traditional data and data infrastructures do a poor job in tracking them. Boundaries across school districts, across states, and between K-12 and postsecondary education all serve to hamper understanding and entrench inequity. Opportunities exist to create and expand data infrastructure to better understand students through social media and mobile phone data. These data sources are less affected by administrative silos that impede research using traditional data infrastructure. Privacy and access are critical concerns when using these alternative types of data, and careful thought must be put into any infrastructure that utilizes these sources.

Data infrastructure should reflect the expansive nature of student learning experiences while engaging learners from different communities. Digital toolkits may allow students from different schools, districts, or even states or countries to work together on projects across time and space, either synchronously or asynchronously. Multi-dimensional infrastructure would give researchers the opportunity to unify qualitative and quantitative teaching, administrative, and intervention data, identifying the multitude of influences on student choice and career pathways in STEM. It could also track important informal learning experiences that occur outside of the classroom. New assessment infrastructure is needed, as traditional metrics contain biases and do not reflect different forms of knowledge and ways in which students demonstrate knowledge.

Critical race spaces in education have acted as incubators for non-traditional research frameworks connecting lived experience, expertise, and traditional education for many years. Researchers should amplify the voices and expertise of scholars of color as they create infrastructure that captures the varied nature of student learning experiences. Education research centers and collaborative groups are a type of social and human infrastructure that could focus on innovative ways to break down barriers and increase equity while working to capture the multifaceted experiences of diverse students and learners.

Connecting Disparate Data

Silos are a major issue for STEM education research and data. Data not only come in a variety of unstandardized formats, but they are stored in distributed databases that are not widely accessible. Poor replicability and the small-scale nature of most education research has always been an issue in the field. In addition, the United States has numerous federal statistical agencies that each have their own rules and regulations, as well as myriad state agencies, school districts, and commercial vendors—all of which can be territorial about their data. Another important boundary exists between K-12 and higher education research. These silos and barriers are a pressing issue that could have an infrastructure solution.

Technologies, algorithms, and data repositories could be useful for tackling the big questions in education and allowing researchers to work across silos and expand collaboration. Methods, tools, and models need standardization as well as flexibility. An NSF-run data repository could be a first step in this direction. Other types of data repositories, platforms, and artificial intelligence applications could help with data-intensive areas of study, such as speech, psychometrics, and administrative data.

Forging better connections between researchers and private sector developers could take advantage of innovative ideas and funding while addressing the deluge of untested tools in the marketplace. Infrastructure should take advantage of public-private partnerships, building bridges between sometimes conflicting groups. Researchers in education should look to private firms and national laboratories as models for how to develop a more robust system to collect multimodal data.

Scaling and Implementation

Current studies of STEM education are hampered by the complexity of the questions being studied and the barriers to collaboration and data gathering. Funding opportunities for research studies rarely account for the time that it takes to build relationships between researchers, educational agencies and institutions, and teachers. Teachers who are interested in taking part in education research are already overwhelmed with their own work requirements and cannot take on the additional burden of classroom-based data gathering. Even with teachers gathering information in their classrooms, it is difficult to obtain the granularity needed. Existing infrastructure does not encourage relationships between scholarly experts and researchers in the wider education community that may be mutually beneficial, particularly with respect to the sharing of data and research methods. These management and communication hurdles likely contribute to the extensive time frame for implementing research ideas.

These deficiencies in the existing infrastructure point to the need for a better approach to implementation research and scaling of evidence-based practices. The ability to capture motion and affective states in an instructional environment could reduce the burden on faculty in collecting data. For example, researchers from Carnegie Mellon use cameras in the classroom to monitor student and teacher movements and even eye motion. Such tools would allow researchers to efficiently capture the human impact of pedagogical strategies and learning activities. Implementation research can also benefit from large-scale networks or organizations that collect, clean, and manage data on STEM education. Such infrastructure can also highlight and scale up ideas shown to work in both the K-12 and postsecondary education spaces.

Implications for Infrastructure

Major education research infrastructure should support communication, collaboration, and understanding across silos. With improved data systems and instrumentation, technological advances can afford enriched educational opportunities in STEM while also addressing current challenges of education research. Methods, tools, and models need standardization as well as flexibility. There is a pressing need for integrated, multimodal data infrastructure. Overcoming technical, policy, and competitive barriers to data sharing is important to realize these benefits, including being able to track students and teachers longitudinally and across boundaries. It is also important to consider and address ways in which assessment and data systems reflect and reinforce systemic inequities. Finally, participants emphasized the need for inclusive organizational and social infrastructure to support implementation and scaling of evidence-based practices.