

**Strategic Re-envisioning for the Education and Human  
Resources Directorate**

**A Report to the  
Directorate for Education and Human Resources  
National Science Foundation**

**by the**

**NSF Federal Advisory Committee for Education  
and Human Resources**

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Any opinions, findings, conclusions or recommendations presented in this material are only those of the authors; and do not necessarily reflect the views of the National Science Foundation.

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## About the

### Directorate for Education and Human Resources

The National Science Foundation (NSF) is the primary federal agency supporting research at the frontiers of knowledge, across all fields of science and engineering (S&E) and all levels of S&E education. NSF-funded research and education projects – selected through competitive, merit-based review—have fueled many important innovations that in turn have stimulated economic growth and improved the quality of life and health for all Americans.

NSF is keenly aware of current national and international trends and government-wide goals and priorities, which inform its strategic direction. Since its inception over 60 years ago, NSF has focused on science, technology, engineering and mathematics (STEM) education. Since 1990 this investment has been centered in the Directorate for Education and Human Resources (EHR) by supporting bold programs and innovative projects that lead to impact by meeting the needs of students, teachers, researchers, and the public.

EHR is committed to a vision of a healthy and vital national STEM education enterprise. The directorate works toward this vision through its mission, which is to support research and development on STEM education and learning and to engage and grow a diverse, STEM-literate citizenry that is ready to advance the frontiers of science and innovate for society. A portion of EHR's investment is strategically aimed at research to understand STEM learning and education.

EHR sought input from its Advisory Committee on a strategic framework for achieving the directorate's mission. Three themes are discussed in this document: STEM Learning and Learning Environments; Broadening Participation and Institutional Capacity, and STEM Workforce Development. The framework positions the directorate to anticipate emerging opportunities created by new technologies, improvements in the STEM education evidence base, Administration priorities, and other national, international, and societal needs.

## Introduction

In May 2013, the Director and Deputy Director of NSF and the Assistant Director of NSF for Education and Human Resources (EHR) requested the EHR Advisory Committee to draw on its unique perspectives from academia, policy, and industry to make recommendations for the priorities and directions of the EHR Directorate.

The response of the Advisory Committee to this charge was to organize this response according to three major EHR themes:

1. STEM Learning and Learning Environments
2. Broadening Participation and Institutional Capacity
3. STEM Workforce Development

These themes, and the supporting recommendations from the Advisory Committee, inform a vision for the future of EHR programs. This report presents each theme and recommendations for its fulfillment, ending with a summary of cross-cutting themes and related commentary.

The Advisory Committee undertook the effort to generate this report independently. The opinions, findings, and conclusions or recommendations expressed in this publication are those of the Advisory Committee and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

## Key Emerging Trends in STEM Education and Society

The members of the Advisory Committee drew on their experience in academia, policymaking, and industry to enumerate a number of major forces in the education landscape that hold tremendous potential for changing the STEM learning of all Americans. We draw attention to the following trends:

1. Significant societal change is being wrought by information, communication, and collaborative technologies, including cyber infrastructure, cyber-physical systems, and connected Internet devices;
2. Growing income disparities, and enormous demographic shifts in populations are occurring;
3. The nature of work and the workplace are radically changing due to technological and social forces, especially in the STEM workforce;
4. The nature and practices of science and engineering are fundamentally changing to adapt to rapid growth in discoveries and methods of disciplinary, interdisciplinary and computational sciences;
5. New education standards that respond to changing college and career-ready demands on successive generations of students are being developed, and proposed for adoption and implementation. Current efforts include the Common Core State Standard Initiative, and the Next Generation Science Standards.

As a result of these trends:

- There is a need to augment preK-12 education with a range of formal postsecondary education offerings, including community college, undergraduate, graduate, and postdoctoral studies;
- New metaphors for STEM learning and workforce development are necessary that draw on ideas of fluid movement across networked communities and use of distributed resources, and that provide an alternative to traditional linear or pipeline models for STEM education;
- Core competencies in mathematics and science at the preK-16 levels should continue to be reconsidered in response to scientific discoveries, and changing skills demands in the STEM workplace;
- New approaches to the study of engagement in learning occurring across a broad ecosystem of formal and informal learning environments and over the life-span of each and every learner may lead to deeper understandings of how people learn;

- The exponential growth of sophisticated web-based and mobile learning platforms that provide ubiquitous access to knowledge may lead to greater realization of personalized learning across the life-span;
- Renewed attention to concerns about privacy, confidentiality and anonymity, including data security for individuals and groups are providing new challenges for STEM education research at the level of the Institutional Review Board (IRB), and the federal Common Rule;
- The growing need for curation of data, data interoperability, and data transparency standards to support the growth of science discoveries will pose new demands on those collecting and analyzing data, and providing data for secondary analyses;
- The ongoing development of shared guidelines on evidence standards for research and evaluation by the field, including recently published guidelines by NSF and the Institute for the Education Sciences at the U.S. Department of Education, are welcome.

## Recommended Responses to Key Trends by Theme

### **Theme 1: STEM Learning and STEM Learning Environments**

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The National Science Foundation’s Directorate for Education and Human Resources (EHR) can help meet the nation’s goals for improving STEM learning by orienting its investments to augment the most promising trends in the field, focusing on high-leverage practices, and building a coherent, cumulative knowledge base. EHR should continue to encourage the creative use of the full range of formal and informal STEM learning environments—including all available and emerging materials, platforms, and learning opportunities—to ensure that all U.S. students have greater access to the highest-quality, and most inspiring, STEM teaching and learning.

The phenomenal growth in interdisciplinary studies and advances in data collection and analyses provide a unique opportunity for EHR to continue to catalyze coordinated programs of research to address areas of widespread need or opportunity across the preK-16 continuum, graduate, and postgraduate education, especially among students from groups underrepresented in STEM. To undergird this growth, EHR should also support the development of new curricula that, with effective professional development and supporting technologies, teachers can effectively use on a daily basis to advance learning.

For the STEM Learning and Learning Environments theme, the Advisory Committee offers three overarching recommendations, along with more specific suggestions and examples to guide EHR investments over the next several years:

#### **Capitalize on Promising Trends in STEM Learning**

EHR should continue to encourage high-risk/high-pay-off education research proposals that are scientifically rigorous, potentially transformative, and informed by cutting-edge, interdisciplinary discoveries about learning. Ideal investments involving STEM learning and learning environments would spark: (a) disciplinary and interdisciplinary interest, (b) deep conceptual understanding, and (c) dialogue regarding how enduring challenges to achievement can be overcome using many emerging social and technological resources of learning environments. Of special interest are various problem-solving tools and resources that significantly increase students’ interest, persistence, and motivation in building STEM knowledge and skills across the life-span. A potential guide for projects may be the AAAS Project 2061 Atlas of Science Literacy, for example.

We recommend that EHR should:

- Encourage researchers and practitioners at all levels to improve our understanding of how STEM learning occurs given the growth of data-intensive tools and analyses. Core questions about how motivation, engagement, mindset, and productive persistence support learners in the development of expertise – which encompasses the

adaptive, dynamic complex of knowledge, skills, dispositions, attitudes and self-conceptions (see National Research Council, 2012, *Education for Life and Work*); EHR should encourage research that promotes the teaching and learning of challenging content for each and every learner;

- Continue to exploit the potential of cyberinfrastructure to transform STEM learning within and across the formal and informal education sectors so that all American students can meet and exceed the expectations articulated in education standards and related policy documents;
- Support research on the shifts in educators' roles at all levels from deliverers of content to facilitators of student learning in the STEM disciplines – across the continuum from pre-K through postdoctoral education and in the informal education sectors, and the informal learning sphere. In this effort, parents, family members and peers can serve as learning brokers and collaborators with educators in developing advanced STEM curriculum;
- Support the development of multi-modal learning analytics and related data-intensive methods to advance a range of educational questions, including the development and use of culturally competent project evaluations and the development of innovative assessments across various STEM learning environments;
- Engage communities of researchers in exploring the emerging concerns for human subjects' protections in rapidly changing, data-intensive, STEM learning environments. We recommend special attention to the principles of the Belmont Report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1978), especially for vulnerable populations (Data & Society Research Institute) (UC Berkeley School of Information) (National Research Council, 2014), and the report *Big Data: Seizing Opportunities, Preserving Values* (Executive Office of the President, 2014).

### **Create Coordinated Programs of Research and Effective Partnerships**

Coordinated programs of research should include partnerships between NSF and sister federal and state agencies, universities, industry, and the non-profit sector. For institutionalizing effective solutions at scale, attention should be paid to the role of effective content-based professional development of teachers, support of student learning, and support of education systems and a broad range of education stakeholders, including parents.

EHR should coordinate intensive research on key concepts and well-defined problems of practice in STEM teaching and learning that pose significant “stumbling blocks” for educating all students. Special emphasis should be placed on raising levels of STEM learning among girls and young women and among students from other traditionally underrepresented groups.

- Among these challenges are well-known problems in understanding rational numbers, ratios, and proportional reasoning – a vector of topics that cuts across STEM education and ties to both the Common Core State Standards and the Next Generation Science Standards’ themes on scale, proportion, and quantity. EHR could support research on the development of tools. For example, forced perspective photography or those developed in the “maker movement” or the use of 3D models in STEM created by 3D printers, which may make difficult concepts explicit and provide accessible, hands-on investigation of core concepts. Other examples include algebraic reasoning, and developing computational thinking, which provide an essential capacity for success across STEM education, with clear workforce implications.
- Related “stumbling block” topics can be adduced for science and engineering. Drawing on the National Research Council framework for K-12 science education and the associated Next Generation Science Standards, some examples include: flows, cycles, and conservation of energy and matter; scale, proportion, and quantity; and systems and system models.

EHR should support research on innovative techniques to deepen interest and persistence in STEM for all learners through innovations in classroom and learning environments; professional development for educators in areas such as content pedagogy, high expectations of students, and peer mentoring; and other efforts to nurture STEM interest among students of all backgrounds.

In addition, EHR should stimulate research on helping students to engage advanced disciplinary and interdisciplinary studies with a clear vision of appropriate scientific and academic career paths.

### **Develop a Knowledge Base of NSF-Funded Research on STEM Learning and Learning Environments**

All scientific research benefits from accumulating findings and insights. EHR is well positioned to develop a coherent, cumulative knowledge base of value to itself, the research community, policymakers, teachers, school leaders, other practitioners, and students. EHR is encouraged to:

- Develop a systems model and associated schematics that effectively articulate the Directorate’s vision and enable preK-12 and postsecondary educators, researchers, and others in the field to recognize potential connections between their work and the activities, priorities, and goals of EHR. These models should be informed by sophisticated analyses of EHR’s portfolio of projects across divisions and with other directorates;
- Develop knowledge bases that draw on innovative data and knowledge management tools and techniques to improve internal and external knowledge synthesis, evaluation, and communication;

- Encourage broader collaborations by practitioners and researchers in research synthesis, knowledge development, and dissemination of research results. Crowd-sourcing platforms and social media may provide promising infrastructure for such activities;
- Cultivate relationships with educators, administrators, parents, and students in order to ascertain research topics that are use-inspired and practice-inspired. Further experimentation with focus groups, Dear Colleague letters, Ideas Labs, and the like is highly recommended;
- Establish or charge research centers that translate research with attention to developing common standards for collecting and tagging learning data in order to maximize analysis, synthesis, evaluation, and communication of IRB-approved research findings to enable widespread participation and adoption and use of effective programs;
- Continue to explore how the evolving NSF/IES *Common Guidelines for Education Research and Development* can provide a sound framework for developing more coordinated programs of knowledge generation (encompassing projects across research types, including foundational, design and development, impact, scaling, and evaluation research) and achieving a balanced portfolio that supports an array of projects sufficient to fill gaps, generate knowledge, and drive innovative design.

## Theme 2: Broadening Participation and Institutional Capacity

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EHR is encouraged to support conversations on the need for a common, working definition of broadening participation: one that takes into account prior and traditional definitions, yet one that is forward-looking, ensures access, and powerfully engages all Americans in the STEM enterprise. This definition and description should be informed by considerations of broadening participation in EHR and other NSF directorates, and by engaging the perspectives of a variety of external partners.

Drawing on the key themes of the introduction, the members of the Advisory Committee see an historic opportunity to move away from deficit models of broadening participation to ones that see broadening participation as a solution to societal challenges and as contributing toward a richer culture of science that draws on powerful designs suggested by diverse communities. We recommend a reorientation for EHR toward the many positive contributions that come from broadening the participation of all Americans in the STEM enterprise in order to generate and develop our nation's most important resource – its human capital.

We recommend that EHR:

### **View Broadening Participation as a *Solution, not as a Problem to be Solved***

Consistent with the themes in the introduction, there is an opportunity for EHR to explore the many possibilities for greater and more meaningful participation that arise from:

- *Engaging social networks and networked communities.* Participation in emerging social and networked communities may provide opportunities for engagement in STEM learning and workforce development that are less limited by disability, age, gender, race, and geographic location. Further, network metaphors may free participation in learning from over-reliance on traditional linear or pipeline metaphors for STEM education and workforce;
- *Building and leveraging partnerships.* Viewing STEM as a collaborative network of communities that develops and uses shared digital resources may allow traditionally underrepresented groups to engage with STEM partners in new and powerful ways during formal education, in informal learning settings, and in the workforce.

### **View Broadening Participation as Central to Cultivating a Culture of Science**

Building a culture of science begins with a quality preK-16 education that leverages common standards in STEM learning. The members of the Advisory Committee believe that broader participation by all Americans will lead to more effective participation in all aspects of STEM learning and greater consideration of the role of STEM in public discourse and

policymaking. Broadening participation is a value-added proposition for STEM education and STEM careers. We invite EHR to consider the importance of:

- *Broadening participation as a means of providing an intellectual context that may enrich perspectives on research on STEM practices.* STEM activity occurs in social contexts. We believe that by broadening the diversity and profiles of stakeholders at all levels of education research, communication, and policymaking, including the voices, skills, and dispositions of women and other underrepresented groups in STEM, we can potentially enrich the socio-cultural aspects of research, including: (a) the sophistication of the research questions that are posed, (b) the choice of appropriate methodologies, (c) conversations on how research results may be interpreted, and (d) how communication of science may occur to the largest possible audience;
- *Broadening the set of methods and metrics for program evaluation.* Evaluation studies should take advantage of new methods and analytical strategies variables made possible by improved methodologies related to “big data” approaches to learning and other applications. A diverse set of stakeholders at all levels of the scientific enterprise and approaches that are sensitive to cultural issues will engage more citizens in the realization of the goals of STEM learning, and are likely to inform: (a) which evaluation questions are asked; (b) how evaluation questions are posed; (c) what evidence is considered in assigning value to educational outcomes; and (d) the generalizability, communication, and adoption of the claims of program evaluation;
- *Communicating about science across multiple media channels.* A recent Kaiser Family Foundation study noted self-report data of up to 13 hours per day spent on non-educational media by 8-18 year-old black and Hispanic students compared to an already high 8.5 hours for white students (Kaiser Family Foundation, 2010). There is growing evidence that more learners need to be engaged in learning not only via a new variety of channels, including tablets and smart phones, but that the competition with non-educational media use by learners should be recognized. Recent efforts on communication of science may provide guidelines for this effort (e.g., Alan Alda Center for Science Communication);
- *Encouraging researchers to consider aspects of broadening participation to inform research in STEM Learning and Learning Environments and Workforce Development.* We encourage EHR and NSF to emphasize the value of broadening participation in proposing research and evaluation questions that intimately involve the other themes of this report, which is likely to produce more adoptable and scalable solutions than via piecemeal approaches.

## **Recommendations**

The Advisory Committee recommends that EHR should continue to provide NSF-wide leadership in advancing understanding of issues specific to participation of underrepresented groups. EHR should enhance the visibility of broadened participation in STEM education and workforce to prospective STEM learners, who may not feel welcomed otherwise due to historically traditional stereotypes of “who belongs.” Furthermore, EHR can contribute more in its central role of defining NSF’s strategic investments in STEM education and human capital development by building a strong research and development core and by continued partnering with all NSF directorates.

The Advisory Committee also recommends that EHR provide leadership on science communication, including understanding how learners use different media and understanding the science of science communication.

While the concerns of broadening participation are shared by all its divisions, the Advisory Committee proposes that EHR’s Human Resource Development Division (HRD) take the lead on Broadening Participation and Institutional Capacity in STEM efforts in EHR. Of course, HRD would continue to expand its work with other divisions and directorates to support this theme and the other themes discussed here.

Central to the EHR mission, the Advisory Committee encourages HRD’s continued investments in Historically Black Colleges and Universities (HBCUs), Tribal Colleges and Universities (TCUs), and Hispanic-serving institutions, as well as majority institutions with strong missions to support broadening participation. These efforts need to be built upon a solid foundation at the preK-12 level, and such a foundation can only be secured through effective partnerships between NSF and sister agencies, including the US Department of Education (e.g., PCAST, 2010).

### Theme 3: STEM Workforce Development

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Drawing upon the themes in the introduction, the Advisory Committee recommends that EHR catalyze the development of a cohesive framework to align NSF investments in research and training with the national need for a workforce prepared to meet current and future STEM needs in the private and public sectors, the preK-12 teaching core, and the community college and university professorate.

How a domestic workforce contributes to American economic well-being and to a scientifically literate democracy should be thought through clearly. Any strategy that attempts to align university degrees with existing job taxonomies will be insufficient to meet this task for two reasons. First, a sufficient research base is not available for specifying specific knowledge, problem solving skills, and other aspects of expertise in within particular job classifications. Second, the nature of many STEM occupations evolves rapidly. Instead, we encourage a research agenda that clearly identifies the foundational competencies and the learning sequences that underlie critical and innovative and entrepreneurial thinking in STEM-based fields.

This workforce challenge occurs against a backdrop of multinational labor markets, changing U.S. demographics, unpredictable immigration patterns, changes in the nature of work itself and where work occurs, and changes in workplace needs and skills. STEM skill sets shift over time within jobs in response to many of the key themes listed in the introduction. Further, individual STEM career and life progressions are becoming far less linear with each passing decade.

The Committee offers three principal recommendations below. These include structural modifications to NSF education-related activities, knowledge gathering, and partnership development.

#### Recommendations

##### **Provide Opportunities to Build Knowledge and Capacity for Workforce Development Within NSF and in its Related Interdisciplinary Fields**

Innovations in engineering, cyber-physical systems, computational cognition, programmable networks, robotics, information technologies, and activities in other NSF directorates provide unique opportunities for EHR to capitalize on cutting-edge frontier research to establish and maintain national leadership in workforce research and development.

The Advisory Committee recognizes the challenge of modeling and predicting workforce needs. There may be sufficient numbers of qualified workers to fill the available jobs in some STEM sectors, but not in others. NSF may wish to draw upon internal (e.g., National Science Board *Science and Science Indicators*) and external data sources (e.g., Department of Labor, Bureau of Statistics) and academic reports to inform this conversation.

## **Align Investments in preK-16 Education with Changing STEM Workforce Needs in Response to the Changing Nature of Science and Engineering Practices**

The technologies depicted at the outset of this report (e.g., networked multimedia computing and data-intensive systems) could contribute vital cyberinfrastructure for a framework for associated ground-breaking interdisciplinary studies. This agenda may inform research on: (a) the preparation of STEM qualified and STEM-literate preK-12 teachers, (b) the use of educational standards documents in workforce research; (3) the form of assessments used to measure achievement, and (4) metrics and methods for program evaluation.

EHR is encouraged to:

- Continue to collaborate with other directorates to harvest discoveries and create knowledge databases that may lead to innovations in STEM workforce development;
- Survey and synthesize the current NSF portfolio for programs that could inform workforce needs and training in addition to the Innovative Technology Experiences for Students and Teachers (ITEST) and the Advanced Technological Education (ATE) programs;
- Provide support for replication of evidence-based programs that support STEM workforce learning, and examine mechanisms to provide sustained implementation support where justified. For example, both the Professional Science Master's and NSF Science Master's programs, showed promise in preparing students for professional STEM careers in business, government, and nonprofits.

## **Continue to Build NSF-University-Industry Partnerships to Leverage Investments in Research, Development, and Training for the STEM Workforce with an Emphasis on Personalized Learning and Broader Participation**

For workforce development, EHR has been concerned with STEM training across a wide range of educational levels. New directions could include the study of innovative developments in STEM applications in the workforce and the qualifications of the innovators and associated entrepreneurs. EHR is encouraged to:

- Support universities (including community colleges), and employers – private and in the not-for-profit sector – in the identification of both foundational STEM competencies and the professional skills necessary for success in the changing knowledge economy;
- Provide opportunities for the field to study and disseminate best practices for STEM workforce development. This may include the development of learning and organization theory in university and industry STEM partnerships;
- Consider short-term and long-term research agendas on personalized learning for the purpose of understanding and increasing the value of career transitions. Such transitions occur not only from college to the workforce but also (and perhaps more importantly) from one job to the next—either within STEM or between STEM and related professions.

Questions of interest include how universities and community colleges can both anticipate and support these transitions by focusing on foundational competencies and career entry and career transition (e.g., the Department of Labor TAACCCT programs);

- Use programs such as the Graduate Research Fellowship (GRF) program to investigate longitudinal effectiveness of STEM education workforce development with the recognition of the challenges of collecting such data;
- Consider convening focus groups of university and industry representatives to clarify what resources are being targeted to workforce training activities in different industries, and to indicate what industry partners would provide in order to support additional learning opportunities for workers. Topics could include the role of educational standards, assessment approaches, learning sequences, and field experiences in promoting excellent STEM workforce development;
- Draw upon the recent *Common Guidelines for Education Research and Development* (NSF 13-126) when considering funding research on workforce development and learning across the phases of foundational research and development and scaling activities.

## Cross-Cutting Topics from All Thematic Areas

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Across the three thematic areas discussed by the Advisory Committee (STEM Learning and Learning Environments, Broadening Participation and Institutional Capacity, and Workforce Development), a number of cross-cutting topics emerge. While these cross-cutting topics are common to all three priority themes, they should not be seen as a separate priority. Rather, these shared topics are best seen as a framework for coordinated action across the three areas.

### ***Knowing what EHR knows about its funded research***

In all theme areas, the Advisory Committee encourages EHR to develop and deploy modern, powerful, and transparent methods of data collection to inform internal and external stakeholders about its investments and their impact. Data collection could occur as early as proposal submission. Metadata fields (including STEM content, research methods used, subject pool, etc.) populated by prospective principal investigators would allow analyses of the types of proposals that are submitted, the types that are declined, the types that are funded, and how these figures change over time (Marrett, 2013). Machine learning and computational linguistics methodologies could exploit these records to identify patterns of relationships of simultaneous benefit to NSF, investigators, and other stakeholders in the directions and quality of funded research.

Such data would support analyses on how themes of STEM learning and learning environments, broadening participation, and workforce development inform:

- Advisory Committee recommendations and field-initiated efforts;
- Program announcement/solicitation design;
- Characteristics of the submitted proposals;
- Characteristics of weak (i.e., declined) proposals;
- Characteristics of the funded proposals; and
- Characteristics of current and past portfolios of funded projects.

Further, these data would inform the effectiveness of communication strategies for a range of stakeholders at all levels of the education enterprise. Especially for novel research programs, analyses of declined proposals may suggest opportunities for investment in capacity building to strengthen the field. The Advisory Committee acknowledges that data terms change over time, but such changes would inform our evolving understanding of, for example, broadening participation over time – an additional benefit.

### ***Protecting subjects in funded research***

The Advisory Committee recognizes that the emerging phenomenon of “big data” across all sectors of society poses new challenges for the protection of all human subjects (e.g., PCAST, 2014). The Committee recommends renewed attention to the implications of these data sources and data security for individuals and groups along the principles of the Belmont Report and the Common Rule, including privacy, confidentiality, fairness, beneficence, and justice.

Some themes that arise here include: (a) issues of anonymizing or de-identification data, (b) intellectual ownership in instances of crowd-sourced data, (c) informed consent, (d) reasonable

expectation of privacy for those participating in research projects, and (e) the evolving role of the Institutional Review Board at funded institutions. In addressing these themes, EHR should consider collaborations with other NSF directorates, and with sister federal agencies.

### ***Building Partnerships Within and Outside of NSF***

The Advisory Committee noted a number of key emerging themes in the introduction that provide new challenges and opportunities for building partnerships within and outside of NSF. Partnership collaborations that address many of these themes were raised by each of the three framing thematic areas. NSF should continue to deepen partnerships with academia, for-profit and non-profit businesses, and other partners to ensure a highly educated population and workforce preparation for global competitiveness and to generally advance the national health, prosperity, and welfare (National Science Foundation Act of 1950 (42 U.S.C.§1862)).

### ***Understanding Core Competencies and Skills***

STEM content is changing in response to discoveries funded by NSF and those emerging in other contexts. The nature of science and engineering practice is transforming because of rapid changes in technology, communications, media, research methods, and data sources. This observation has implications for the definition, identification and mastery of core competencies and skills of research and education within formal and informal learning and within the workforce.

### ***Developing New Models for the STEM enterprise***

As brick-and-mortar schooling has begun to engage new forms of distributed, any-time, anywhere learning, and as the boundaries between formal and informal learning and between academic, research, and industry partners have become more malleable, new models for the entire STEM enterprise are emerging and need to be encouraged. These models may better align investments in education and in workforce development and may provide new points of entry for broadening participation. Current examples include the development of open source educational materials and the provision of massive open online courses by consortia of universities and for-profit entities.

### ***Having the Area of Emphasis Drive the Research and Evaluation Questions***

The Advisory Committee stresses that progress in STEM education comes from simultaneous consideration of all three thematic areas. For example, the identification of conceptual barriers in STEM Learning and Learning Environments is enriched when broadening participation is actively considered in research and evaluation practices. In addition, prospective research questions in workforce development must build on scientific progress in preK-16 STEM education.

### ***Employing Research and Evidence Guidelines***

The Advisory Committee affirms the continual need that all funded research that produces findings in learning and teaching across the entire STEM enterprise for all Americans be based on appropriate use of evidence standards and support robust and defensible claims about innovation, efficacy, effectiveness, and scaling research. As noted in the Broadening Participation theme, EHR should support scientific reasoning and critical thinking for each and every student so that all Americans can contribute to an effective culture of science.

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