BROADENING PARTICIPATION, WORKFORCE DEVELOPMENT, EVALUATION, PEDAGOGY
RELEVANT LITERATURE

BROADENING PARTICIPATION

Committee on Science, Engineering & Public Policy (2007). Rising above the gathering storm: Energizing and employing America for a brighter economic future. National Academies Press: Wash DC. nap.edu/catalog.php?record_id=11463 A comprehensive and coordinated federal effort is urgently needed to bolster US competitiveness and pre-eminence in science and technology. This congressionally-requested report makes four recommendations along with 20 implementation actions that federal policy-makers should take to create high-quality jobs and focus new science and technology efforts on meeting the nation’s needs: 1) Increase America’s talent pool by vastly improving K-12 mathematics and science education; 2) Sustain and strengthen the nation's commitment to long-term basic research; 3) Develop, recruit, and retain top students, scientists, and engineers from both the U.S. and abroad; and 4) Ensure that the United States is the premier place in the world for innovation.

National Action Council for Minorities in Engineering (2013). A comprehensive analysis of the “new” American dilemma. nacme.org/publications/data_book/NACMEDatabook2013-final.pdf. The U.S. population is becoming more diverse each year. By 2050, URMs will represent more than 40% of the population, and there will be no majority race. The demand for qualified STEM professionals is high, but the supply is at risk if underrepresented groups are not engaged in these fields. The data featured in this report highlight some of the challenges that exist for URMs in the STEM fields. URMs complete high school at lower rates than their peers. They also score lower on their standardized test scores, which can serve as a barrier to college admission. The retention-to-graduation rates for URMs who do enroll as undergraduate STEM majors are comparatively low as well. As a result, the engineering workforce does not look like America. However, this data also shows that progress has been made. URMs earned nearly three times as many engineering bachelor’s degrees, more than four times as many engineering master’s degrees, and more than seven times as many engineering doctorate degrees in 2011 than they did in 1977. The engineering workforce is also diversifying over time, though at a slower rate than the overall population. The report’s data decks provide in-depth information for researchers, policymakers, educators and businesses on all of the critical issues that are associated with URM participation in the engineering field.

Committee on Underrepresented Groups and the Expansion of the Science and Engineering Workforce Pipeline; Committee on Science, Engineering, and Public Policy; Policy and Global Affairs; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2011). Expanding underrepresented minority participation: America’s science and technology talent at the crossroads. National Academies Press: Wash DC. nap.edu/catalog/12984/expanding-underrepresented-minority-participation-americas-science-and-technology-talent-at. In order for the United States to maintain the global leadership and competitiveness in science and technology that are critical to achieving national goals, we must invest in research, encourage innovation, and grow a strong and talented science and technology workforce. Expanding Underrepresented Minority Participation explores the role of diversity in the science, technology, engineering and mathematics (STEM) workforce and its value in keeping America innovative and competitive. According to the book, the U.S. labor market is projected to grow faster in science and engineering than in any other sector in the coming years, making minority participation in STEM education at all levels a national priority.

Council of Graduate Schools (2009). Broadening participation in graduate education. cgsnet.org/broadening-participation-graduate-education-0. This report addresses the need to strengthen and expand diversity and inclusiveness in graduate education. It highlights initiatives that have had success in these areas, and offers policy recommendations for broadening participation in graduate education as a key component of a national talent development strategy, with particular focus on people from traditionally underrepresented groups.
Babco M, D Chubin, and G May (2005). Diversifying the engineering workforce. Journal of Engineering Education, 94 (1): 73-86. Engineering, education to workplace, is not just about technical knowledge. Rather, who becomes an engineer and why says much about the profession. Engineering has a “diversity” problem. Like all professions, it must narrow the gap between practitioners on the one hand, and their clientele on the other; it must become “culturally competent.” Given the current composition of the engineering faculty and the profession’s workforce more generally, it behooves engineering education to diversify while assisting current and future practitioners in becoming culturally competent. Programs that work to diversify engineering are reviewed, with research and evaluation-based findings applied to education and workforce practice.

WORKFORCE DEVELOPMENT & EXPANDING THE STEM PIPELINE

National Science Foundation (2010). Preparing the next generation of STEM Innovators: Identifying and developing our nation’s human capital. (Publication No. NSB-10-33). nsf.gov/nsb/publications/2010/nsb1033.pdf. This report contains a series of policy actions, a research agenda, and three key recommendations detailing how the US might foster the identification and development of future STEM innovators: 1) Provide opportunities for excellence through coordinated, proactive, sustained formal and informal interventions to develop their students’ abilities. Students should learn at a pace, depth, and breadth commensurate with their talents and interests and in a fashion that elicits engagement, intellectual curiosity, and creative problem solving—essential skills for future innovation.; 2) Cast a wide net by developing and implementing appropriate talent assessments at multiple grade levels and preparing educators to recognize potential, particularly among those individuals who have not been given adequate opportunities to transform their potential into academic achievement.; and 3) Foster a supportive ecosystem by creating a culture that expects excellence, encourages creativity, and rewards the successes of all students regardless of their race/ethnicity, gender, socioeconomic status, or geographical locale.

President’s Council of Advisors on Science & Technology (2010). Prepare and inspire: K-12 education in science technology, engineering, and math (STEM) for America’s future. whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf. Outlines the need to improve STEM education through better student preparation, more inspiring curriculum, and improving the federal government’s strategy for K-12 STEM education.

Committee on Facilitating Interdisciplinary Research and Committee on Science, Engineering, and Public Policy (2004). Facilitating interdisciplinary research. National Academies Press, Wash DC. nap.edu/catalog/11153/facilitating-interdisciplinary-research Examines current interdisciplinary research efforts and recommends ways to stimulate and support such research.


Espinosa, LL (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. Harvard Educational Review 81, no. 2: 209-241. This quantitative study examines the effect of precollege characteristics, college experiences, and institutional setting on the persistence of undergraduate women of color in STEM majors and also investigates how this pathway might differ for women of color in comparison to their White peers. The author utilized hierarchical generalized linear modeling (HGLM) to examine the experiences of 1,250
women of color and 891 White women attending 135 institutions nationwide. Results revealed the paramount role of women’s college experiences. Women of color who persisted in STEM frequently engaged with peers to discuss course content, joined STEM-related student organizations, participated in undergraduate research programs, had altruistic ambitions, attended private colleges, and attended institutions with a robust community of STEM students. Negative predictors of persistence include attending a highly selective institution.

Fakayode, SO, M Yakubu, OM Adeyeye, DA Pollard, and AK Mohammed (2014). Promoting undergraduate STEM education at a Historically Black College and University through research experience. Journal of Chemical Education 91 (5), pp 662–665. Diversification of our country’s science talent pool is critically needed and can only be achieved by stimulating interest in science, technology, engineering, and mathematics (STEM) among students from a wide variety of cultural backgrounds. However, motivating, increasing the number, improving retention rates, and graduation rates of underrepresented minority (URM) students in STEM disciplines continue to be a major challenge and of active pedagogical interest to historically black colleges and universities (HBCU). Early involvement of URM students in research is a viable strategy to excite minority students in STEM areas. This work reported the use of the Raising Achievement in Mathematics and Science (RAMS) scholar and Summer Undergraduate Research Experience (SURE) programs at Winston-Salem State University (WSSU) as a strategy for promoting and stimulating the interest of URM students in STEM education at a HBCU institution. The influence of the RAMS scholar and SURE programs on the retention rate and STEM education of the URM students was examined. The experience of RAMS scholars and SURE participants was also evaluated by administering a survey to the participants upon completion of the program. The retention rates of the RAMS scholars and SURE participants were better than that of non-RAMS scholars or non-SURE participants. The analysis of the survey results indicated that the RAMS scholar and SURE programs clearly generated URM student excitement, while promoting critical thinking, teamwork, and leadership skills. Moreover, RAMS scholars and SURE participants particularly enjoyed other program enrichment activities, including professional development seminars and social activities as well as poster and oral presentations at regional and national conferences.

Hirst, RA, G Bolduc, L Liotta, and B Wai-Ling Packard (2014). Cultivating the STEM transfer pathway and capacity for research: A partnership between a community college and a 4-year college. Journal of College Science Teaching 43, no. 4 (2014). Summer research experiences have been identified as important vehicles for fostering the learning, skill development, and retention of undergraduates in the sciences. In this initiative, community college faculty and students partnered with private 4-year college colleagues on summer research in order to expand the capacity for research for community college faculty and to cultivate a STEM transfer pathway. Data from community college students, community college faculty, and 4-year faculty demonstrated that the initiative supported the transfer of community college students in STEM majors and students' future prospects through an expanded sense of science, lab experiences, and aspirations for graduate school. The collaboration also developed capacity for faculty research at the community college. The findings highlighted the burdens of participation for community college students and faculty. The discussion focuses on various ways to adapt research experiences for community colleges and ways to forge sustainable partnerships with 4-year institutions.

Thiry, H, SL Laursen, and AB Hunter (2011). What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates. The Journal of Higher Education 82, no. 4 (2011): 357-388. In this study of curricular and co-curricular learning in STEM disciplines at four liberal arts colleges, comparative analysis of 62 interviews with graduating seniors demonstrates that out-of-class experiences fostered many intellectual, personal, and professional gains. Undergraduate research, in particular, helped to shape science identities and socialize students into the scientific profession. The findings suggest that participation in authentic, independent work with adequate guidance is critical to student learning and development in experiential contexts.

Tsui, L (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. Journal of Negro Education Vol. 76, No. 4, pp. 555-581. This literature review presents the
research evidence that exists for ten intervention strategies commonly adopted by programmatic efforts striving to increase diversity in STEM fields. Also presented is empirical support for three model intervention programs: The Meyerhoff Program, The Minority Engineering Program (MEP), and the Mathematics Workshop. The article concludes with recommendations for future action and research in this area.

Wilson, ZS, L Holmes, MR Sylvain, L Batiste, M Johnson, et al (2012). Hierarchical mentoring: A transformative strategy for improving diversity and retention in undergraduate STEM disciplines. Journal of Science Education and Technology 21, no. 1: 148-156. In the US, less than half of the students who enter into STEM undergraduate curriculum as freshmen will graduate with a STEM degree. There is an even greater disparity in the national STEM graduation rates of students from underrepresented groups: approximately three-fourths leave STEM disciplines at the undergraduate level. A host of programs have been designed and implemented to model best practices in retaining students in STEM disciplines. The Howard Hughes Medical Institute (HHMI) Professors Program at Louisiana State University, under leadership of HHMI Professor Isaiah M. Warner, represents one of these programs and reports on a mentoring model that addresses the key factors that impact STEM student attrition. By integrating mentoring and strategic academic interventions into a structured research program, an innovative model has been developed to guide STEM undergraduates in adopting the metacognitive strategies that allow them to excel. Comparisons of the persistence of participants and nonparticipants in STEM curricular, at the host university and with other national universities and colleges, show the impact of the model’s salient features on improving STEM retention through graduation for all students, particularly those from underrepresented groups.

Hunter, L, S Seagroves, AJ Metevier, B Kluger-Bell, L Raschke, et al. (2010). Diversity and equity in the lab: Preparing scientists and engineers for inclusive teaching in courses and research environments. Learning from Inquiry in Practice: 436, p. 50. Despite high attrition rates in college-level science and engineering courses, with even higher rates for women and underrepresented minorities, not enough attention has been given to higher education STEM classroom practices that may limit the retention of students from diverse backgrounds. The Professional Development Program (PDP) has developed a range of professional development activities aimed at helping participants learn about diversity and equity issues, integrate inclusive teaching strategies into their own instructional units, and reflect on their own teaching practices. In the PDP, all participants develop and teach a STEM laboratory activity that enables their students to practice scientific inquiry processes as they gain an understanding of scientific concepts. In addition, they are asked to consider diversity and equity issues in their activity design and teaching. The PDP supports participants in this challenging endeavor by engaging them in activities that are aligned with a PDP-defined Diversity & Equity Focus Area that includes five emphases: 1) Multiple ways to learn, communicate and succeed; 2) Learners’ goals, interests, motivation, and values; 3) Beliefs and perceptions about ability to achieve; 4) Inclusive collaboration and equitable participation; 5) Social identification within STEM culture. We describe the PDP Diversity & Equity focus, the five emphases, and the supporting activities that have been designed and implemented within the PDP, as well as future directions for our diversity and equity efforts.

Metevier, AJ, L Hunter, BK Goza, LM Raschke, and S Seagroves (2010). Improvements in professional development program participants’ understandings about inclusive teaching. Learning from Inquiry in Practice Vol. 436, p. 515. A major emphasis of the Center for Adaptive Optics Professional Development Program (PDP) is training early-career scientists and engineers to teach more inclusively as well as more effectively. To this end, the PDP includes workshops on diversity and equity, and PDP participants are explicitly encouraged to weave inclusive instructional strategies into the inquiry laboratory activities they design and teach. In an initial effort to gauge the effectiveness of the PDP’s diversity and equity training, we have analyzed 2008 and 2009 PDP participants’ responses to a survey knowledge question that asks them to briefly describe how they would engage a diverse undergraduate student population through their teaching and research. Each participant answered the survey question before any PDP training, as well as after a series of intensive PDP workshops. We developed a rubric to score and analyze participants’ pre- and postworkshop responses, and have found that their
response scores improve significantly after PDP training. This indicates that PDP training does improve participants’ understandings about how to teach inclusively. Furthermore, survey respondents who participated in the PDP in both 2008 and 2009 showed little decrease in response scores between years, but continued increases with continued training. In this paper, we detail our rubric development, survey response scoring, analysis, and results, as well as the implications our results have had for refining our goals for PDP participants and for further improving PDP workshops.

**Evaluation of Educational Activities**

**National Science Foundation (2002).** User Friendly Handbook for Project Evaluation. [http://www.nsf.gov/pubs/2002/nsf02057/start.htm](http://www.nsf.gov/pubs/2002/nsf02057/start.htm). This handbook is intended to provide a basic guide for the evaluation of NSF’s educational programs. It is aimed at people who need to learn more about both what evaluation can do and how to do an evaluation, rather than those who already have a solid base of experience in the field. It builds on firmly established principles, blending technical knowledge and common sense to meet the special needs of NSF and its stakeholders. The Handbook discusses quantitative and qualitative evaluation methods, suggesting ways in which they can be used as complements in an evaluation strategy. As a result of reading this handbook, it is expected that program managers will increase their understanding of the evaluation process and NSF’s requirements for evaluation, as well as gain knowledge that will help them to communicate with evaluators and manage the actual evaluation.

**Center for Advancement of Informal Science Education (2011).** Principal investigator’s guide: Managing evaluation in informal STEM education projects. Association of Science-Technology Centers, Wash DC. Bonney R, K Ellenbogen, L Goodyear, and R Hellenga, Editors. [http://informalscience.org/documents/CAISEVSAPI_guide.pdf](http://informalscience.org/documents/CAISEVSAPI_guide.pdf) Project evaluation, carefully designed and conducted in collaboration with project developers, can help any informal STEM project improve its deliverables, achieve its goals, and measure the degree to which its targeted objectives have been met. Also, when results are disseminated widely, evaluations can provide critical information for helping projects throughout the STEM education field improve their overall practice. This guide is designed to help principal investigators and other leaders of informal STEM education projects integrate evaluation into all phases of project design, development, and implementation. Such projects include exhibits, media projects, websites, community science projects, afterschool programs, festivals, family activities, online games, and citizen science projects.

**National Research Council (2010).** Surrounded by science: Learning science in informal environments. Fenichel M, and HA Schweingruber, Editors. [http://www.nap.edu/openbook.php?record_id=12614](http://www.nap.edu/openbook.php?record_id=12614). Surrounded by Science is intended for practitioners in informal science settings, such as museums, after-school programs, science and technology centers, libraries, aquariums, and zoos. It focuses on what science learning in informal environments looks like, how to measure it, and what practitioners can do to ensure that people of all ages, from different backgrounds and cultures, have a positive learning experience.

**National Research Council. (2002).** Scientific research in education. Committee on Scientific Principles for Education Research. Shavelson RJ, and L Towne, Editors. [http://www.nap.edu/openbook.php?record_id=10236](http://www.nap.edu/openbook.php?record_id=10236). Researchers, historians, and philosophers of science have debated the nature of scientific research in education for more than 100 years. Recent enthusiasm for “evidence-based” policy and practice in education, now codified in the federal law that authorizes the bulk of elementary and secondary education programs, have brought a new sense of urgency to understanding the ways in which the basic tenets of science manifest in the study of teaching, learning, and schooling.

outcomes for underrepresented minority students (URMs), evaluation, program improvement, and interventions will likely yield positive outcomes for all students.

Institute of Education Sciences, Department of Education and the National Science Foundation (2013). Common guidelines for education research and development. http://www.nsf.gov/pubs/2013/nsf13126/nsf13126.pdf. This document describes NSF and the Dept. of Education’s shared understandings of the roles of various types or “genres” of research in generating evidence about strategies and interventions for increasing student learning. These research types range from studies that generate the most fundamental understandings related to education and learning (for example, about brain activity), to research that examines associations between variables, iteratively designs and tests components of a strategy or intervention, or is designed to assess impact of a fully-developed intervention on an education-related outcome. More specifically, the document describes the agencies’ expectations for the purpose of each type of research, the empirical and/or theoretical justifications for different types of studies, types of project outcomes, and quality of evidence.

The Center for Advancement of Informal Science Education (CAISE) http://www.informalscience.org/evaluation. The CAISE website contains many free evaluation resources, including evaluation frameworks, guides, handbooks, tools and instruments; an evaluator directory; a forum for research involving human subjects; evaluation databases; and more.

Science of Learning

National Research Council. 2000. How people learn: Brain, mind, experience, and school. Committee on Developments in the Science of Learning. Donovan MS, JD Bransford, and JW Pellegrino, Editors, with additional material from the Committee on Learning Research and Educational Practice. nap.edu/openbook.php?isbn=0309070368 Evidence from many branches of science has significantly added to our understanding of what it means to know, from the neural processes that occur during learning to the influence of culture on what people see and absorb. How People Learn examines these findings and their implications for what we teach, how we teach it, and how we assess what our children learn. The book uses exemplary teaching to illustrate how approaches based on what we now know result in in-depth learning. This new knowledge calls into question concepts and practices firmly entrenched in our current education system.

National Research Council (2007). Taking science to school: Learning and teaching science in grades K-8. National Academy Press. Duschl RA, Schweingruber HA, and Shouse AW, Editors. nap.edu/catalog.php?record_id=11625 Drawing on a vast array of work from neuroscience to classroom observation, Taking Science to School provides a comprehensive picture of what we know about teaching and learning science from kindergarten through eighth grade. By looking at a broad range of questions, this book provides a basic foundation for guiding science teaching and supporting students in their learning. The book also provides a detailed examination of how we know what we know about children’s learning of science, including the role of research and evidence. It answers such questions as: When do children begin to learn about science? Are there critical stages in a child’s development of such scientific concepts as mass or animate objects? What role does nonschool learning play in children’s knowledge of science? How can science education capitalize on children’s natural curiosity? What are the best tasks for books, lectures, and hands-on learning? How can teachers be taught to teach science?


The central problem addressed by this report is that most widely-used assessments of academic achievement are based on highly restrictive beliefs about learning and competence not fully in keeping with current knowledge about human cognition and learning. Likewise, the observation and interpretation elements underlying most current assessments were created to fit prior conceptions of learning and need enhancement to support the kinds of inferences people now want to draw about student achievement. The report argues that a model of cognition and learning should serve as the cornerstone of the assessment design process. This model should be based on the best available understanding of how students represent knowledge and develop competence in the domain.


Brown JS and Adler RP (2008). Minds on fire: Open education, the long tail, and learning 2.0. Educause Review, 43(1). This article focuses on social learning in virtual environments and peer-to-peer learning through these environments. The authors emphasize the importance of forming a community of practice so that students can learn the “practices and the norms of established practitioners in that field”. Also, this article stresses inquiry in terms of a “demand-pull” model instead of the “traditional supply-push” mode of building up an inventory of knowledge in students’ heads.” They also mention virtual networking between students and scientists. Finally, the article discusses examples of how scientists have answered student questions.

Falk, JH, JE Heimlich and S Foutz (2009). Free-choice learning and the environment. Rowman AltaMira Press, NY, NY. Most environmental learning takes place outside of the formal education system, but our understanding of how this learning actually occurs is in its infancy. By surfing the internet, watching nature documentaries, and visiting parks, forests, marine sanctuaries, and zoos, people make active choices to learn about various aspects of their environment every day. Free-Choice Learning and the Environment explores the theoretical foundations of free-choice environmental education, the practical implications for applying theory to the education of learners of all ages, and the policy implications for creating new and sustainable environmental education opportunities.

Informal Science.org http://www.informalscience.org/research The resources on this website are include references, abstracts, and reviews of published, peer-reviewed work that reflects what we know about the theory, practice and evaluation of informal learning.

BROADER IMPACTS—APPROACHES & APPLICATIONS

Heath, KD, E Bagley, AJ Berkey, DM Birlenbach, MK Carr-Markell, et al. (2014). Amplify the signal: Graduate training in broader impacts of scientific research. BioScience, 64(6), 517-523. Expertise in the broader impacts of scientific research is an increasingly important aspect of professional development, particularly because federal grant proposals are commonly reviewed using both the Intellectual Merit and the Broader Impacts Criteria. Unfortunately, training in broader impacts, such as science communication and outreach, is not typically part of undergraduate or graduate curricula. We initiated one of the first graduate-level biology courses on broader impacts, focusing on giving graduate students firsthand, authentic experiences with grant writing, science communication, and educational outreach. Students in this interdisciplinary course learned from experts, wrote for a broad audience about their own research, and proposed and implemented outreach in collaboration with local organizations. We outline our approach, discuss outcomes from each activity, assess our impact, and finally consider how future programs might expand on this model.

Science museums play a role in creating visitor experiences that relate to contemporary issues in science, and in linking audiences to the scientific enterprise and the community of scientists. In the Portal to the Public approach, researchers are trained by museum educators with experience in inquiry-based learning, and are then given opportunities to translate their current research for museum audiences. Portal to the Public offers one solution to museums seeking to sustain a commitment to delivering experiences that reflect the dynamic pace of research, and the need to connect local communities to research occurring in their midst.


Additional resources:

Outreach for Scientists, Center for the Advancement of Informal Science Education (CAISE). http://www.informalscience.org/about/informal-science-education/for-scientists The resources and links on this site were chosen to provide strategies and exemplars from a variety of informal STEM education settings.

Portal to the Public http://popnet.pacificsciencecenter.org/ Portal to the Public is designed to help informal science education institutions bring scientists and public audiences together in face-to-face interactions. The program framework has been implemented at diverse institutions that form the Portal to the Public Network.

The Network for Broader Impacts http://broaderimpacts.net/ The Network for Broader Impacts, initiated at the University of Missouri, is creating a community of practice that fosters the development of sustainable and scalable institutional capacity and engagement in broader impacts activity.