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Research Brief

S.T.E.M. Initiatives

Questions: What are the characteristics of exemplary STEM (Science, Technology, Engineering and Mathematics) initiatives?
What are some exemplary STEM initiatives?

In A Nutshell

STEM (Science, Technology, Engineering, Mathematics) initiatives represent an extensive and expanding movement across American education. Nationally, funding for K-12 STEM programs increased from $700 million to almost $1 billion from 2005 to 2007 alone (US DOE, Report of the Academic Competitiveness Council, 2007, p. 51). Although there is a dearth of high quality evaluation of existing STEM programs, current research has identified a set of characteristics of effective STEM programs that are outlined in this research brief. While there are few programs that meet all of these criteria, there are numerous notable programs implemented at the national, state, and school levels.

Summary:
Over the past several decades, starting most dramatically with the launch of Sputnik in 1957, but particularly since the mid-1980s, there has been a growing concern that the United States has not remained competitive as nations seek to gain political and economic advantage in an increasingly “flat” and technology-driven global community. To remain competitive in this environment, the US workforce must evolve to meet the changing needs of America’s economy: “All sectors of the workforce – from entry-level jobs to more advanced positions – are requiring workers to have a greater capacity to think critically, work independently, and apply an ever widening set of sophisticated skills. Even entry-level jobs require these sophisticated skills from their ‘unskilled’ workers” (National High School Alliance, 2010). Ensuring an adequate supply of talented workers in the STEM fields is one key step in addressing this critical issue.

To address this STEM challenge, there are two types of initiatives: 1) programs which ease existing immigration rules within the STEM fields in order to increase the levels of foreign-born scientists and engineers working in the US; and 2) programs which improve the domestic supply of scientists and engineers. Related to this second category, there are certainly daunting challenges. Research indicates that there is a severe shortage of student pursuing degrees in the STEM fields:

> “On a host of science, math, and engineering metrics, America is falling behind. The United States now lags behind much of the world in the share of its college graduates majoring in science and technology. As a result, the United States ranks just 29th of 109 countries in the percentage of 24 year olds with a math or science degree… As the economy is becoming more science and technology-based, fewer American students are studying science, technology, engineering and math (STEM). For example, while total U.S. citizen nonscience and engineering graduate degrees increased 64 percent between 1985 and 2002, the graduate degrees in STEM fields awarded to U.S. citizens increased by just 14 percent, while degrees in STEM fields awarded to foreign-born students more than doubled.”(Atkinson, 2007, pp 1-2).

As a consequence of this shortage, a wide range of programs has emerged to improve STEM education.

Defining STEM Programs
In general, the US Department of Education defines STEM education programs as “those primarily intended to provide support for, or to strengthen, science, technology, engineering, or mathematics (STEM) education at the elementary

and secondary through postgraduate levels, including adult education." (US DOE, Report of the Academic Competitiveness Council, 2007, p. 10).

However, the National High School Alliance provides a more revealing definition of STEM education:

> "STEM education is not simply a new name for the traditional approach to teaching science and mathematics. Nor is it just the grafting of 'technology' and 'engineering' layers onto standard science and math curricula…. STEM education removes the traditional barriers erected between the four disciplines, by integrating the four subjects into one cohesive means of teaching and learning. The engineering component puts emphasis on the process and design of solutions instead of the solutions themselves. This approach allows students to explore math and science in a more personalized context, while helping them to develop the critical thinking skills that can be applied to all facets of their work and academic lives. The technology component… allows students to apply what they have learned, utilizing computers with specialized and professional applications like CAD and computer animation. These and other applications of technology allow students to explore STEM subjects in greater detail and in a practical manner." (National High School Alliance, 2010)

Although numerous STEM programs have a primary focus on post-secondary education, there is an increasing number that focus on K-12 level programs. And there is certainly a serious STEM challenge at the K-12 level: "In a 2007 international assessment of 15-year-old students, the U.S. ranked 28th in math literacy and 24th in science literacy… A shortage of STEM teachers in the United States has been directly linked to the low quality of STEM education in this country. The United States faces a critical shortage of highly qualified math and science teachers - projected to reach 283,000 by 2015." (retrieved from http://www.massachusetts.edu/news/news.cfm?mode=detail&news_id=810 on June 15, 2010)

The Goals of K-12 STEM Programs

Overall, the goals of K-12 STEM programs fall into three areas (US DOE, Report of the Academic Competitiveness Council, 2007, p. 18): 1) student learning; 2) teacher quality, and 3) student engagement. In addition to these goals, there is a particular interest in increasing the percentage of female and minority students who excel in STEM programs. Currently, there is an especially acute shortage of women and minorities in STEM fields nationwide: "Underrepresented minorities (URM)… provide an untapped reservoir of talent that could be used to fill technical jobs. Over the past 25 years, educational diversity programs have encouraged and supported URM pursuing STEM degrees. Yet, their representation in STEM still lags far behind that of White, non-Hispanic men." (George et al., 2001).

What are the characteristics of high quality STEM programs?

Although there is a dearth of high quality evaluation of existing STEM programs, current research has identified the following characteristics of effective STEM programs:

1) Programs should broadly address student learning, including core content knowledge and critical thinking skills as defined by the relevant standards from professional organizations such as the International Technology and Engineering Educators Association (ITEA), the International Society for Technology in Education (ISTE), the National Research Council (NRC), the National Council for Teachers of Mathematics (NCTM), and the National Science Teachers Association (NSTA);
2) Programs should address student engagement (by illustrating the value of STEM in students' lives, as well as building interest in STEM fields and encouraging students to pursue STEM-related careers);
3) Programs should have an over-arching STEM "framework" which clearly maps standards for knowledge, skills, and dispositions to curricular activities;
4) Programs should integrate the teaching of all four STEM areas into a "meta-discipline";

5) Programs should ensure that all students have an opportunity to learn the "design" process (a core part of engineering), including "Global Engineering" (a system design process for a geographically distributed environment).
6) Programs should provide opportunities for open-ended "research-based" activities supported by cutting-edge technology.
7) Programs should provide activities that are hands-on, technology-based, applied, holistic, real world, integrative, collaborative, and personalized.
8) Programs should have a strong evaluative component that allows both formative and summative evaluation.
9) Programs should have a strong professional development component for teachers and administrators;
10) Programs should develop partnerships among a broad range of education stakeholders, including schools, businesses, higher education, government, and community, in order to provide authentic mentoring relationships and internships for students.

What are examples of noteworthy STEM programs?
STEM programs can be organized into three groups: National, State, and School-based Programs (National High School Alliance, 2010).

National programs include: the STEM Education Coalition, the American Association for the Advancement of Science's (AAAS) "Project 2061"; the National Governors Association's "Innovation America"; the National Math and Science Initiative (NMSI); the National Science Foundation's Advanced Technical Education (ATE) program; and the United States Department of Labor's Workforce Innovation in Regional Economic Development (WIRED) Initiative.

At the national level, the Council of State School Officers' Mathematics and Science Education Task Force has made the following recommendations to support STEM programs: 1) Bring together preK-20 education stakeholders to form state, regional, and national support networks; 2) continuously update curriculum, instruction, and assessment practices; 3) design new approaches for teacher professional development; 4) create innovative approaches to pre-service work and credentialing; 5) implement comprehensive approaches to program evaluation, and 6) provide resources and strategies for sustaining and expanding of successful programs. (The Council of Chief State School Officers, 2006).

At the state level, the most prominent programs include: the California Center for STEM Excellence at Sacramento State University; the Connecticut "CONNvene PreK-16 Initiative"; the Illinois "High Technology School-to-Work Program"; the Kentucky "STEM Imperative: Competing in a Global Economy"; the Massachusetts STEM Collaborative; the Missouri "Math, Engineering, Technology, Science (METS) Initiative"; the Ohio "STEM Initiative", and the "Texas Science, Technology, Engineering, and Math (T-STEM) High School Project".

Additional State programs include: the Alabama Math, Science and Technology Initiative (AMSI) (http://www.amsti.org/); the California Mathematics, Engineering, Science Achievement (MESA) program (http://www.ucop.edu/mesa/); the Colorado science, technology, engineering, and mathematics (STEM) after-school education pilot grant program; the Delaware Forum for the Advancement of Minority Engineers (FAME); the Delaware Minority, Engineering, Regional, Incentive, Training (MERIT) program; the Florida College Out-Reach Program (CROP)**;** the Florida Educational Equity program; the Florida Center for Mathematics and Science Education Research; the Hawaii High Technology School-to-Work Program; the Kentucky Center for Mathematics (KCM) (http://kentuckymathematics.org/); the New York Science and Technology Entry Program (STEP); the Ohio STEM-Focused Summer Academies (http://www.osln.org), the Oklahoma State EXPLORE and PLAN programs; the Texas Cooperative Program With Johnson Space Center (JSC); the Texas T-STEM academies (http://www.tstem.org/); the

Utah Mathematics, Engineering, Science Achievement (MESA) program; and the Washington Mathematics, Engineering, Science Achievement (MESA) program (http://depts.washington.edu/mesaweb/).

These state programs often include one or more of the following strategies: 1) state recruitment for STEM teachers; 2) targeted professional development for STEM teachers; 3) state support for pre-AP alignment courses; 4) end-of-course exams in STEM disciplines; 5) state support for STEM mentoring and real work internship programs for students; 6) state-level dual enrollment/early college/middle college programs focused on STEM; 7) state support for afterschool/ELO programs in STEM such as robotics, science Olympiad, INTEL, that focus on supporting student interest in STEM; 8) college readiness assessments in mathematics and/or science; 9) rigorous graduation requirements in mathematics and/or science for all students; 10) state programs targeted at STEM achievement among female, low-income and minority students. **(**The Education Commission of the States, 2010).

Two notable school-based programs include the "Project Lead The Way", and the "High School/High Tech Program" (see weblinks under "Online Resources" below).

In addition to these programs and initiatives, there are organizations at Hawaii High Technology have a particular focus on increasing female and minority involvement and success in STEM fields. These organizations include the Benjamin Banneker Institute, the National Action Council for Minorities in Engineering, the National Association for Blacks in Bio, the National Association of Mathematicians, the National Organization of Black Chemists and Chemical Engineers, National Society for Black Engineers, the National Society of Black Physicists, and the Society for the Advancement of Chicanos and Native Americans in Science.

Online Resources:

Addressing the STEM Challenge by Expanding Specialty Math and Science High Schools , Atkinson, R.D., Hugo, J., Lundgren, D., Shapiro, M.J., and Thomas, J. (2007). The Information Technology and Information Foundation, March 2007: http://www.ncsssmst.org/CMFiles/Docs/STEM%20Final_03_20_07.pdf

CIRTL Network – Supported by the National Science Foundation and committed to development of faculty to teach in STEM Programs
http://smhc-cpre.org/

The Education Commission of the States (2010). "High School STEM Initiatives" (http://mb2.ecs.org/reports/Report.aspx?id=1409)

High School/High Tech (2010): http://www.dol.gov/odep/programs/high.htm .

High School STEM Initiatives – This list of programs describes those targeted at STEM achievement among female, low-income and minority students.
http://mb2.ecs.org/reports/Report.aspx?id=1425

Mathematics and Science Education Task Force: Report and Recommendations , The Council of Chief State School Officers (2006).. http://www.ccsso.org/publications/details.cfm?PublicationID=344

National High School Alliance (2010): "STEM: Science, Technology, Engineering, and Mathematics": http://www.hsalliance.org/stem/index.asp .

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NSF National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program: New Projects and a Progress Report. D-Lib Magazine, November 2001, Volume 7 Number 11, ISSN 1082-9873: http://www.dlib.org/dlib/november01/zia/11zia.html

Ohio STEM Learning Network – This website provides links to exemplary schools, research on STEM programs and important national reports about STEM education.
http://www.osln.org/

Preparing for the Perfect Storm: Developing a National Action Plan to address the "T&E" of STEM., Coppola, R.K., and Malyn-Smith, J. (2006). : http://www.iteaconnect.org/Publications/Promos/NAE.pdf

Project Lead The Way (2010): http://beta.pltw.org/ .

Report of the Academic Competitiveness Council, US Department of Education (2007).
http://www2.ed.gov/about/inits/ed/competitiveness/acc-mathscience/report.pdf

Resources Supporting STEM Programs and STEM Education – Developed by the Ohio STEM Learning network this site provides links to many resources for educations, parents and students.
http://www.osln.org/national/finding-resources.php

The STEM Education Coalition. http://www.stemedcoalition.org/ .

Recognized STEM Programs

Mathematics, Engineering, Science Achievement (MESA) – Award winning program and nationally recognized program that began in California in 1970.

- California - http://www.ucop.edu/mesa/
- Washington - http://depts.washington.edu/mesaweb/
- Arizona - http://azmesa.arizona.edu/
- Colorado - http://www.cmesa.org/
- Utah - http://www.schools.utah.gov/curr/MESA/
- Oregon - http://oregonmesa.org/
- New Mexico - http://nmmesa.org/

Boston College Urban Ecology Program – Recognized by the National Science Foundation for its preparation of students for college and careers in STEM fields.
http://www.bc.edu/offices/pubaf/news/Urban_ecology2010_0616.html

STEM Magnet High School - Anne Arundel (MD) County Public Schools
http://www.aacps.org/admin/templates/stemnews.asp?articleid=404&zoneid=5

National High School Alliance: STEM Initiatives – Provides a list of national STEM initiatives, Minority-Focused national STEM initiatives and state STEM initiatives.
http://www.hsalliance.org/stem/index.asp

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North Dakota Center for Science and Mathematics Education – The center provides numerous scholarships and internships for students interested in science and math education.
http://www.ndsu.edu/csme/noyce/

Massachusetts Institute of Technology STEM Program – Provides information about MIT's STEM program with local public school students.
http://web.mit.edu/stem/STEM_Home.html

High Tech High – San Diego, CA
http://www.hightechhigh.org/

McKinley Technology High School – Washington, DC
http://mths.k12.dc.us/

Carver Magnet High School of Engineering, Applied Technology and the Arts - Houston, TX
http://schools.aldine.k12.tx.us/webs/002/home.htm

The Denver School of Science and Technology - Denver, CO
http://www.scienceandtech.org/

Additional References:

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George, Y. S., Neale, D.S., Van Horne, V, and Malcom, S.M. (2001). *In Pursuit of a Diverse Science, Technology, Engineering, and Mathematics Workforce: Recommended Research Priorities to Enhance Participation by Underrepresented Minorities.* American Association for the Advancement of Science: Washington, DC, December 2001. (Retrieved from http://ehrweb.aaas.org/mge/Reports/Report1/AGEP/)

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http://books.google.com/books?hl=en&lr=&id=iwOqlhZpsHoC&oi=fnd&pg=PA161&dq=STEM+Science+Technology+Engineering+Mathematics+high+school&ots=ZN-mB1yhD_&sig=pY09gIuUpVcANN0hqPtGAuEJ7EE#v=onepage&q=STEM%20Science%20Technology%20Engineering%20Mathematics%20high%20school&f=false)

Tyson, W., Lee, R, Borman, K.M., Hanson, M. A. (2007). Science, Technology, Engineering, and Mathematics (STEM) Pathways: High School Science and Math Coursework and Postsecondary Degree Attainment. *Journal of Education for Student Placed at Risk (JESPAR)*. Volume 12, Issue 3, October 2007, pp. 243-270.

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