Fostering STEM Diversity

Eda Davis-Lowe
OPAS Diversity Committee
November, 2006

Abstract

To remain competitive in an increasingly global and technology-driven economy, educating students to take part in a robust community of engineers, scientists, and technologists must be a priority. For too long, the number of students who engage in the STEM (Science, Technology, Engineering and Mathematics) fields of science, technology, engineering, and mathematics has lagged behind other nations. Even more alarming are the small numbers of women and ethnic minority students in STEM careers. Diversity is important to STEM fields to increase the pool of students and the availability and vitality of viewpoints and solutions in these fields.

Much research identifies barriers that limit the participation and success of female and minority students; non-academic and academic best practices that engage student in STEM; and vital components of STEM experiences for students, parents, and teachers. Effective STEM diversity programming should include:

- building sustained, supportive learning environments to help youth move along the STEM educational and career pathways, using several of the following:
  - challenging content,
  - contextual meaning and personalization of learning,
  - collaborative, cooperative, and project-based learning
  - pedagogical methods and materials inclusive of multiple learning styles,
  - maintaining a safe environment for creativity, experimentation, risk-taking, failure, and thoughtful reflection;
- fostering more positive youth attitudes toward school, learning, and dealing with stereotypical low expectations;
- encouraging youth's intrinsic motivation to learn;
- building visions for entering higher education, and support the learning of academic and life knowledge and skills to prepare for higher education STEM study and careers through
  - college readiness and on-campus experiences,
  - career awareness experiences;
- maintaining a strong, ongoing professional development component enabling both content knowledge and classroom practice;
- Sustained commitment of collaborators in a college-going culture – parents, educators, community members and students, with
  - Ongoing relationships,
  - Encouraging group participation to minimize isolation of individuals.

Introduction

A recent report, the *Condition of Education 2004,* shows that the decline in science and engineering majors among college students during the later 1980s to mid 1990s has leveled off (National Center for Education Statistics 2004). However, the progress in these areas by female and minority students continues to be disproportionately slow. For many years intervention programs have tried to promote the inclusion and support the success of women and minorities in science, technology, engineering, and math (STEM) careers. Despite these efforts over the past 30 years, there is continued underrepresentation of females and ethnic minority students in STEM careers (National Research Council 2000). A more recent publication, *Rising Above the Gathering Storm* (2006), focused the nation's attention on STEM workforce problems. Achieving the STEM workforce for the 21st century can only happen by building greater participation of women and minorities in those fields. Further delays will continue to compromise the future for members of these groups and jeopardize the prosperity of this nation in a global economy. Now is the time to get things right.

There are large numbers of local, regional, and national higher education intervention programs designed to increase the participation of ethnic minority and female students in undergraduate science and mathematics. The pool of students available for recruitment and retention by these programs depends on the success of precollege efforts to create interest in and provide motivation to learn science and mathematics. Effective precollege science and mathematics education, formal and informal, must enlarge the pool of students available and prepared for courses and career options in STEM. Early experiences shape students' ideas about the value and role of science and mathematics in their lives. Attitudes toward and achievement in science and mathematics require continued classroom experiences in STEM, extracurricular activities involving STEM and the encouragement of others significant in a student's life (College Board 1999).

A large body of research enumerates the barriers that limit the participation and success of female and minority students in STEM courses and careers. Consistently, the research shows that primary barriers are similar for both of these underserved and underrepresented populations. These barriers for females and minorities are:

(1) negative attitudes regarding mathematics and science along with negative perceptions of themselves as science and mathematics learners;

(2) lower performance levels and lower rates of participation in mathematics and science courses and on standardized tests;

(3) limited exposure to extracurricular activities in STEM;

(4) lack of information, limited role models, varied influence of significant adults, and little interest or aspirations for STEM careers;

(5) competitive rather than cooperative learning environments;

(6) more limited, often inferior, resources to support engaged learning;

(7) teaching and learning environments that fail to support different learning and interaction styles; and

(8) discrimination and harassment in the classroom, especially against girls.

(Clewell, Anderson, and Thorpe 1992; Rosser 1990; National Center for Education Statistics 2000b; Gatta and Trigg 2001).

The need for improving the course and career participation of females and minorities in STEM is well documented and remains a serious concern in realizing greater diversification of the STEM workforce (National Center for Education Statistics 2000a). Although current educational reform policies are primarily focused on academic content, performance standards, and high stakes testing, other responsibilities for student development remain for schools to address. For example, Victor Battistich et al 1999 list three non-academic outcomes of education that should be seen as equal in importance to the acquisition of academic outcomes: 1) social, ethical, and civic attitudes, motives, and skills; 2) attitudes toward school, learning and motivation to learn; and 3) metacognitive skills. Given what is known about the virtual invisibility of women and minorities in certain STEM careers, the limited efficacy of traditional classroom experiences in addressing the needs of these students, and the isolation (or marginalization, relative to the formal educational system) of effective extracurricular STEM activities to engage larger numbers of students, how does one design an effective, comprehensive program to redress these concerns?

Building a broader base of STEM talent requires a level of intervention that the formal education system cannot be expected to provide alone. (Building Engineering and Science Talent 2004). In its report, BEST identified a framework of design principles as a first approximation of what it takes to succeed over time in demanding educational and social environments. Comprehensive programming designed to increase diversity in STEM courses and careers should address several areas. (The associated BEST design principle is listed.). The necessary areas include:

(1) academic enrichment in science and mathematics (challenging content);
(2) contextual learning that enhances personal meaning and motivation to learn (personalization);
(3) college readiness experiences through on-campus or other college-connection events (defined outcomes);
(4) substantive, ongoing professional development in science and mathematics for teachers, including ongoing contact with content experts (engaged adults); and
(5) broad-based, collaborative partnerships that promote high expectations and a college-going culture (sustained commitment).

The BEST report found that the STEM-broadening programs that work seem to encompass all of the design principles, rather than in individual offerings. In terms of non-cognitive outcomes, early efforts should focus on students' attitudes toward school and their own learning, their behaviors that support their academic success, and their aspirations and preparations for higher education.

Within various teaching and learning environments, practices that promote these outcomes are:

(1) Adapting curricula (or instructional materials) and teaching methods to support engagement and success through multiple learning styles;
(2) Fostering collaborative and cooperative interactions between students; interactive exercises; project-based work;
(3) Using project-based experiences to apply knowledge to real-world problems;
(4) Establishing a context where risk-taking, questions, and failure are expected and supported as appropriate learning tools;
(5) Fostering creativity and experimentation, as well as knowledge and skill development, through inquiry-based and other active engagement strategies;
(6) Providing career exploration opportunities;
(7) Watching for and strongly discouraging discriminatory and harassing behavior between students and use of examples or exercises that favor one gender or group over another;
(8) Valuing both the use of different tool as means for solving problems and the actual tools themselves;
(9) Forming ongoing relationships with content- and skill-knowledgeable mentors, including near-peers;
(10) Encouraging participation by groups of students, so individuals are not isolated.

(Gatta and Trigg 2001; Intel Corporation; David Coronado, personal communication; Jo Oshiro, personal communication).

Essential Experiences for Students

Many precollege students state their hopes and plans to go to college (Flick, Cerny, Collins and Hinkle 2005). Large numbers of these students, however, lack clear pathways to college (Pathways to College Network 2004). Increasing diversity in STEM requires efforts that help students to identify their individual pathways to college and support them as they negotiate their journeys to college.

Appropriate learning communities (classrooms, afterschool clubs, summer camps, etc.) should be a place where students and adult leaders or facilitators build community, develop a context for learning, and establish and maintain relationships and continuity. These communities should provide personally meaningful connections for students (National Study Group for the Affirmative Development of Academic Ability 2004). In this way the students will be able to construct reasons and meanings for their learning experiences. High expectations are needed to stretch their minds and expand their confidence (Gullat and Jan 2003). A focus on STEM will provide students with some of the tools they need to be successful, both throughout school and into college and the workforce, as well as fostering an enthusiasm for and an awareness of the world around them. STEM content can be used as a vehicle to develop the analytical and problem-solving skills necessary for college (Conley, 2006). Ongoing connections with institutions of higher education will give students a familiarity with college and a view of themselves as future college students (Clewell, Anderson, and Thorpe 1992). An emphasis on teamwork will satisfy students' need for positive social interaction and provide valuable experience in working with people of diverse ages and backgrounds (Gullatt and Jan 2003). The effective, long-term programming should provide various points of entry for students into the STEM pipeline.

College access research has found that the key to influencing attitudes and behaviors rests on the relationships students form with teachers, community members, college students, faculty and staff, and other interested, caring adults (Herrera, Sipe and McClanahan 2000). The efforts of the mentors help to establish an environment that nurtures positive learning experiences, provides diverse ways for students to establish understanding and meaning, and encourages personal goal-setting to achieve success. Mentoring should be offered so that it works in conjunction with other important factors to provide comprehensive learning opportunities that meet the needs of students.

Recent research highlights and well documents the positive effects of mentoring for youth. The most significant are improvement in youth's grades, school attendance and family relationships, and the prevention of drug and alcohol initiation (Herrera, Sipe, and McClanahan 2000). Also cited in this report is the empirical evidence that spending more time with mentored youth is better than spending less time. However, of greater importance is what youth and mentors do during their time together. While other academic enrichment programs support the power of mentoring, even in a small-group setting, to effect positive changes in youth's lives, the mentoring time should be centered on engaging, challenging activities and open a world of possibilities for the youth.

Professional Development for Teachers

Effective professional development of teachers is a key strategy for supporting students and providing higher education access and supporting success for greater numbers of underserved students. Too often, traditional professional development activities for teachers include short-term engagement at local, state, or national workshops. These isolated exposures do not get at the heart of the professional development needs of in-service teachers. The professional development needs of science and mathematics teachers, as cited by the Office of Technology Assessment (US Congress 1988), should allow teachers to make application of new knowledge and skills through their own teaching and learning opportunities in a supportive learning community. These opportunities should include venues through which teachers share what they have learned with their peers. (Hopkins 2006).

Widely accepted guidelines for effective professional development in STEM emphasize maintaining opportunities that:

- allow teachers to enhance their content knowledge;
- engage STEM researchers and professionals in the development and delivery of workshop experiences;
- model inquiry-based and cooperative learning strategies;
- utilize the knowledge and participation of science education professors and outreach faculty;
- utilize standards-based activities; and
- provide substantive, ongoing experiences

(National Research Council 1996; Loucks-Horsley 1998; Kahle 2001). Professional development experiences should also:

- provide sessions based upon current knowledge on how to create a culture of success and
- how to meet the needs of minority and low-income students

(Culotta and Gibbons 1992; Banks 1994; Allen-Sommerville 1996; Kreinberg and Wahl 1997; National Science Teachers Association 2001). Educators also benefit from seeing how the skills and knowledge they are imparting are used in the working world, enabling them to pass on new information and enthusiasm to their students (Sam Tupou and others, personal communication). An additional consideration is building leadership capacity around teachers teaching teachers (both in-service and pre-service) so that maximum benefits are derived from a range of professional development strategies (Christenson 2005).

Family and Community Involvement

According to a research and development report from the National Center for Education Statistics (2000b), parental support has been identified as a predictor of the selection of a science or engineering major in college. Parents' educational attainment has indirect influence on their children's decision-making about a college major in the areas of financial support and encouragement of career choices (NCES). Thus, it is not enough to help students build aspirations for college apart from thoughtful attention to helping parents build stronger aspirations for their children's educational and career futures.

Intervention STEM efforts should help students and their families become more familiar with and build aspirations for higher education. More thoughtful attention is needed to concretely convey the message that a student's path to higher education is a personal choice and not one being dictated by programs or mentors. Collaborations with nearby institutions of higher education (IHEs) will help to make higher education more accessible and tangible to precollege participants and their family members. Collaborations should allow science, mathematics, and pre-education students at IHEs to support STEM awareness and interest. Other opportunities should bring underrepresented students and their families onto college campuses to engage in STEM learning and to explore STEM careers.

Conclusions

Both the available qualitative and quantitative data strongly suggest that effective STEM diversity programming should include efforts that:

- build sustained, supportive learning environments to help youth move along the STEM educational and career pathways;
- foster more positive youth attitudes toward school and learning;
- encourage the youth's intrinsic motivation to learn;

- build visions for entering higher education, and support the learning of academic knowledge and skills to prepare for higher education STEM majors and careers; and
- include a strong professional development component fostering both content knowledge and classroom practice.

In its report "Engagement in Youth and Education Programming," the Kellogg Foundation states that the role of its Youth and Education programs is to "support movement from institutional outreach to engagement, from continuing education to lifelong learning." The report further adds that the foundation's efforts "align well with emerging 'P-16' strategies nationwide to form a cohesive educational pipeline from pre-kindergarten through college" (Kellogg 2000).

According to the Kellogg Report, true engagement results when higher education "institutions and communities form lasting relationships that influence, shape, and promote success in both spheres." According to Kellogg, finding true engagement is rare. A more likely occurrence is unilateral outreach rather than the desired partnership – a relationship that is based on mutual benefit, mutual respect, and mutual accountability. While effective in addressing their individual goals of serving underrepresented and other educationally underserved students through effective STEM teaching and learning, institutions, community organizations, and enrichment programs are at a crossroads of achieving critical collaborations that draw on the strengths, experiences, and expertise of one another and other partners to be identified.

In terms of doable actions likely to bring measurable impact in addressing the challenges in Oregon, two recommendations have emerged. One suggestion is to provide start-up grants for pilot programs that are developed around the essential elements supporting STEM diversity. Such pilot programs might extend or enhance current successful initiatives, or these programs could be newly developed. A second suggestion focuses on the preparation of teachers by helping these pre-service teachers build their knowledge of and enthusiasm for STEM careers. Linking careers to classroom content would be key, as well as providing supporting materials to bring the information to K-12 students in personally meaningful ways. While these recommendations seem simple, implementing them would require the buy-in and support of multiple partners. Whether our next steps are to act on these recommendations or to identify and act on others, it is imperative that we begin to make well-considered, broadly supported, sustainable steps to broaden participation in STEM careers.

References

Allen-Sommerville L. 1996. Capitalizing on diversity. *The Science Teacher*. 2: 20-23.

Banks, J.A. 2001 (3rd Ed.). *An introduction to multicultural education.* Boston: Allyn and Bacon.

Battistich, V., M. Watson, D. Solomon, C., Lewis, and E. Schaps. 1999. Beyond the three r's: a broader agenda for school reform. *The Elementary School Journal* 99: 415-432.

Building Engineering and Science Talent (BEST). 2004. What it takes: pre-k-12 design principles to broaden participation in science, technology, engineering and mathematics. San Diego: BEST.

Christenson, L. (2005). Teacher quality: teachers teaching teachers. *Rethinking Schools Online,* 20(2). <http://www.rethinkingschools.org/archive/20_2/ttt202.shtml>. (7 November 2006).

Clewell, B.C., B.T. Anderson, and M.E. Thorpe. 1992. *Breaking the barriers: helping female and minority students succeed in mathematics and science.* San Francisco: Jossey-Bass.

College Board. 1999. Reaching the top: a report from the national task force on minority high achievement. New York: The College Board.

Committee on Prospering in the Global Economy of the 21st Century. (2006). *Rising above the gathering storm: energizing and employing america for a brighter economic future*. Washington DC: National Academy of Science.

Conley, D. 2006. *College knowledge: what it really takes to succeed and what we can do to get students ready.* Powerpoint slides for a presentation made to the IB Organization. <http://cepr.uoregon.edu/>. (17 October 2006).

Culotta, E and A. Gibbons, Ed. 1992. Minorities in science: the pipeline problem, 1st annual report. *Science* 258: 1175-1237.

Flick, L., Cerny, L. Collins, T., and S. Hinkle. 2006. *Increasing the use of science and mathematics knowledge: student views on technical careers and the role of academics*. Paper submitted to the annual meeting of the National Association for Research in Science Teaching, San Francisco, CA, April 3-6, 2006.

Gatta, M. and M. Trigg. 2001. *Bridging the gap: gender equity in science, engineering and technology.* New Brunswick, NJ: Center for Women and Work, Rutgers University.

Gullat, Y. and W. Jan. 2003. *How do pre-collegiate academic outreach programs impact college-going among underrepresented students?* Washington, DC: Pathways to College Network Clearinghouse.

Herrera, C., Sipe, C.L, & McClanahan, W.S. Arbreton, A.J.A. and Pepper, S.K. 2000. *Mentoring school-age children: relationship development in community-based and school-based programs.* Philadelphia: Public/Private Ventures.

Hopkins, G. (2006). Teachers teaching teachers: professional development that works. *Education World.* <http://www.education-world.com/a-admin/admin/admin459.shtml>. (7 November 2006).

Intel Corporation. <http://www97.intel.com/discover/DesignDiscovery/DD_Research/default.aspx> (17 October 2006).

Kahle, J.B. and Ohio's Systemic Reform of Science and Mathematics Education. Professional development guidelines for science and mathematics teachers, 2001. http://www.discovery.k12.oh.us/PROGRAMS_01.HTM. (15 May 2003).

Kreinberg N and E. Wahl, Ed. 1997. *Thoughts and Deeds: Equity in Mathematics and Science Education*. Washington DC: American Association for the Advancement of Science.

Loucks-Horsley, S; Hewson, P.W., Love, N., and Stiles, K.E.. 1998. *Designing professional development for teachers of science and mathematics*. Thousand Oaks CA: Corwin Press.

National Center for Education Statistics. 2004. *The condition of education 2004.* Washington, DC: US Department of Education

National Center for Education Statistics. 2000a. *Entry and persistence of women and minorities in college science and engineering education.* Washington, DC: US Department of Education

National Center for Education Statistics. 2000b. *Trends in educational equity for girls and women.* Washington, DC: US Department of Education.

National Center for Public Policy and Higher Education. 2004. *The educational pipeline: big investment, big returns.* <http://www.highereducation.org/reports/pipeline/> (13 December 2004).

National Research Council - Board on Higher Education and Workforce. 2000. *Addressing the nation's needs for biomedical and behavioral scientists.* Washington, DC: National Academy Press.

National Science Teachers Association. 2001. *Celebrating cultural diversity*. Arlington VA: NSTA Press.

National Study Group for the Affirmative Development of Academic Ability. 2004. *All students reaching the top: strategies for closing academic achievement gaps.* Naperville IL: Learning Point Associates.

Pathways to College Network. 2004. *A shared agenda: a leadership challenge to improve college access and success.* <http://www.pathwaystocollege.net/agenda/index.html> (3 January 2005).

Rosser, S. 1990. Female-friendly science: applying women's studies methods and theories to attract students. Elmsford, New York: Pergamon Press.

U.S. Congress - Office of Technology Assessment. (1988) *Educating scientists and engineers: grade school to grad school.* Washington, DC: U.S. Government Printing Office.