



2005 Awardees

Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM)

September 26, 2006

Dr. Arden Bement, Jr., Director
Dr. Kathie Olsen, Deputy Director
National Science Foundation

Dear Drs. Bement and Olsen:

We are writing to transmit the results of our efforts on the position paper for mentoring and the science, technology, engineering and mathematics (STEM) workforce, entitled *"Mentoring for Science, Technology, Engineering and Mathematics Workforce Development and Lifelong Productivity: Success across the K through Grey Continuum."*

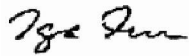
As you know, those who received the 2005 Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM) were asked to produce a white paper on mentoring in STEM fields as a means to increase the participation of underrepresented groups. We worked alongside a number of PAESMEM award winners from previous years to develop a draft at the 2006 NSF Division of Human Resource Development Joint Annual Meeting (JAM) in March, 2006. After submission in April to your office, we met in Washington in June to review your analyses and comments and then, working with Dr. Ann Carlson, developed a series of editorial changes which are incorporated in this final draft.

The motivation for this white paper is the intersection of recent reports addressing the needs for human resource development in the science, engineering and mathematics workforce from, among others, the National Academies (*Rising Above The Gathering Storm*), the President's Council of Advisors on Science and Technology, and the Business Roundtable indicating there is a broad consensus on the scope of the problem. President Bush proposed increases in the numbers of science and mathematics teachers and science and mathematics professionals within his American Competitiveness Initiative in his 2006 State of the Union Address. The increased focus and available resources for science and mathematics education is a sign to all of us that there is a strong understanding of the depth of the needs in this country.

The focus of this paper is the role and potential impact of mentoring to increase the participation of underrepresented groups in the STEM workforce. Mentoring is an approach that affects ***all levels of participation and learning***. We believe that mentoring, expanding and implementing programs that develop mentoring skills, and fostering institutional environments where mentoring is valued are critical to addressing the STEM workforce needs for the future of the United States. In the paper, we ask the National Science and Technology Council (NSTC) to take the lead to place a high priority on the coordination of federal, state and industry programs.

Thank you for the strong interest, direction and guidance you have given us. We now ask you to consider how we can finalize the paper and release it. We would like to identify additional specific actions and assist in the implementation of the suggestions, perhaps as an ad-hoc advisory group. We hope that the white paper provides concrete ideas for action within NSF and support for its transmittal to Dr. Marburger of the Office of Science Technology Policy, and broadens the growing consensus to improve the participation of diverse people in STEM fields.

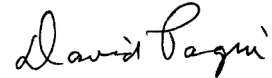
Sincerely,




Tanya Furman



Joseph A. Gardella, Jr.



David L. Pagni



Ashok Puri



Cheryl B. Schrader



Sheryl A. Tucker

For the 2005 PAESMEM Recipients and other PAESMEM participants listed below.

Xc: **Wanda E. Ward**, Acting Assistant Director, Education and Human Resources

Ann Carlson, Senior Staff Associate for Policy & Planning, Office of the Director

David L. Temple, Jr., Program Director, PAESMEM, Education and Human Resources

2005 PAESMEM Awardees

Alonzo Ashley, Stanford University

Sarwan Dhir, Fort Valley State University

Tanya Furman, Pennsylvania State University

Joseph Gardella, Jr., University at Buffalo, SUNY

Rosemarie Gillespie, University of California, Berkeley

Jong Pil Lee, SUNY Old Westbury

David Pagni, California State University, Fullerton

Ashok Puri, University of New Orleans

Cheryl Schrader, Boise State University

Sheryl Tucker, University of Missouri

Luis Mota-Bravo, University of California, Irvine, Institutional Winner

Past PAESMEM Awardees who participated at JAM and contributed to the White Paper

Carol Muller, MentorNet, 2001 Institutional Awardee

Judith Vergun, University of Hawaii, Manoa, 2004 Awardee

Eda Davis-Butts, Oregon State University, 1999 Awardee

Steve Watkins, Louisiana State University, 2004 Awardee

Herb Schroeder, University of Alaska-Anchorage, 2004 Awardee

Christine Grant, North Carolina State University, 2003 Awardee

David Manderscheid, University of Iowa, 2004 Institutional Awardee

Barbara Burke, California State Polytechnic University, Pomona, 2004 Awardee



Mentoring

for Science, Technology, Engineering
and Mathematics Workforce Development
and Lifelong Productivity:
Success across the K through Grey Continuum



Executive Summary

The strength of the scientific discovery and technological innovation enterprise is always built upon a foundation of **mentoring**. This intergenerational transfer of knowledge and processes enables one generation to stand upon its predecessor's shoulders to advance wisdom, creativity, discovery and innovation.

Underrepresentation of women, minorities and disabled persons in science, technology, engineering and mathematics (STEM) fields has been a documented concern for more than 25 years. Continuing calls for increasing participation in STEM education focus on the need for a diverse and educated workforce to advance the nation's technological capability and economic competitiveness. Meaningful programmatic efforts to boost the number of students graduating with STEM degrees have been identified, implemented and celebrated. Yet the United States continues to recognize a clarion call for more effective STEM educational practices and ways to increase the participation in these fields.

While programs to encourage underrepresented groups in STEM education abound, it is essential that we all realize that the success of these programs can only be measured **one person at a time**. Mentoring, which is defined by individual interaction, is an appropriate, essential and powerful but often overlooked vehicle to overcome underrepresentation in STEM fields. The changing workforce demographics of the 21st century require a concomitant change to our implicit paradigm of relying on spontaneous mentoring, which tends to replicate the status quo. This paper examines the basis of successful mentoring, documents the achievements and impacts of mentoring on diversifying the STEM workforce, and recommends specific actions to utilize, expand and institutionalize mentoring as a pivotal means to realizing sustainable improvements in the STEM educational and workforce crisis.

Mentoring methods have been effectively used in formal educational settings – i.e., graduate, postdoctoral and undergraduate research, teacher education and development, and K-12 classrooms – and also in informal educational settings among parents, community organizations and civic groups. Despite the success of mentoring, barriers to institutionalization of best practices exist at the academic, communal and industrial level.

Mentoring is by its very nature a one-on-one relationship, and as such often develops from a “grass-roots” effort. It is the desire of the mentor to provide individual guidance and coaching that creates the nurturing environment of a mentoring relationship. The challenge described by this paper is not to create new mentoring practices – many excellent models already exist – but to identify the best practices of the individual or team mentor and provide the framework and incentives necessary to create a nationwide emphasis on the practice of mentoring, and to then provide the infrastructure required to expand mentoring practices throughout the K through grey continuum. Specific actions to achieve this goal are outlined below:

- There should be an immediate interagency effort in the federal government, a consensus process in state governments, and a coordinated response from industry and trade group leadership to recognize mentoring processes as critical methods for achieving a more diverse and augmented STEM workforce and to provide the resources to expand mentoring efforts in a national context.
 - The National Science and Technology Council or a similar organization with broad interagency scientific leadership should

provide the necessary national focus for achieving the federal government response, given the recent success of the National Nanotechnology Initiative (www.nano.gov).

- A consensus building process among industry leadership, trade groups and professional organizations is required to stem the loss of research and development and the associated outreach and mentoring programs.
- Continued focus needs to be placed on national image and awareness campaigns that promote mentoring practices and participation in STEM careers.
- Mentoring programs, which are grounded in research that documents their effective practices like all other human resource development and research programs, must document their successes, account for the results, and disseminate best practices. All agencies and state governments should agree on standards for quantitative and qualitative evaluation of the impact of mentoring programs and for the effective dissemination and communication of results.
- Kindergarten-12 programs have exceptional need and opportunity for mentoring. Workshops on mentoring for middle and high school counselors and principals need to be funded and developed to provide cost effective ways to connect with students at critical junctures in their personal and educational development.
- Teacher incentives are key tools to place math and science teachers in inner city schools and to encourage master teachers and professional learning communities to mentor new teachers. This must be prioritized at a national level.
- With leadership and support from the National Science Foundation (NSF), the establishment or augmentation of the following programs will promote and advance mentoring in STEM fields.
 - Research mentoring programs at the NSF, such as Research Experiences for Undergraduates (REU) and the Integrative Graduate Education and Research Traineeship Program (IGERT), need to be expanded to allow broader participation of all students in research opportunities.
 - Incentives for mentoring, including grant programs for the development and implementation of mentoring practices, should be established at a national level.
 - Ongoing interactions among Presidential mentoring awardees should be supported and funded to create and maintain a regional- and institutional-level focus that mirrors national mentoring initiatives.
- Universities must demonstrate clear leadership in mentoring by valuing mentoring as part of institutional mission statements and faculty expectations for promotion and tenure. Mentor training for faculty, staff, supervisors and administrators should be the norm not the exception.
- Universities, colleges, professional organizations and industries must form partnerships with K-12 institutions to create and sustain a mentoring culture and continuum to particularly address students underrepresented in STEM disciplines.

Introduction and Context

If you ask successful scientists, engineers or technical professionals how they chose their field of study, many will tell you about a special person who recognized, nurtured and encouraged their curiosity when they were younger. You might hear a scientist describe how he was considering dropping out of college until a professor showed a personal interest and hired him to participate in meaningful research, giving a focus to his education and life. You might hear a woman engineer from an underprivileged background that offered no dream of higher education tell how her mathematical abilities were discovered by a high school teacher, who motivated her to apply to top-tier universities. Through one-on-one relationships, the college professor and the math teacher in these examples enabled each student to achieve individual success through the process of mentoring.

This paper addresses two distinct yet interrelated foci: (1) increasing our nation's human capital in the broad areas of science, technology, engineering, and mathematics (STEM), and (2) increasing the role and visibility of mentoring as a primary activity to achieve this end. The synergy between these ideas comes with the recognition that mentoring is a powerful, grass-roots process that creates a supportive and nurturing environment that allows individuals to achieve their fullest potential. The strength of the mentoring process is based on the selfless dedication and inspiration of individuals who desire to provide counseling, training and direction to others. In the sense that mentoring has parallel activities and qualities often associated with parenting, the impact of an effective, ***national***, mentoring initiative becomes apparent. In order for our nation to move forward and reassert its leadership role in the international scientific arena, we must implement specific strategies to promote, empower and expect mentoring.

Recent bipartisan and consensus calls to increase attention to science and mathematics education have been reported throughout the United States. In references ranging from the National Academies report *Rising Above the Gathering Storm*,¹ to President Bush's 2006 State of the Union Address,² the Business Roundtable,³ the US Congressional Progressive Caucus,⁴ and Time Magazine,⁵ these and other reports⁶⁻¹⁰ articulate a widespread and long-standing concern about STEM education in our nation. This heightened attention to the continuing need for STEM education has led to a variety of programs proposed in both federal and state initiatives. Some of these initiatives focus on increasing qualified K-12 science and mathematics teachers and all focus on expanding the educated science and engineering workforce. Central to the discussion is the need to increase the participation of underrepresented groups in STEM disciplines.¹¹

More than 25 years of data clearly document the underrepresentation of women, minorities and the disabled in STEM disciplines. Despite numerous high profile programs throughout the United States that address this concern and a consensus among citizens, government officials and business leaders, we are still discussing the problem rather than seeing widespread progress. This discussion is not academic, but is fundamental to our nation's ability to recapture a leadership role in innovation, creativity and economic prowess. Further, given the changing demographics in the U.S. population, failure to increase participation in STEM disciplines will result in a workforce with a shortage of qualified workers at all levels of business and industry.

This paper recommends actions for federal, state, local and business leadership to support, reward and promulgate ***mentoring*** techniques throughout the K-20 education pipeline. Mentoring is more than simply an

effective means of guiding individual students: it is an **essential and successful method** to achieve higher participation of individuals from underrepresented groups in the science and engineering workforce. The recommendations build on the experiences of recipients of the National Science Foundation Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (PAESMEM).

The PAESMEM awards recognize the efforts of exemplary college and university faculty and staff, and the impact of their institutional programs. The range of mentorship activities developed by these award winners extends far beyond the confines of college or university science, mathematics and engineering students to include elementary, middle and high school students, scouts, youth organizations, pre-service and in-service teachers, parents, colleagues and administrators. The pipeline of students interested in STEM fields has many holes where students trickle out, from elementary school through college. Mentoring activities reduce attrition from STEM disciplines through early and repeated intervention at all stages of the leaky pipeline and provide new **conduits** into the pipeline, thereby supporting the economic growth and global competitiveness of the nation.

An important premise of this document is that while mentorship is recognized and rewarded on a national level, for example through the PAESMEM awards, little has been done to extend the unique programs and experiences of the individual and group awardees, and the policies and successes of the institutions that promulgate mentorship across all levels. Together, the PAESMEM awardees propose that the acceleration of the contribution of women, minorities and the disabled into STEM fields requires promotion of institutional excellence in mentoring.

In this paper we review (1) defining mentorship, (2) ways in which mentoring works at all educational and professional levels, and (3) actions recommended to improve, institutionalize and support mentoring approaches.

I. Defining mentorship.

Mentoring is a two-way learning relationship between a more experienced individual and a less experienced one. Mentors typically provide encouragement, advice, support and information over an extended period of time. They may also afford access to networks, and/or champion advancement. Such mentoring relationships are ubiquitous and play an essential role in transferring knowledge and know-how from one generation to the next. Attention to the process of mentoring can enhance its effectiveness and thereby progress in a field. Mentors internal to one's business can be particularly helpful in imparting knowledge about organizational policies, politics, practices and personalities. External mentors can frequently offer additional breadth in perspective and are less likely to combine their roles as mentors with sometimes conflicting roles of advisor, supervisor, teacher, etc. Mentoring is often compared to the historic craft union system of apprenticeships. This relationship is commonly observed in STEM research environments, specifically for graduate training and undergraduate research.

The PAESMEM awardees strongly believe that mentorship is a lifelong learning strategy that works for everyone across the **K through grey** continuum, not just for college and university students, not just for graduate students, not just for research students, and not just for elite or at-risk students. Rather, mentoring is a process that affects and multiplies through current and future generations of STEM students and professionals. Mentoring is also embodied in essential professional outreach – through work with K-20 teachers, through conversations with parents and students,

through formal and informal apprenticeships at all levels of education and professional development. **A mentor is anyone who facilitates learning and development, and advances opportunity through sustained, supportive and nurturing relationships.**

II. Ways in which mentoring works at all educational and professional levels.

PAESMEM awardees believe that mentoring reflects our intrinsic responsibility to reach out to students, teachers, parents and colleagues across perceived boundaries. Mentoring is not just about preparing students for the upcoming exam or dissertation defense, but rather it represents a cradle to grave personal commitment that includes finding jobs and helping families in support of career development.

K-12 Level Students. Mentoring can be effective throughout the educational pipeline. In the early years, mentoring helps students visualize themselves as scientists and engineers, form goals, reinforce their aspirations, master content and develop effective study skills. In particular, a large and growing sector of our school-age population comprises minorities who face significant barriers to educational opportunity and whose vocational options preclude careers in science and technology. Minority students tend to be concentrated in poor, urban schools where the curricula, teacher and peer expectations, and social networks reinforce limited aspirations among students.

Mentoring, when combined with a strong educational curriculum, promotes aspirations and achievements in science and technology among this potential talent pool. Programs that match students with professionals in the STEM fields help students learn about career opportunities and, thus, reinforce the relevance of their school experience, shape educational and professional aspirations, and help students understand how they must prepare themselves in order to pursue their goals. Matching minority students with professionals and college students who have overcome barriers and achieved high levels of success can be particularly inspirational to students who come from a similar background as their mentors.

Community College and Technical Institute Students. The importance of community colleges in STEM education cannot be underestimated. Approximately 50 percent of individuals traditionally underrepresented in the STEM fields enroll in these institutions.¹¹ A comprehensive mentoring program that targets community colleges can play a significant role in the retention of underrepresented students in STEM disciplines. Many will complete terminal technical degrees; others will transfer to four year institutions. Given this talent pool, it is critical to

engage and retain these students. Universities must coordinate with local community colleges to ensure a supportive environment that

enables students to successfully complete appropriate coursework prior to transferring. Mentoring students transferring from a two-year to a four-year institution plays a significant role, providing a seamless transition from community college to university life.



e-Girls, where the “e” stands for enthusiasm, engineering and other energetic words, is an annual two-day adventure camp for 9th and 10th grade Idaho girls exploring careers in science and technology. Four messages drive the curriculum and communications that occur during the camp: that engineers 1) help the world; 2) think creatively; 3) enjoy working with other people; and 4) earn a good living. Workshops include: Biomechanics of High Heels, Rocket into Space, Physics of Rock Climbing, Packaging and the Environment, and Secure Communication. Staffed by women professionals and engineering students and sponsored by professional organizations, industry and academic partners, the camp is free to participants. Each of the 50 annual participants is assigned a female engineering student for continued mentoring after the event. **(Cheryl B. Schrader)**



The Oregon-Hawaii Mentoring Model: Comprehensive mentoring is the foundation for the Oregon-Hawaii Model that integrates research internships with educational programs in a unique free-choice learning process that encourages individual critical thinking skills and supports commitment and responsibility to society. Scientific research, education, diversity and community outreach are linked to create a complex network of learners, mentors and participants who provide the basis for a new body of collaborative knowledge and wisdom. The intergenerational mentoring network that includes families and communities forms a mentoring pathway, channeling students through the pipeline of K-12, community college, undergraduate, graduate and professional careers. Curricula relevant to students' lives and role models from their own communities are also keys to success. **(Judith R. Vergun)**

College and University Level Students. In higher education, mentoring is important to help students integrate both academically and socially into the college environment. A close interpersonal mentoring relationship helps the student develop confidence as he or she selects an appropriate course of study, formulates academic and professional goals, and prepares for successful transitions to the workplace or graduate study. Mentoring in engineering and the sciences is particularly effective through research experiences because research gives the mentor-protégé duo a structured activity around which the mentoring goals can be pursued: acquiring knowledge, modeling behavior and learning new skills; providing a supportive context in which the protégé can take risks; and demonstrating what a career in STEM fields offers. Mentoring can also include peer mentoring, advising, and tracking and helping students successfully complete an undergraduate or graduate degree.

Professional internships with industry, national laboratories, college or university laboratories provide students with valuable hands-on experience in research and design environments, as well as a suite of professional contacts with insight into the myriad opportunities outside academe. Through internships, the broadest spectrums of STEM professionals are engaged in the mentoring process.

Mentoring is especially important when students are in new environments. Transitions into postsecondary education and from two-year to four-year programs are particularly daunting, and it is often at these points when an inordinate number of women and underrepresented minorities leave the STEM disciplines.¹¹ Informal relationships among students and faculty do arise, but these tend to involve students and faculty who share similar social characteristics (gender, class, social status). Minorities and women, who one may argue have a greater need for mentoring, are at a disadvantage because they may be excluded from ad-hoc faculty-student connections unless more formal or structured programs are in place to facilitate mentoring relationships. College-level teaching is not simply a matter of objectively communicating the subject matter. Students, especially minority students in the sciences and women in engineering, enter the classroom with a broad set of social experiences that shape the way that they approach learning. Their previous educational experiences, values and goals, and perceptions about opportunity, all mediate the classroom experience. Through mentoring, we can facilitate successful learning by responding more directly to the whole student. In fact, minority students who do persist in science and engineering fields often cite their relationship with a mentor in their field as having more influence in their decision to enter science and engineering than their parents, friends or teachers.¹²

Pre-and In-Service Teachers. Accessibility to a quality education in STEM disciplines is powerfully linked to teacher effectiveness.¹² Thus, careful mentoring of new K-20 teachers is particularly important if the next generation is to fulfill the high expectations of the nation. The formal components of an effective teacher-mentor program include monitoring the new teacher's lesson plans and presentations. Besides learning to write lesson plans, develop effective questioning, classroom dialogue, and classroom management skills, the course material should be engaging and rigorous, yet accessible to all students and both interesting and challenging at the various student levels. At an informal level, classroom control and engagement can be learned only on the job, ideally under the watchful eye of a caring mentor. Such mentoring is essential at all educational levels, from elementary through postsecondary settings. Universities are not exempt from providing critical mentoring in teaching for those within the academy.



MentorNet, the E-Mentoring Network for Diversity in Engineering and Science, supports One-on-One mentoring programs pairing undergraduate and graduate students, postdocs, and early career faculty with professionals in industry, government, and higher education for structured, e-mail-based mentoring relationships. MentorNet's research-based, regularly-evaluated programmatic and technological infrastructure supports thousands of mentorships at a time, providing high quality, flexibility in addressing individual needs and efficiency. Since 1998, more than 15,000 pairs of mentors and protégés have been matched through MentorNet's One-on-One programs. In 2005-06, approximately 130 organizations partner with MentorNet: **(Carol B. Muller)** www.MentorNet.net



Exploring California Biodiversity uses collections of animals and plants in UC Berkeley's Natural History Museums, together with the institution's remote field stations, as pedagogical tools for graduate and K-12 education. Graduate students work with teachers at 8 schools (5 urban, 3 rural), targeting the collective eyes of the K-12 community towards biodiversity, offering insights into the natural world. The program provides new learning opportunities to ~320 students/year, and has built bridges between the university and a diverse K-12 student population. Initially funded by NSF in 2002, it has changed the attitude of the university towards the role of graduate students in K-12 education. (Rosemary G. Gillespie)

Mentoring for all teachers should be steeped in the culture of a Professional Learning Community (PLC) whereby the subject matter department takes on the responsibility of success for each of its members. For example, a PLC of math teachers in a particular school would develop common agreements for homework, grading, and assessment with the goal of increasing success for all students. Lesson design and student engagement that demonstrates the excitement of math and science becomes a concerted effort of the PLC. Teachers within a PLC can observe each others' instruction and even assign teachers known to be effective with specific strategies to mentor teachers whose skills with that strategy are emerging. A PLC can also consult with teachers recognized by the NSF Presidential Awards for Excellence in Mathematics and Science Teaching (PAEMST) for their exemplary teaching, a resource that is somewhat untapped for this purpose. In a PLC, professional growth is an ongoing process for all members, either through grant-supported or district-supported programs.

Mentoring in Informal Education Environments. Mentoring activities that target the K-12 educational system are laudable and have a long history of success. However, teachers continue to have more demands placed on their time than ever before. For example, mandatory proficiency testing is now the norm in most all public and some private schools, and testing days take away from classroom time spent on learning new concepts. Moreover, programming from higher educational institutions targeting teachers and classrooms can become an overwhelming time commitment for teachers, particularly in locations where school systems are in close proximity to colleges and universities. Even when the potential payoff for the teacher and student is high, realistic limits of time available in and after the school day must be treated with respect.

Community organizations are a unique and often overlooked venue to reach both children and parents. The influence of the parents, or a care-giving adult role model in a child's life should not be neglected, as they are key players in increasing STEM participation. Perceptions of appropriate careers are transferred to the next generation through parents, primary care givers and educators in our society, most of whom are women. If the mentoring parent or educator does not see a STEM career as a viable opportunity, we have potentially lost another student from the STEM pool.

Partnerships with community organizations are ideal, and most welcome meaningful programs as their own resources are rather limited. These associations often have the infrastructure necessary to deliver programs and make tangible contributions, including handling flyers, registrations, permission slips, and providing liability insurance, physical facilities, and volunteers. Local prospects such as the Girl Scouts, Boy Scouts, Campfire Boys and Girls, and 4-H Groups, are tied to national organizations, which facilitate program dissemination across the country. These groups also tend to have diverse memberships that include minority, disabled, and economically disadvantaged youth. These organizations often have parental involvement, which is a key factor in changing attitudes towards STEM careers. Other local targets might include church groups, day care centers, or after-school programs. Partnerships among such organizations, industry, government and academia allow mentors to focus on the educational program content and shift their effort away from some of the administrative tasks associated with these offerings.

Collaboration with informal educational organizations in the community is also a natural fit with the strategic initiatives of higher educational institutions. For example, most college and university mission statements specifically address the involvement of the institution in the community. Additionally, public universities are frequently charged with improving the lives of the state's citizenry. The fundamental reality is that partnering with community organizations where children and parents are readily accessible is a win-win situation. They offer venues rich with opportunity for exposing young and old alike to the awesome world of STEM.

Mentoring for Faculty and Other Professionals. Many times mentoring is associated with youth, as children and young adults are normally in need of guidance and direction as they navigate a series of education and career changes early in life. However, mentoring is necessary at all ages, particularly when people transition into other roles throughout their careers. Universities often mentor untenured faculty yet do not continue to mentor more senior level faculty to full professor ranks and beyond. Further, there is a lack of underrepresented groups in leadership positions throughout higher education, industry and government. Mentoring can play a critical role in the grey continuum to advance minorities, women and the disabled into positions where they have a positive impact on the overall participation of underrepresented groups in STEM. The NSF ADVANCE (Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers) grant program, for example, addresses this concern and mentoring can be a part of the solution.

Mentoring can also be an effective tool to assist science and technology professional communities in adjusting the workforce to meet the needs of professionals, the economy and the nation. For example, retired engineers and scientists can make excellent middle or high school science and math teachers. Education colleges can provide programs that mentor these professionals through the process required to attain teaching certification. Another underutilized source of science and engineering professionals is women and others whose careers have been interrupted by family responsibilities. Mentoring programs can help these individuals resume their careers as productive contributors to the STEM workforce.

Importance of Mentoring by Retirees. An enormous wealth of knowledge and manpower is available in the population of STEM retirees. With years of training and experience, the retiree often leaves the workforce with accumulated knowledge that will take the new scientist or engineer years to develop. Retirees possess more than the technical knowledge of their field, in addition, they understand the subtleties of the business and profession that are gained through experience. Often, the retiree is also interested in sharing this knowledge. While some opportunities exist through professional societies for the retiree to volunteer as a mentor, this remains an underutilized resource. The establishment of a formal mentoring network for the engagement of retirees could span from the K-12 classroom, through industry and government. With access to the insights of the retiree, the new scientist or engineer will be enabled to go beyond the accomplishments of the mentor, and finally, provide this insight as they subsequently enter the ranks of the retired mentor.



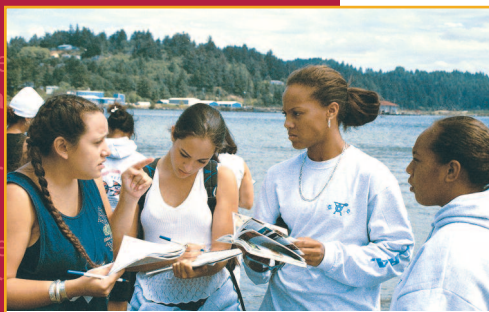
Sharing the "Magic of Chemistry" with Girl Scouts is a hands-on, inquiry-based educational outreach program that has been nationally recognized by the American Chemical Society, Girl Scouts of the USA, National Science Foundation and White House. Workshops are held on Saturdays, during National Chemistry (October) and Girl Scout (March) Weeks, on university campuses. Three workshops — "Case of the Unsigned Letter", "Fun with Polymers", and "Chemistry of Color" — rotate annually, allowing junior Girl Scouts (fourth through sixth graders) to be exposed to different experiments every year. Since 1998, over 2000 girls and 750 volunteers (troop leaders, older Girl Scouts, parents and university students) have participated in the program. (Sheryl A. Tucker) <http://www.chem.missouri.edu/tucker/GS-page.html>

The Outreach and Minority Science Programs (MSP) at the University of California, Irvine has developed a series of research training and mentoring experiences provided by over 50 faculty to encourage and prepare underrepresented minorities — from K-12 to graduate students — to pursue biomedical research careers. Over 100 science teachers have participated in professional development workshops and summer institutes and 2,220 K-12 students have presented scientific projects. Over 80% of the 123 community college student participants have transferred to 4-year baccalaureate programs. MSP undergraduates are co-authors of 55 papers published in prestigious journals and they have received 40 research prizes, including 23 awards at the American Association for the Advancement of Science (AAAS). (Luis Mota-Bravo) <http://port.bio.uci.edu/>



Eight Essential Components of Effective Mentoring Programs: (1)

Research and Planning, (2) Resource Development, (3) Program Protocols and Implementation: Participant Recruitment Strategies, (4) Program Protocols and Implementation: Matching Strategies, (5) Program Protocols and Implementation: Training, (6) Program Protocols and Implementation: Coaching and Communications, (7) Program Protocols and Implementation: Closure - Continuing, Transforming, or Exiting the Relationship and (8) Formative and Summative Evaluation. (Carol B. Muller)



The Strategies for Ecology Education, Development and Sustainability (SEEDS) Program

began in 1996 as a collaborative effort to increase the number of minorities in the field of ecology. It is an education and diversity initiative of the Ecological Society of America which promotes opportunities to spark and nurture the interest of underrepresented students in the science of ecology. SEEDS has shown to be an effective model for stimulating interest in pursuing ecology, providing professional development to aid science faculty in creating new ecology offerings, and taking new steps to increase cultural diversity within the Ecological Society of America. (Alan Berkowitz, Judith R. Vergun) <http://esa.org/education>

III. Actions recommended to improve, institutionalize and fund mentoring approaches.

III.A. Recommendation #1:

Involve the National Science and Technology Council (NSTC) to advance mentoring and research programs.

III.A.1. NSTC should coordinate a national mentoring program in the same vein as the National Nanotechnology Initiative, coordinating similar activities across all agencies.

Created in 1993, NSTC is the principal means within the executive branch to coordinate science and technology policy across the diverse entities that make up the Federal research and development enterprise. The National Nanotechnology Initiative was established in 2001 to review, assess, monitor and make recommendations regarding national nanotechnology research.

III.A.2. NSTC should also convene a consensus building process among industry leadership, trade groups and professional organizations to stem the loss of research and development and the associated outreach and mentoring programs.

NSTC is in a unique position to follow the model of the National Nanotechnology Initiative to coordinate the diverse list of calls for increases in STEM workforce by creating a focus on mentoring. Industry and trade groups, such as the Business Roundtable, have joined the call of the National Academies, the President's Council of Advisors on Science and Technology and the National Science Board to increase and diversify the STEM workforce. Secondly, many industry scientists and engineers participate in mentoring programs outside of their work assignments, through programs that focus on local schools or the national MentorNet¹³ program. In some regions of the United States, the continued loss of manufacturing and cuts in industry research and development have greatly reduced the available number of dedicated professionals seeking to mentor in K-12 outreach programs.

National leadership must identify mentoring as central to industry's interest in increasing diversity in STEM workforce development. Industry scientists and engineers constitute a huge resource for mentoring in schools, for college students, for young professionals in industry and academics, and even for faculty development. NSTC should organize the coordination of these interests with an overall strategy for mentoring across the K through grey continuum.

The role of professional organizations in mentoring should not be overlooked. These groups already are committed to increasing awareness of their respective career opportunities and shaping the public image of scientists. Many are already actively involved in the community via outreach programs at the K-20 level. A few societies specifically target underrepresented groups. These organizations should be strongly encouraged to continue and increase the opportunities for STEM participation by women, minorities and disabled persons, and should actively recruit retirees to serve as mentors and role models for younger scientists and engineers.

III.A.3. Implement a national image campaign to promote science, technology, mathematics and engineering and a national awareness campaign to promote mentoring success stories.

The nation should initiate a national mass marketing and public relations campaign to promote public interest in, a positive image of and student motivation toward for science, technology, mathematics and engineering. The promotional campaign could include extra-curricular activities, student symposiums, student academic tournaments, TV programs for general interest, podcasts of current science and engineering human interest stories, public service announcements, news reports, articles in general as well as professional journals, parent workshops, community projects and other activities. Materials and programs should be designed with input from consultants or advertising agencies who can discern messages and programs that are relevant and attractive to young people today. NSF, NIH and other government agencies should partner with STEM professional organizations to fund the national image campaign.

III.B. Recommendation #2:

Coordinate and expand mentoring priorities among federal, state, interagency and industry mentoring programs.

III.B.1 Incorporate mentoring as a central priority into all federally funded programs.

The PAESMEM Awards, now ten years old, offer a means to identify and recognize excellence and creativity in mentoring by individuals, and by institutional programs. A critical feature of this paper is the recommendation to implement a broader role for mentoring and to use the experiences of PAESMEM leadership to guide broader institutionalization of mentoring as a means to increase participation of women, minorities and disabled people in STEM fields. PAESMEM is an outcome of the longstanding focus of the National Science Foundation (NSF) on human resource development (HRD).

As NSF's role in the funding of STEM research and education programs is but one facet among federal and state governments, it is important to identify mechanisms to extend the enthusiasm and recommendations beyond NSF and the community that it leads. Other federal agencies that support STEM research and/or laboratories have myriad programs that engage, train or implement mentoring approaches. Indeed, this year's award to Stanford Linear Accelerator Center program originator and mentor Al Ashley shows exemplary activity in the Department of Energy laboratories, another federal agency with clear support for mentoring and human resource development.

We encourage and challenge other federal agencies to replicate these much-needed programs in the areas of mentoring, education and increasing diversity. The largest budget for federal science research is spread among many parts of the National Institutes of Health (NIH). Within NIH, the Roadmap for Medical Research is an effort to focus new attention on interdisciplinary training and research. Among the three Roadmap focus areas – Re-engineering the Clinical Research Enterprise, New Pathways to Discovery, and Research Teams of the Future – the latter specifically deals with human resource development by funding training opportunities.



Making Math Meaningful with MISS (Mathematics Intensive Summer Session) is a program for high school females from minority groups, many of whom are the first in their families to aspire to attend college. Study math for 6 hours a day? Unbelievable! Students engage in mathematical investigations and problems solving from 8 a.m. to 3 p.m. (1 hour for lunch) in a setting that supports learning and leadership. Students use graphing calculators and hear female role models from industry and education. Since 1990 over 600 students have completed the program; 98% have gone on to college; 20% chose STEM majors. **(David L. Pagni)**

NSF Broader Impacts: Since 1997, all NSF proposals are evaluated through use of the two merit review criteria: 1) What is the intellectual merit of the proposed activity? 2) What are the broader impacts of the proposed activity? Broader impacts are defined as follows: How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society? **(NSF)** www.nsf.gov

2006 State of the Union Address by the

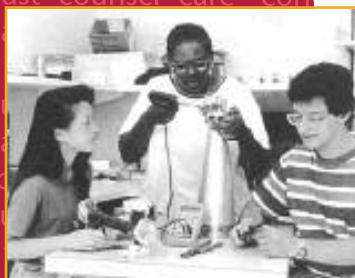
President: And to keep America competitive, one commitment is necessary above all: We must continue to lead the world in human talent and creativity... First, I propose to double the federal commitment to the most critical basic research programs in the physical sciences over the next 10 years. This funding will support the work of America's most creative minds as they explore promising areas such as nanotechnology, supercomputing, and alternative energy sources. **(George W. Bush)**

<http://www.whitehouse.gov/stateoftheunion/2006/index.html>

2006 State of the Union Address by the

President: And to keep America competitive, one commitment is necessary above all: We must continue to lead the world in human talent and creativity... Second, I propose to make permanent the research and development tax credit – to encourage bolder private-sector initiatives in technology. With more research in both the public and private sectors, we will improve our quality of life – and ensure that America will lead the world in opportunity and innovation for decades to come. **(George W. Bush)**

<http://www.whitehouse.gov/stateoftheunion/2006/index.html>



SLAC Science Internships Introduce Students to Future

Careers: Hundreds of underrepresented minority engineers and scientists have actively participated in the Stanford Linear Accelerator Center Science Undergraduate Laboratory Internships (SULI). Originally known as the Summer Science Program, this nine-week summer internship program is the first introduction for many students to their future careers. Students who participate in SULI spend the summer both conducting hands-on research and attending formal classes, lectures, and seminars. Since 1970, thousands of students have received meaningful and lifelong learning through this program. SULI has produced ten African American Ph.D. Physicists and numerous master degree graduate scholars in Engineering, Computer Science, Mathematics, and Environmental Science.

(Al Ashley)

Unfortunately, there is little specific guidance from NIH for coordination of evaluation and dissemination of best practices from the programs. While any NSF funded program in HRD would require such aspects, NIH program management and funded investigators have not incorporated these necessary components into their education plans. Further, while NIH training practices identify mentoring within traditional and obvious areas of research advising, they do not recognize its role in faculty development and outreach beyond the laboratory and university.

We therefore recommend that NSTC coordinate the development of common approaches to assessment, evaluation, and dissemination for all federally funded agencies. We also recommend that NSTC coordinate the sharing of best practices in mentoring across all agency funded work.

III.B.2. Support cultural change in research universities.

In order to attract the most outstanding students to STEM careers and to consider academic careers, faculty members and key administrators at the nation's top research institutions must be purposeful in their integration of basic research with mentoring activities. Federally-funded research provides one of higher education's most effective means of mentoring STEM students. Funding for basic research is only one of many pressures on the federal budget; however, faculty are keenly aware of the increased competition for grant monies. This situation has led to a perception that the funding climate is inhospitable to researchers, contributing to the attrition of capable students from the STEM pipeline. At the same time, increased funding opportunities do exist for individuals who balance their portfolios to include meaningful mentoring activities. There is a tremendous need for cultural change within academe in order to take proper advantage of new grant programs and mentoring opportunities within the National Science Foundation and other funding agencies. We identify two areas of concern and need.

III.B.2.a. Increase recognition for basic scientific research that incorporates mentoring.

At present, evaluation of Criterion 2 in NSF proposals is implemented unevenly and with little clarity across the broad spectrum of research directorates. As a result, faculty members and administrators receive little encouragement to incorporate meaningful outreach and human resource development into grant proposals. Furthermore, significant mentoring activities have been viewed with both skepticism and disdain by many research scientists. Unfortunately, in some cases, research faculty who receive funding from programs addressing human resource development in STEM fields are not viewed with the same respect as grants awarded from basic research programs. In fact, human resource development activities are often seen as leading to decreased research productivity. Program officers would benefit from guidance – perhaps from PAESMEM recipients – in developing and disseminating clear statements regarding expectations and best practices in this area, both in the proposal development and the review stages. This focused emphasis would encourage and diversify collaboration among disciplines and institutions, including those which serve underrepresented groups and have not had long traditions of grant funding. It would also counter the pervasive sentiment that mentoring detracts from an individual's research endeavors. A top-down emphasis by the funding

agency is one effective way to achieve rapid and widespread cultural change in research institutions.

III.B.2.b. Continue funding for successful programs.

NSF supports a number of initiatives to identify promising young faculty members and/or for project initiation that include successful components for STEM workforce development. For example, the CAREER award emphasizes a balance between research, education and outreach, rewarding the combination of novel programs in all areas. However, when mid-career scientists continue their efforts in achieving this balance, the expectation is that good programs and principal investigators will either become essentially self sufficient over time, perhaps with NSF HRD funding in combination with NSF research funding, or often through non-NSF funding, where there is less emphasis on a balance of human resource development and research. This funding modality leads to frequent disappointment or frustration at the mid-career level, and often stalls the faculty member's career growth and research potential. Integrated research-education programs present even greater funding challenges that most faculty are not trained to address. All STEM graduate students – and many undergraduates – are aware of the difficulties in obtaining sufficient grant support to maintain a program of research or education, and they correctly perceive this situation as a barrier to success. As a result, gifted and talented young people leave academe and STEM altogether, and top programs languish rather than flourish. PAESMEM award winners, along with NSF leadership, can take the lead on educating the community on continuing the balance of research, education and outreach that affects STEM human resource development.

III.C. Recommendation #3:

Implement and augment specific programs in federal and state agencies with leadership and support from the National Science Foundation.

III.C.1. Augment existing programs (e.g., REU) to enhance mentoring opportunities and availability.

Research mentoring programs such as NSF's Research Experiences for Undergraduates (REU), need to be expanded to allow participation in research opportunities of students at their home institutions. Currently, the REU program is designed to make mentored research opportunities available in NSF-funded laboratories, but only a limited percentage of the participants at an REU site may be from the host institution. This management philosophy has been effective in allowing students to broaden both their social and academic experiences, while gaining valuable research experience in well-established laboratories.

We encourage this program to expand its impact by allowing an unrestricted number of students to participate in REU programs at their home institution. This change is of critical importance to the stated goal of the REU program to increase the participation of women, minorities, and the disabled in STEM fields. Requiring REU participants to change their physical location limits disproportionately the participation of these underrepresented student groups. While it is recognized that the experience gained in the current REU program can be a profound, life-changing event, we feel that many underrepresented students are unable to participate due to family obligations, social constraints or economic realities. Further, we feel that this requirement limits the ability of a faculty member to develop a true mentoring relationship with the participating student based upon the relatively short period of interaction.



The Research Experiences for Undergraduates (REU)

program supports active research participation by undergraduate students in any research areas funded by the National Science Foundation. Fort Valley State University is one NSF REU site, where undergraduates participate in summer research experiences in biotechnology. Students become a part of a stimulating research community. This program also includes many exciting scholarly, cultural, and social opportunities. Participants meet and interact with research scientists, conduct an eight-week independent laboratory research project, participate in workshops covering research topics of interest, and tour major research institutions. At the end of the internship, students deliver a scientific presentation at an End-of-Program Symposium.
(Sarwan Dhir)
<http://www.fvsu.edu/biotech/Reu/reuindex.asp>

The goal of the **ADVANCE program** is to increase the representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. Creative strategies to realize this goal are sought from men and women. Members of underrepresented minority groups and individuals with disabilities are especially encouraged to apply. Proposals that address the participation and advancement of women from underrepresented minority groups are encouraged.
(NSF)
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383&org=NSF&from=fund



Moreover, every effort should be made to persuade other federal agencies (e.g., NIH) that programs like REU and IGERT are a tremendous opportunity and a shared responsibility. Following the direction of the Roadmap¹⁴, NIH has developed short summer programs for interdisciplinary research training; however, the structure does not emphasize developing mentoring relationships. Finally, since the REU program serves primarily as a resource development function, some funds should be available within the HRD Division to increase the number of funded sites, and to help other divisions fund marginal, yet meritorious, programs.

III.C.2 Initiate grant programs for mentoring that parallel the ADVANCE program.

We recommend that the NSF initiate an institution-level grant program for mentoring in STEM. The NSF ADVANCE program is an excellent model for institutional transformation involving mentoring. For example, the dissemination of best practices in mentoring could be funded in a similar fashion to the Partnerships for Adaptation, Implementation and Dissemination (PAID) program in ADVANCE. The ADVANCE site evaluations conducted by NSF have shown that mentor training is feasible, successful and cost-effective.¹⁶ Moreover, the emphasis on senior faculty by the ADVANCE program is also important to include in any mentoring initiative. The structure and focus provided by a grant program specific to mentoring would significantly aid nationwide efforts to establish and improve the practice of mentoring and would contribute to the goal of increasing participation and retention in STEM careers.



The SMILE Program was created to address higher education readiness and access, and the participation of students in science, technology, engineering, and mathematics (STEM) that come from minority, low-income, first-generation-in-college, and rural backgrounds. Through long-term mentoring, SMILE assists students in their efforts to build broader visions for their futures, realize academic success during their precollege years, and gain the skills and attitudes that facilitate their movement through the educational pipeline. SMILE advances the university's mission by facilitating ongoing, substantive school-university partnerships and engaging various partners to support the academic aspirations, achievement and attainment of historically underrepresented and educationally underserved students. **(Eda Davis-Butts)**

The PAESMEM Program seeks to identify outstanding mentoring efforts that enhance the participation of groups (i.e., women, minorities, and persons with disabilities) that are underrepresented in science, technology, engineering, and mathematics. The awardees serve as leaders in the national effort to develop fully the Nation's human resources in science, technology, engineering, and mathematics. Since its inception in 1996, the PAESMEM program has recognized 97 individuals and 68 institutions. Each year's awardees add to the recognition of a widening network of outstanding mentors in the United States, assuring that tomorrow's scientists and engineers will better represent the nation's diverse population.

(NSF)
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5473

The Institute of Leadership Training for Teaching Mathematics and Technology

was founded to develop a core of twenty five in-service teachers each year who are trained in the latest approaches to integrating mathematics instruction with technology and who will in turn, train other teachers in their school districts. Additionally, five pre-service teachers are selected to participate in workshop sessions along with in-service teachers. The workshop sessions introduce the participants to equity and diversity issues, problem-solving processes, hands-on activities, integration of technology with mathematics teaching, real-life applications, New York State and NCTM Standards and Assessments, and leadership and presentation skills at conferences. During the past 20 years the Institute trained over 500 teachers of grades 1–12 by rotation from Long Island and New York City.

(Jon P. Lee)



III.C.3. Support and fund ongoing interactions among PAESMEM awardees.

In consultation with past PAESMEM recipients, a strand at the NSF Division of Human Resource Development Joint Annual Meeting should provide professional development and goal-oriented activities for all awardees to build on their collective knowledge. At this meeting the Presidential awardees, who may apply for travel grants to attend, should discuss specific national issues and be tasked with making joint proposals to the nation to promote and enhance science and mathematics education in the broadest sense. A PAESMEM Web presence with communication, networking and best practices should be funded, developed and maintained.

III.D. Recommendation #4:

Implement and fund K-12 programs that support and promote mentoring.

The PAESMEM awardees strongly endorse the recommendations made by the National Academies report *Rising Above the Gathering Storm*,¹ particularly the intentions to attract well-qualified, creative teachers to the STEM workforce. In the context of this report, additional programs and resources are needed to develop and disseminate a culture of mentoring within the K-12 communities and between primary, secondary and tertiary education professionals. The following are areas where immediate gains could be made with modest investment.

III.D.1 Implement STEM training/mentoring workshops for middle and high school guidance counselors and principals.

Research has indicated that eighth grade mathematics represents a turning point for STEM engagement, particularly for women and minorities. Targeted mentoring efforts in middle school can help overcome this barrier by providing encouragement in the form of information regarding long-term employment possibilities in traditional and non-traditional STEM fields (e.g., engineering, medicine, agriculture, manufacturing, banking, etc.).



Summer Experience in Earth and Mineral Sciences (SEEMS) is a summer research program operated in conjunction with Upward Bound Math/Science at the Pennsylvania State University. Students in grades 9-12 attend classes in core academic subjects at grade level or above, and work in teams of 4-6 on mentored research projects under faculty and graduate student guidance. Over 60 students participate each summer, many returning for several years to gain more experience and become familiar with the campus environment. Recent SEEMS graduates have matriculated to Penn State, where they may continue mentored research throughout their careers. **(Tanya Furman)**

III.D.2 Increase focus on teacher professional development to strengthen teachers as mentors.

The best teachers are also typically the best mentors for a student outside of the home. For all students, there are critical junctures when it is imperative that the teacher/mentor is available and capable of delivering appropriate guidance. For underserved populations, access to quality education continues to be lacking. The following two teacher professional development recommendations will improve the mentoring environment in K-12 by advancing accessibility and awareness of the teacher/mentor.

III.D.2.a. Professional development and mentoring workshops for in-service STEM teachers should be made available throughout the country facilitated through partnerships between schools and institutes of higher education (e.g., Math Science Partnerships).

Most primary teachers have little or no formal training in, for example, the Earth Sciences, yet this topic is of intense interest among elementary students and provides the spark for young people to approach their world in a logical and ultimately scientific manner. Inquiry-based approaches to science, engineering and mathematics have been demonstrated as more successful than traditional instructional methods.

III.D.2.b. Establish national, state and local incentives to place high quality math and science teachers in inner city public schools, where many students are ethnic minorities.

Investment in inner city schools should include adequate salaries and incentives for teachers, as well as improvements to buildings and modern laboratory equipment. Additionally, efforts should be made to insure that an



Middle School Science Mentoring in an Urban High Needs School:

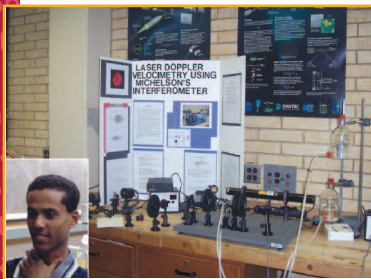
With the cooperative leadership of science teacher Ms. Maciejewski, faculty in chemistry, physics, biology, medicine and engineering collaborate with undergraduates and graduates to provide a series of opportunities to enhance science classes at the Native American Magnet School in Buffalo, a K-8 school with 600 students, 90% in poverty, 90% minority and 225 Native American. University at Buffalo faculty mentor for Ms. Maciejewski's Ph.D. studies in science education helps develop hands-on science experiments and curricular content aligned with NY State standards. A science after school program complements the in-class work.

(Joseph A. Gardella, Jr.)
www.nams19.org



Santa Ana – Cal State Fullerton Math Scholarship is a program for math majors from the Santa Ana Unified School District (97% Hispanic) who attend Cal State Fullerton planning to become high school math teachers. Each year since 1995, Dr. Pagni joins the Mayor of Santa Ana in presenting a scholarship to two new recipients. Pagni mentors all students to graduation and he is their student teaching supervisor. He writes letters of support and advises the students on the credentialing process and job placement. He mentors them as full time teachers, introducing them to professional organizations like the California Mathematics Council. To date, he has awarded scholarships to 32 students. **(David L. Pagni)**

Summer Workshops: The chief underlying weakness that underrepresented minority students in all STEM disciplines typically face is under-preparation in mathematics and science. In the past 10 years, Dr. Puri has designed and conducted summer workshops on Introductory Physics and Mathematics with 15-20 students typically participating in the program. The workshop requires completing a science project in a group or as an individual. Students work on projects to develop a deeper understanding on a specific topic of investigation. They do an independent literature search, conduct their own research, draw conclusions from their findings, and present to their peers. Selected projects are presented at undergraduate research conferences. **(Ashok Puri)**



adequate share of federally sponsored research, education and mentoring program funds go to schools and programs serving minority populations who are underrepresented in STEM fields.

III.D.2.c. PAESMEM awardees could sponsor or identify a potential PAEMST nominee from underrepresented groups.

PAEMST awardees constitute an untapped resource. However, most are from suburban districts with less connection to increasing diversity in the STEM workforce. Increasing connection between PAESMEM and PAEMST awardees will provide a focus on mentoring as a recognized portion of PAEMST criteria. In addition, PAESMEM awardees could facilitate the nomination of

teachers from underrepresented groups for the PAEMST program.

III.D.3 Establish incentives and infrastructure at the school district level or regional level to encourage and support discipline-based professional learning communities to mentor new teachers.

Effective teachers can make valuable contributions by taking on the responsibility of mentoring new teachers. In a Professional Learning Community, teachers share the responsibility of helping each member become more effective. District and site administrators can provide time and support for this collaboration on mentoring.

III.E. Recommendation #5:

Colleges and universities should adopt policies and procedures that value mentoring by administrators, faculty, staff and students.

The challenges and rewards of mentoring current and future college students cannot be overstated. Most of today's youth are well-versed in specific aspects of technology, but their career ambitions are molded by their peers and their leisure activities, including the jobs presented most frequently on television. One-on-one mentoring is essential to enable students to reach their full potential through selection of courses, awareness of job opportunities and encouragement to persevere. This sort of mentoring activity takes critical time away from faculty members' other pursuits, in particular the securing of crucial research funds that support the creation of new knowledge. We advocate development of university and college policies and new funding initiatives that recognize these diverse needs, and reward individuals who pursue a **balanced portfolio** of professional activities.

The following methods can be implemented by higher education institutions:

- Provide workshops in mentoring strategies and evaluation techniques for university deans and department chairs.
- Articulate the value of mentoring in the institution/department mission statement.
- Include mentoring activities among expectations for faculty promotion and tenure and college student service.
- Host workshops and provide handbooks to prepare faculty, graduate and upper level undergraduate students to be effective mentors.
- Provide faculty allowances/awards to cover the cost of student research to encourage faculty to mentor students, particularly undergraduates and students from populations underrepresented in STEM disciplines.
- Implement semi-structured or structured mentoring programs to help match student and faculty mentors, giving special attention to students who are unlikely to form spontaneous or informal mentoring relationships with faculty.

- Provide guidance regarding expectations about protégé and mentor commitments to the relationship.
- Recognize accomplishments of mentoring by publicizing stories in campus, local and national publications.
- Provide continuing education programs for engineers and scientists to equip them to respond to the changing economy by enhancing, refreshing or changing their skills.

Conclusions

The STEM workforce and the demographics of this country are out of sync with one another. While the science and technology labor force is predominantly white and male, the population of the United States comprises approximately 66 percent female, ethnic minorities and disabled people. Therefore, the majority of the total population is significantly underrepresented in the STEM employment sector. Although the United States struggles to train an adequate number of engineers and scientists, we have this vast, untapped pool of talent that we are not engaging in the STEM workforce. It is imperative to the economic future of the country that we effectively recruit and retain individuals from this 66 percent majority of the country's citizens for the STEM disciplines.

Mentoring is a powerful and natural human relationship. The teacher and the parent provide mentoring to children throughout their developing years. As adults, we are mentored by co-workers, supervisors, friends – by anyone who has a desire to help advance knowledge or insight, and has the ability to convey this knowledge in a nurturing manner. Mentoring, by its nature, is a one-on-one relationship and often occurs in an informal format. It is common that these relationships will develop between people who have a common background or frame of reference on which to build communication and trust.

In the case of the STEM workforce, however, when there are a limited number of role models available, the person seeking a mentor may not be able to forge this type of relationship. If there are a limited number of mentors who also share a common set of experiences or background, it may prove to be difficult to develop a strong mentoring relationship. This lack of role models is a central limiting factor affecting women, minorities and people with disabilities as they enter STEM fields.

It is the responsibility of both practitioners and academics in the STEM fields to provide mentoring opportunities for all people. The mentoring relationship must not be limited to those with whom we are most comfortable, but must be available to all of our students and co-workers. By creating strong mentors, by encouraging the development of the mentoring process, and by establishing the infrastructure and reward system in support of mentoring, significant gains will be realized in both the diversity and number of people participating in the STEM workforce.

The authors of this paper present a number of opportunities that will enhance the mentoring process and assure growth of the STEM workforce. Most importantly, we see a need for strong advocacy for mentoring developed at the national level to enable the systematic and widespread adoption and recognition of mentoring practices. There are many excellent mentoring models which can be deployed and adapted for a variety of situations. What is missing in national discussions is a demand that all of our students have equal access and opportunity to role models and mentors that can guide them to attaining their goal of a STEM education and career. The combination of PAESMEM with NSTC or a similar organization with broad interagency scientific leadership will create an influential, nationwide body to promote mentoring and accessibility of STEM careers and education for all.

References

1. Committee on Science, Engineering, and Public Policy: National Academy of Sciences, National Academy of Engineering, and Institute of Health of the National Academies, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, 2006.
2. George W. Bush, President, USA, *State of the Union Address by the President*, Jan. 31, 2006, <http://www.whitehouse.gov/stateoftheunion/2006/index.html>.
3. Business Roundtable, *U.S. Innovation And Competitiveness, Addressing The Talent Gap: Public Opinion Research Sponsored by Business Roundtable with Support from Compete America*, 2005-2006, www.businessroundtable.org.
4. Major Owens, *Education Mobilization*, The Nation, February 6, 2006, <http://www.thenation.com/doc/20060206/owens>.
5. Michael D. Lemonick, *Are We Losing Our Edge*, Time Magazine, Feb. 13, 2006.
6. The President's Council of Advisors on Science and Technology (PCAST), *Sustaining the Nation's Innovation Ecosystems: Report on Information Technology Manufacturing and Competitiveness*, 2004.
7. National Science and Technology Council, *Science for the 21st Century*, 2004, http://www.ostp.gov/nstc/21stCentury/Final_sm.pdf.
8. National Science Board, *The Science and Engineering Workforce: Realizing America's Potential*, The National Science Foundation, NSB 03-69, August 14, 2003, <http://www.nsf.gov/nsb/documents/2003/nsb0369/nsb0369.pdf>.
9. Council on Competitiveness, *Innovate America: Thriving in a World of Challenge and Change*, 2004, http://www.compete.org/pdf/NII_Interim_Report.pdf.
10. National Science Foundation, National Science Board, *2020 Vision*, 2005.
11. Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development, *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology*, 2000, http://www.doleta.gov/h-1b/pdf/cawmset_report.pdf.
12. Research and Policy Committee, Committee of Economic Development, *Learning for the Future: Changing the Culture of Math and Science Education to Ensure a Competitive Workforce*, 2003, http://www.ced.org/docs/report/report_scientists.pdf.
13. MentorNet: *The e-Mentoring Network Program for Diversity in Science and Engineering*, <http://www.MentorNet.net/>
14. National Institutes of Health, *NIH Roadmap for Medical Research*, 2006, www.nihroadmap.nih.gov.
15. National Research Council, *Bridges to Independence: Fostering the Independence of New Investigators in Biomedical Research*, National Academics Press, Washington D.C., 2004.
16. New Mexico State University, *Report to the National Science Foundation: ADVANCE Institutional Transformation Award, Site Visit: October 31-November 2, 2004*, Las Cruces, New Mexico.