Pathways to STEM Careers:
Preparing the STEM Workforce of the 21st Century

BROADENING PARTICIPATION THROUGH A COMPREHENSIVE, INTEGRATED SYSTEM

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FINAL WORKSHOP REPORT

CHARGE TO THE WORKSHOP

This report summarizes discussions and recommendations resulting from a workshop convened at the National Science Foundation to examine issues surrounding the development of a diverse and well-prepared science and engineering workforce for the 21ˢᵗ century. The workshop was given five major charges. The first was to review existing research findings and gaps as well as programs related to workforce issues. The second was to discuss actions needed to broaden participation in the science, technology, engineering, and mathematics (STEM) workforce, comprising all of the fields supported by National Science Foundation program areas – including biology, physics, mathematics, computer and information sciences, engineering, environmental research, geosciences, social, behavioral and economic sciences, and education. The third was to identify strategic research areas and education funding priorities that will result in a rich and diverse STEM workforce strengthened by broader participation of U.S. citizens. The fourth was to identify evaluation methodologies, criteria, and metrics to measure the success of future programs. The fifth was to identify and propose strategies and funding mechanisms that will facilitate more members of under-represented groups – including women, persons with disabilities, African Americans, Latinos, and American Indians – to enter STEM leadership positions.

Workshop attendees represented a range of diverse leaders employed in a variety of sectors and representing the disciplines supported by the National Science Foundation. Participants included leading scientists and engineers; educators from the pre-college through graduate levels; representatives of organizations or programs directed toward communities under-represented in science and engineering; employers from academic, industrial, and governmental sectors; public and private funders of research and development; and representatives of professional organizations. Every effort was made to ensure that the participants reflected both demographic and disciplinary diversity.

The workshop consisted of plenary presentations and panel discussions, each followed by breakout group discussions that were summarized for the entire assembly. Candor and a willingness to articulate deep-seated concerns characterized the workshop, along with growing enthusiasm and excitement that the steps being discussed had the potential to create substantial improvements in the recruitment, retention, and advancement of all US citizens, especially under-represented groups, in STEM careers.

The workshop did not seek to achieve consensus on programmatic recommendations, nor was it able to speak to all the questions underlying the issues raised. Nevertheless, several strong recommendations and principles emerged from the workshop that are reported herein. The report is presented in three parts. Part I elucidates the problem by citing data that indicate the current lack of diversity in the STEM workforce. Part II describes the recommendations from workshop participants, based upon research and exemplary programs that address the problem. Part III describes a future vision of the way we view the enterprise of science that focuses on developing human intellectual potential.

The National Science Foundation has taken an essential step in making the development of the STEM workforce a priority. This report is designed to inform the STEM community about setting a national agenda for possible actions and policies in the vital pursuit of developing a highly skilled, technically competent, and diverse workforce.

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EXECUTIVE SUMMARY

The continuing lack of full and diverse participation of all citizens in the science, technology, engineering, and mathematics (STEM) workforce threatens the economic strength, national security, and well-being of U.S. citizens. The under-representation of certain groups also raises serious issues of social justice and lack of opportunity in a society that professes to be egalitarian and democratic. As groups under-represented in the STEM workforce become an increasingly larger part of the U.S. population, the vitality of the STEM workforce may further decline unless action is taken to broaden participation of all parts of our society.

Educational and career paths are idiosyncratic and difficult to predict, but a variety of projects and policies have proven effective in increasing the diversity of individuals pursuing STEM careers. However, many of these programs and policies have remained marginal to the core activities of institutions; many have not been institutionalized due to reliance on external funding sources; and many programs have been conducted in a piecemeal fashion without links to other programs or evaluation that can guide future activities.

Research on the pathways and training leading to STEM careers and on the workplace environment has already produced valuable findings about how to increase access to these fields for all U.S. citizens. Yet, too often, these research findings have not been widely disseminated or fully integrated into assessments of current programs or the development of new ones. In addition, important research questions have gone unanswered because of inadequate integration across programs and a lack of support for such research. The current piecemeal approach to the development of the STEM workforce must be unified so that individual efforts contribute to the whole and exert beneficial effects on the entire educational and workforce system. When individual students travel along the various pathways toward the ultimate goal of joining the STEM workforce, there must be transition mechanisms in place so that they do not get lost along the way.

Federal agencies and other funding organizations must implement program principles designed to increase the full and diverse participation of all citizens in STEM fields. Programs include research, implementation, education and other funded activities. The following seven program principles are recommendations from the workshop:

1	Focus on diversity in STEM leadership and faculty development.
2	Focus on integrative initiatives across multiple programs and to include multiple organizations, such as professional societies and private industry.
3	Focus on identifying and strengthening transition points along STEM pathways.
4	Focus on centers of excellence that address multiple aspects of STEM pathways.
5	Focus on developing assessment methodologies and metrics to measure success.
6	Focus on long-term sustainability of successful programs.
7	Focus on national dissemination of results from exemplary programs.

The goal of the principles is to guide integration of existing and future programs and initiatives into an overall system that attracts, retains, and enhances the experiences of all individuals who are preparing for and engaged in STEM careers. The challenge for funding agencies will be to use the program principles to call attention to capacity building throughout the entire scientific and engineering enterprise. The principles will enable them to provide a more focused and uniform set of guidelines in new program solicitations to insure the development of a broader talent pool over time. This will require federal agencies that are engaged with all educational levels and across all fields of scientific research to serve as catalysts for transforming the scientific enterprise by engaging new partners in academe, government, and industry. These partnerships, must work collaboratively across disciplines to meet the challenge of developing a competitive and diverse domestic workforce that is truly representative of the U.S. population base.

It became clear that some groups will need more resources and support than others all along the multiple STEM pathways in order to enjoy full participation in the workforce of the future. The workshop strongly recommends that policy makers encourage the development of a network of pathways that allows students from diverse backgrounds to achieve success in a range of roles, such as researcher, educator, evaluator, industry leader, or entrepreneur.

Realizing the capability of all its citizens requires that the nation's policy makers view the development of human resources as inseparable from the goal of expanding the research frontier. Developing people to their full intellectual potential and developing a vibrant science and engineering enterprise should be seen as a synergistic, two-way relationship, with both aspects being of equal importance and dependent upon each other for success.

PART I

The STEM Workforce: Establishing the Need for Change

The majority of the children who will be born in the United States in the 21st century will belong to groups that are now under-represented in careers involving science, technology, engineering, and mathematics (STEM) (see Figure 1). Without broader participation of all parts of our society in these careers, the vitality of the STEM workforce may decline and good jobs will continue to be exported to other countries. Our economic vitality, national security, and future well-being depend on strategically broadening participation in these critical fields (Colwell, 2002; BEST, 2004; NSB, 2004a,b).

Projected Racial Ethnic Composition of 18-24 Year-Olds
2001 - 2100

Legend:
- White, non-Hispanic
- Black, non-Hispanic
- American Indian, non-Hispanic
- Asian/Pacific Islander
- Hispanic

Source: Population Projections Program, Population Division, U.S. Census Bureau, Washington, D.C. 20233, http://www.census.gov/population/www/projections/natsum-T3.html
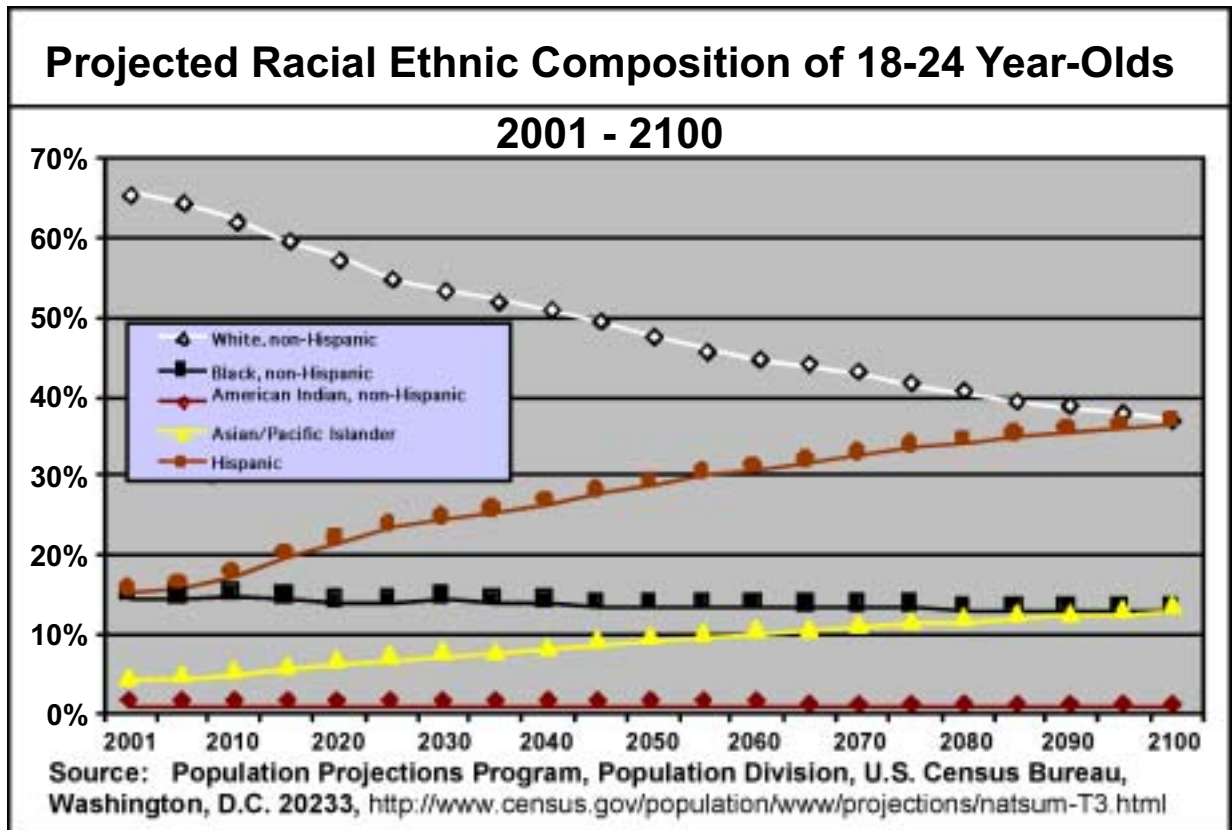
Figure 1: Racial Ethnic Composition of US Population

Issues regarding the development of the STEM workforce are complex (Pearson and Fechter, 1994; Jackson, 2003; Mervis, 2003; NSB, 2003, 2004b; Monastersky, 2004). Among these issues are the factors students take into account as they consider alternative careers, the overall health of the economy, balance between foreign and domestic workers, and the political process of allocating public funds for STEM fields and training. Given this complexity, progress in assessing adequacy and in developing the talent among under-represented groups will require contributions from a wide array of disciplines. The federal government recognizes this and subsequently established an inter-agency working group to examine its investments in programs and research on developing human resources for the STEM workforce. This includes identifying programs that have been rigorously evaluated as well as those that are promising.

Under-Representation as a Social Justice Issue

The under-representation of minorities, persons with disabilities and females in the STEM workforce is a serious social justice issue in a society that professes to be egalitarian and democratic (Wardle, Martin and Clarke, 2004). Considerations of social justice, national security, and economic well-being call for all individuals to have opportunities to pursue STEM careers. If we are to address it at the roots, it is imperative that the nation begins seriously to focus on this under-representation as a human capability realization problem, rather than as a STEM capacity building problem. The loss of opportunity and economic cost to individuals far outweighs the cost of lost STEM workers to society.

Current Lack of Diversity and Opportunity in the Workforce

The members of groups under-represented in STEM careers, including women, African Americans, Latinos, Native Americans, and persons with disabilities, face multiple and reinforcing obstacles if they choose to pursue these professions. Though many of these individuals have the greatest educational needs, they tend to be the least well served by the K-12 educational system. Quantitative capability is a significant "digital divide" for many U.S. students, noted one workshop participant. Except for non-Hispanic White women, students from under-represented groups are more likely than other students to emerge from pre-college education without the mathematical and scientific background needed to achieve later educational and career success in these fields.

More broadly, a lack of social capital and status can be critical factors for pre-college students. For example, many people now in STEM careers had access to professionals who were in similar fields and could offer advice and support, but fewer minorities have such resources. Similarly, majority students often can draw on family connections or other points of contact in their pursuit of high-quality preparation for work in STEM fields; this is not the case for many underrepresented minority students (NSF, 2004b).

More obstacles can be encountered during the undergraduate, graduate, and postgraduate years, leading to gradually declining percentages of underrepresented minorities at the higher levels of academia in science and engineering. For example, though the representation of women in some fields has increased, in other fields they remain severely under-represented ((National Science Foundation, 2004b,c; National Science Board, 2004). Research into the causes for this reveals that there are many complex and inter-related factors that contribute to this under-representation. They begin with early socialization of young women away from an interest in STEM, self-selection out of math and science courses in college, and multiple barriers encountered in graduate school and in the workforce that inhibit their desire to participate in STEM-related careers (Byer, Rynes and Haller, 2004;Weinburger, 2004).

Workshop participants pointed out that mathematics and science education can be great equalizers for underrepresented minority and low-income students with disabilities. Proficiency in these fields can enable them to excel in school and gain fulfilling and rewarding jobs. In addition, new information technologies have the potential to remove some of the obstacles to achievement for under-represented groups. However, research has shown that students from under-represented groups often need extra encouragement and mentoring to realize these skills and benefits.

PART II

The STEM Pathways Workshop: Describing the Change

With this strategic concern in mind, the federal government and industry have exhibited keen interest in developing the scientific and engineering workforce of the 21st century. The strategic focus is to identify new and existing programs that will create easily navigable pathways to STEM careers by attracting more U.S. students and broadening participation in STEM fields. The ultimate goal is to prepare a STEM workforce capable of meeting the challenges of the 21st century. To explore these issues a workshop was convened in the fall of 2003 to provide an opportunity for experts from the relevant communities to explore the extent to which the existing knowledge base on STEM workforce issues can inform the creation and expansion of such pathways. The workshop was organized around the five goals shown below.

1	Review and discuss existing research findings and programs related to workforce issues
2	Discuss actions needed to broaden participation in the STEM workforce
3	Identify strategic research areas and education funding priorities that will result in a rich and diverse STEM workforce strengthened by broader participation of U.S. citizens
4	Identify evaluation methodologies, criteria and metrics to measure the success of future programs
5	Identify and propose strategies and funding mechanisms that will propel more underrepresented group members in STEM leadership positions

The overall goal of the workshop was to determine the state of extant knowledge, to identify knowledge gaps, and to propose key components of a program agenda to address the problem. It began with a series of plenary and panel presentations followed by intense discussions in breakout sessions and with the group as a whole. The critical themes emerging from the discussions and breakout sessions are summarized below.

Broad Issues Related to the STEM Workforce

The Internationalization of the STEM Workforce

Several important issues related to the development of the STEM workforce arose repeatedly during the workshop. One centered on the changing demand for and supply of STEM personnel. Globalization, new technologies, and national security considerations are creating new forces in the educational pathways leading to STEM careers. U.S. industry now operates in a global marketplace and faces unprecedented international competition. Consequently, employers are moving jobs wherever they can find talent, value, and cost-effective solutions.

A stagnant marketplace in some sectors of the U.S. economy has accompanied the movement of some STEM jobs overseas. Most engineering disciplines experienced little or no growth between 1996 and 2001, with some experiencing declines (National Science Board, 2004). Workforce growth rates for the physical sciences, life sciences, computer sciences, and mathematics vary, but by number of workers the only significant growth during this period was in information technology occupations.

At the same time, the number of non-U.S. citizens in science and engineering programs in U.S. universities and in the STEM workforce has increased. For example, data from National Science Foundation confirm a significant increase in the presence of foreign students in U.S. graduate schools. As a result, the United States has become increasingly dependent on foreign students and foreign workers in STEM fields, despite the inherent unpredictability of relying on foreign sources of STEM expertise. This has become very apparent with the change of immigration policies since the 9/11/01 attack. As foreign students find it more difficult to obtain student visas to the U.S., it becomes more essential for U.S. students to fill the gap (National Science Foundation, 2004b; National Science Board, 2003, 2004a,b).

Dealing with Complexity

Another theme emerging from the workshop was the need for educational institutions to prepare students for jobs that will make unprecedented demands on multiple skills. To compete in the global marketplace, STEM personnel will need to handle complex problem-solving tasks in addition to the more traditional tasks they might expect. For example, one workshop participant noted that many engineers can no longer be simply "technologists" — rather, they need to apply wisdom and judgment to novel or sophisticated problems encountered on the job and to be able to assess the social impact of systems.

"We must educate our students to handle cultural and technical complexity," said a participant. "We need to give them an education that will make them employable." Such preparation is not uncommon for students in Europe and Asia where, for example, fluency in several languages is expected and familiarity with the cultural norms of neighboring countries is assumed.

Several workshop participants noted that workforce diversity strengthens the ability to deal with complexity. To solve difficult problems, different and unique perspectives can contribute creative approaches that would not otherwise be taken. "Diversity is one means to achieve our goal of a highly trained and competent workforce," said one attendee.

Building an Academic Base

Finally, an especially important consideration in broadening participation in the STEM workforce is the diversity of the faculty in academic institutions, including two-year and four-year colleges. Women, minorities, and people with disabilities are seriously under-represented as faculty, especially at major research universities, in most STEM disciplines (NSF, 2004a,b,c). "If academia looked more like America," noted one presenter, "we would be a lot closer to a solution."

Members of under-represented groups suffer from high rates of attrition at each transition point in the pathway toward a faculty position: graduating from high school, from college to graduate school, from graduate school to postdoctoral fellowships, and from fellowships to faculty positions. Furthermore, the under-representation of some groups in teaching positions is a problem through-out the educational system, including in K-12 education. "We have one faculty in this country, not two," was a comment made at the workshop. Without role models and mentors, members of groups under-represented in STEM fields are less likely to see themselves pursuing these subjects and succeeding in a STEM career. Efforts to broaden the participation of U.S. students in these fields must include incentives to increase the number of women, minorities, and people with disabilities in academic positions (NSF, 2004a).

From Successful Programs to Large-Scale Change

Plenary, panel, and breakout discussions all included lively and sometimes sharp exchanges about government, university, industry, and school system initiatives to prepare, recruit, and retain under-represented populations for the STEM workforce. These discussions allowed participants to draw the following generalizations about the characteristics of successful programs.

Lessons Learned from Prior/Existing Programs

Leadership: Strong leadership at all levels is a key to success of any program. Successful programs commonly are championed by individuals dedicated to long-term improvements who can obtain buy-in from others in leadership positions (BEST, 2004). The importance of champions points to the need for succession planning for leadership (in part, to prevent burn-out and encourage new ideas) and for the continuity of institutional commitment. In addition, leadership must come from multiple levels and a range of communities such as academe, industry, professional societies and government.

Mentoring: A strong mentoring or coaching component, whether between researchers and teachers, between graduate and undergraduate students, among peers, or involving other groups, is characteristic of many successful programs.

Institutional Support: The long-term success of programs depends on engaging institutional support and commitments from a broad network of partners among faculty, schools and departments, students, industry, and the community. Programs with goals that are aligned with those of their home institution are more likely to thrive and become a priority for local funds.

Funding: Many successful programs have diverse sources of funding to ensure program continuity. Although the highly competitive nature of the grant-seeking process may help clarify and strengthen program goals, funders need to be flexible to allow for innovation and risk-taking based on program evaluations or external peer review. To that end, it is essential that proposal review panels reflect the personal and institutional diversity desired for the project outcomes.

Measures of Success: Measurable objectives and formal evaluation are crucial for assessing program success (BEST, 2004). Assessments should provide continuous feedback to guide program design, planning, and implementation and offer opportunity for partnerships with social scientists engaged in evaluative research on STEM workforce issues. Social science and education researchers should be called upon to play a key role in developing meaningful metrics, designing robust evaluation protocols, and implementing the assessment process for projects (Levine, Abler, and Rosich, 2004).

Focus on Transition Points: Students take multiple and intersecting career paths to STEM careers, many of which can be idiosyncratic and therefore hard to predict. Innovative solutions to recruiting students into STEM fields can come from looking at intersections and transitional points in the educational and workforce system. In addition, a focus on transitions can enhance an individual's successful academic and social integration into a scientific discipline.

Focus on Communities: Many programs are successful because they are targeted at a specific under-represented group, educational level, or problem. At the same time, this focused approach can serve broader groups — for example, programs designed to encourage females or underrepresented minorities to pursue STEM careers have often proven to be equally helpful for all demographic groups of students and workers.

The Dangers of Isolation of Programs: While workshop participants acknowledged that many institutions have implemented activities that can create pathways to STEM careers, they also pointed out that many existing programs have inherent and often severe limitations. The underlying problem with many programs is that they do not build on other successful programs to create a whole that is greater than the sum of the parts.

"We have numerous examples of projects that are successful," said one workshop participant. "But these are individual projects. We need to change the overall system if we are to achieve critical mass."

Many programs have been developed by trial-and-error and in relative isolation. As a result, programs tend to engage in a phenomenon of "parallel discovery," where similar programs have evolved less efficiently than would have been the case had better communication existed. These isolated programs have few ways to communicate with other programs to share experiences and incorporate improvements. Overall, targeted programs that address diversity issues often suffer from the same shortcomings:

1	Loss of a champion for a program, which can undercut its effectiveness or even lead to its discontinuation.
2	Being developed and operated in a piecemeal fashion without links to other programs or evaluations that can guide future activities. Because of the isolation of such programs, they are not viewed as part of a larger whole.
3	Despite their successes, many programs have remained marginal to the core activities of institutions. Such programs can be eliminated without affecting the institution of which they are a part, and in times of budget constraints these programs are prime candidates to be eliminated.

The Contributions of Research to Large-Scale Change

Research into programs and policies that can successfully broaden participation in STEM fields shares many of the strengths and weaknesses of the programmatic initiatives directed at the problem. Research has produced much useful information about the design and operation of educational and workplace programs. Yet too often the research findings are poorly integrated into the assessment of existing programs or the development of new ones.

Lessons Learned from Prior Research

Research into the practices and cultures of educational institutions and the workplace can benefit all groups, not just those groups under-represented in STEM fields. As one participant noted, "Underserved groups are like canaries in the coal mine – if an educational institution or workplace has a 'toxic' environment, women, persons with disabilities, and under-represented minorities will be the first to suffer." Research into institutional and interpersonal environments can identify components of a healthy STEM culture and elucidate the characteristics and practices of successful departments, research groups, advisors, and employers.

A wide range of research approaches will be necessary for addressing the many aspects of STEM workforce problems. A necessary component of any program is a robust assessment process to provide feedback on the effectiveness of programs as they are being implemented.

Formative assessments that focused on processes can help programs identify what is working and what is not working and can provide feedback that programs can apply in real time. Summative assessments focused on outcomes and products can provide valuable lessons for policymakers, leaders and administrators of other projects. As in the discussion of successful programs, several issues arose repeatedly in discussions of research needs.

The Potential Contributions of the Social Sciences: Many workshop participants pointed toward the value of the social sciences in not only evaluating programs and policies, but also in developing new initiatives. Social scientists are rarely involved in the design or evaluation of programs for increasing participation in the STEM workforce, even though there is a clear need to bring their insights and expertise to bear. Furthermore, the social sciences need to be seen as an integral part of the research enterprise, with similar needs for a diverse and well-trained workforce and with special expertise about the best ways to meet those needs (Levine, Abler, and Rosich, 2004).

For example, social scientists can help identify and address factors that appear to pose barriers to participation in STEM fields, such as institutional and departmental attitudes toward women, persons with disabilities, and under-represented minorities. They can investigate the tensions between meeting community needs in places such as American Indian reservations and training individuals who may leave their communities and thereby reduce the resources available to those communities. They can function as "institutional anthropologists" in examining the social context and organizational arrangement of an educational institution or workplace. They can investigate topics in which little work has previously been conducted — such as the distinct barriers to participation in STEM fields by people with disabilities.

By bridging STEM disciplines, social scientists create an additional pool of qualified individuals to increase the recruitment and retention of more U.S. citizens and especially women and minorities into the STEM workforce. In addition to social scientists, researchers from business schools who study management and organizations can provide valuable insight into institutional change and organizational behavior.

The Importance of Disaggregated Data: Current data often are not collected or presented in enough detail to understand issues and trends for specific groups. Although women, minorities, and people with disabilities share under-representation, the factors causing that underrepresentation may differ from one group to another as well as from one discipline to another. As one participant quipped, "the assumption becomes that all women are white, and all minorities are men."

Data need to be disaggregated by race, gender, disability, field, sector, academic degree, and other characteristics, workshop participants said. Potential similarities among underserved group, such as isolation, tokenism, and undervaluation, need to be investigated, as do potential differences, such as self-confidence, academic experiences, and attrition. Effective solutions then can be tailored to serve the needs of each group.

A significant problem with data disaggregation is that group sizes become too small to analyze effectively or even to discuss, given privacy concerns. Innovative methodological solutions need to be devised to deal with this problem. Longitudinal surveys, case studies, and working with specific individuals all offer possible solutions to small cell sizes.

Existing disaggregated data already point toward intriguing results. For example, within the social sciences, sociology has significantly more African American, Hispanic, and women participants than does economics; also in economics a disproportionate number of doctorates are awarded to non-U.S. citizens (Commission on Professionals in Science and Technology, 2000). In general, group experiences by field offer many fruitful research questions — for example, why women are more likely to study the biological sciences than the physical sciences, and whether all Asians – or only Asian men — are disproportionately represented in some fields (National Science Foundation, 2002; Xie and Shauman, 2003).

Similarly it is imperative that more research is done to examine how different disabilities are dealt with in the work place. There remains a major gap in our understanding of the impact and accommodations needed for various types of disabilities if persons with disabilities are going to enjoy full participation in the STEM workforce. Researchers need to examine what we know so far and what we need to know about various types of disabilities. Some workshop participants called for more research on persons with non-physical disabilities. We continue to know little about how or if the workplace accommodates workers with disabilities associated with aging. This is an area where new research tools and techniques are needed to allow sufficient disaggregation of data to produce meaningful results specific to particular types of disabilities, while at the same time protecting the confidentiality of individuals involved in the studies.

Strategic Research Areas and Integrated Funding Priorities

Workshop participants identified several features of a more integrated and comprehensive approach to research on the factors that contribute to the choice of a STEM career. The research areas articulated below need to be carried out at both the institutional and individual levels. In addition new methodological approaches and tools need to be developed to facilitate this research.

Research on the beliefs and actions of gatekeepers: The beliefs, attitudes, and practices of faculty and administrative gatekeepers at all levels of education and employment are a critical factor in attracting and retaining STEM students and employees. Similarly, experimental modeling of hypothesized mechanisms for change, collaboration, and negotiation could stimulate the greater participation of under-represented groups in the STEM workforce.

Research on the "culture of science": A key challenge for attracting people to STEM careers in future years will be improving educational and working conditions in these fields. Long hours, the scarcity of funding for younger investigators in many fields, for women the tension between the biological and tenure clocks, and a lack of rewarding work for graduate and postdoctoral researchers are among many barriers in academe and industry that may discourage participation in STEM careers. An important question to examine is why such factors seem have greater impact on STEM than other professional careers, such as law and medicine (Teitelbaum, 2001). An often-cited problem is the existing practice of science based upon a traditional, male-oriented model that presumes the

ability of the researcher to be totally devoted to the scientific endeavor due to a helpmate in the background taking care of children and family concerns. This model no longer works within the current culture of dual career couples who now often share childcare and family responsibilities equally and may deter both men and women from participating in STEM careers. Further understanding of how the structure of institutions and organizations and the practice of science can influence career choice could provide insight into recruiting and retaining a diverse STEM workforce.

Research on individual choices: Investigations of the social and psychological factors contributing to individual choices can reveal factors that appear to pull or push students or employees into or away from STEM fields. Examples include personal and professional self-image, family or community expectations, and existing or apparent tradeoffs between a STEM career and family obligations.

Research on different levels of workforce development: Attention should be focused not just on the participants in the STEM educational and career pathways but on the system within which people operate. In this way, research can emphasize the connections among policies, practices, and people in educational institutions and the workplace. Such research also can examine the important issues of sustainability and scalability.

Research on career patterns and experiences of under-represented minorities and women: Longitudinal, survey, and case study data need to be gathered to determine whether certain career patterns and experiences exist that marginalize these groups and prevent their progress in STEM fields. In particular, data about the under-representation of minorities and women in all STEM fields at top tier research universities need to be gathered to determine the causes behind this under-representation and to suggest remedies.

Research on leadership: Practices in such areas as recruitment, retention, recognition, and promotion can heavily influence advancement to positions of scientific and administrative influence, and this can be an important focus for research on STEM program outcomes.

Research using existing databases: The databases of individual programs should be designed for both research and administrative purposes. Historical data should be preserved for future study rather than being discarded. Ways of funding the creation, preservation and maintenance of these databases must be included in programs.

Evaluation Methodologies and Metrics to Assess Success: While participants were unable to devote much time to the issue of evaluation methodologies and metrics, these issues were referenced in several contexts, most notably exemplary programs. Participants pointed out that only recently has program evaluation received the attention that it deserves. Much of the early federal funding of programs did not include budgetary support for evaluation. Consequently, evidence of program effectiveness was elusive. Although there is more awareness of and inclusion of evaluative components in programs, funding still lags. Many participants called for more funding support for evaluation research (especially involving cultural competency) and for training evaluation researchers, particularly from underrepresented groups**.**

An Action Plan for Comprehensive, Integrated Change

The most important theme emerging from the workshop was the need for a unified approach to achieving STEM workforce diversity. "Now is a time for integration, to make the whole greater than the parts," said one workshop participant. "We must work together to enlist and engage the next generation of scientists and engineers and prepare them for careers." A valuable step for federal agencies is to provide leadership in implementing program principles designed to increase the diversity of those involved in STEM fields, where programs include research, implementation, education and other funded activities. A set of seven program principles emerged from the workshop sessions. In addition to the specific disciplinary focus of research programs, all programs should include one or more of the following workforce development components:

1	Focus on diversity in STEM leadership and faculty development.
2	Focus on integrative initiatives across multiple programs and to include multiple organizations, such as professional societies and private industry.
3	Focus on identifying and strengthening transition points along STEM pathways.
4	Focus on centers of excellence that address multiple aspects of STEM pathways.
5	Focus on development of assessment methodologies and metrics to measure success.
6	Focus on long-term sustainability of successful programs.
7	Focus on national dissemination of results from exemplary programs.

Strategies and Funding Mechanisms to Foster Leadership and Integrative Action

To attract, retain, and enhance the experiences of those individuals who will constitute the STEM workforce of the 21st century, existing and future workforce programs and initiatives must be part of a comprehensive, integrated system. The current piecemeal approach to the problem must be consolidated and coordinated so that individual efforts contribute to the success of other efforts and exert beneficial influence on the entire research and educational enterprise. As one presenter said, "We need to embed diversity in everything we do."

No one model program can guarantee success, just as no one research program will produce the lessons needed to solve all problems. There must be vertical linkages"across programs that range from pre-kindergarten through pre-college education through undergraduate and graduate education into a career, with bridges across current divides. And there must be horizontal linkages among research, policy, and practice so that programs become part of the educational and workforce culture, not incidental and temporary add-ons to existing efforts. Above all, program leaders and researchers have a moral imperative to work together to address this issue.

Institutional Partnerships

More and stronger partnerships among all of the institutions involved in the preparation and employment of the STEM workforce are essential in forging an integrated and comprehensive system. There needs to be greater connections among educational institutions, businesses, nonprofit organizations, and professional societies to accelerate progress and fill gaps where expertise is missing. In addition, many institutions, such as churches, civic associations, or even sororities and fraternities, which are often overlooked, can play valuable roles.

Partnerships must include community colleges, where a significant pool of African American, Hispanic, women, first-generation, and older students begin their college careers. Pathways from community colleges into four-year colleges and beyond can be a powerful means to increase the recruitment and retention of under-represented groups. In addition, professional societies of scientists and engineers from under-represented groups have proven that they can have a significant influence on choices about STEM careers.

Partnerships among institutions and within institutions can create pathways into STEM careers that have been underused in the past. "It's important to look outside of standard source pools and consider not only demonstrated skills but potential," said one workshop participant. "We need to think beyond current models, by recruiting from other [non-STEM] undergraduate majors, for example." Within institutions, efforts should be facilitated to create and maintain synergies among STEM programs at different levels (e.g., viewing programs that target underrepresented groups as sources from which to recruit.)

Partnerships are an important mechanism for fostering the development of leaders and program champions, who often rise to the fore when confronted with the challenges of meshing different cultures. By providing support for women, persons with disabilities, and under-represented minority groups, federally supported programs can help grow leaders from within these communities.

Instituting Incentives through Research Funding

Change within individual institutions and across institutions requires that success be tied to reward systems. Federal agencies and other funding agencies should use all the mechanisms and partners at their disposal to effect change. First and foremost, they must use the grants they award as a policy tool, and the projects they support should be seen as interventions for the achievement of explicit outcomes.

"There are not good mechanisms for accountability at institutions that receive federal funding," said a participant summarizing a workshop breakout session.""Funders should look at institutions that have a good track record for improving diversity and fund them more, and look at institutions that don't do as well and develop mechanisms for improvement."

Several other proposals for change were discussed at the workshop. Federal agencies and other funders could fund the development of an online inventory of past educational and research programs that includes available information about program characteristics and assessment metrics for success. They could establish an award program recognizing leadership in the support of diversity in preparing the STEM workforce, just as there are now award programs for outstanding teaching and mentoring. They could provide support to convene annual workshops and conferences at federally supported centers to raise awareness of STEM workforce issues and to provide opportunities for practitioners and leaders in STEM fields to share ideas and methods for increasing diversity.

One idea that was discussed extensively was for federal funders to create regional or national alliances of educational and research programs focused on broadening participation in the STEM workforce. Such alliances could create new pathways to successful STEM careers, with specific metrics and indicators of success. The alliances could have goals for five, ten, and fifteen years, with provisions to scale up those parts of the effort that prove most successful. The overall goal of the initiative would be to create alliances that are an integral part of the educational system so that programs become self-sustaining.

At the same time, federal agencies and private foundations need to be willing to fund programs that take risks by trying new approaches. Funders should be visible advocates of these programs and create institutional environments conducive to their success. As one participant said, "We need to be innovative and eclectic. It's an experiment to develop human talent, and experiments may not always be replicable." Funders must determine how to optimize the return on their investment and how to leverage their higher education constituency to create lasting change. They must take actions that are "risky, novel, and bold," as one presenter said.

Using Program Principles for Capacity Building

The challenge for funding agencies will be to use the seven program principles delineated in this report to call attention to capacity building throughout the entire scientific and engineering enterprise. The principles will enable them to provide a more focused and uniform set of guidelines in new program solicitations to insure the development of a broader talent pool over time. Educational and research programs then would be evaluated for funding and renewal based upon their contributions to and alignment with these principles. An effort to assess the outcomes of programs around common principles will help integrate these programs into a more unified system.

At the same time, we encourage all federal agencies to work together to build a robust and diverse STEM workforce. We recommend that federal agencies In particular, NSF, NASA, the National Institutes of Health, Department of Energy, and U.S. Department of Education, need to share information about research and solutions and develop policies and procedures for discussing STEM issues at all levels of education and in the workplace. Partnerships with government agencies could yield significant benefits, such as in the case of the Department of Defense, which has both great resources and great need for STEM employees.

The task ahead is formidable. It will require federal agencies to serve as catalysts for transforming the research enterprise by engaging new partners in academe, government, and industry – and through these partnerships, work collaboratively across disciplines to meet the challenge of developing a competitive and diverse domestic workforce that is truly representative of the U.S. population base. Where possible, federal agencies and private foundations should take leadership roles in fostering synergies across programs, particularly when there are several funded projects from the same funding source or from multiple funding sources at a given institution. The ultimate goal is for the entire federal portfolio of activities to be coordinated with respect to workforce development so that a robust pipeline with multiple entry and exit points is created to provide numerous educational and career opportunities for a diverse set of people across the science and engineering enterprise.

PART III

Conclusion: Toward a New Vision for the Enterprise of Science

Multiple conversations were going on at the workshop. Some were addressing the human resource issues such as educational experiences, demographics and socialization of females and minorities. Others were addressing the changing dynamics of the workforce and the skills needed to enter it. Others were focusing on the educational pathways and how to keep students engaged in STEM topics all along the way. Still others were looking at the problem through the lens of science, the perceptions of what is "real" science, who has the capacity to do research, and how a peer review process leading to funded programs encourages status quo. What emerged was a complex picture of the many factors that need to be addressed simultaneously if real and enduring change is to take place (Figure 2).
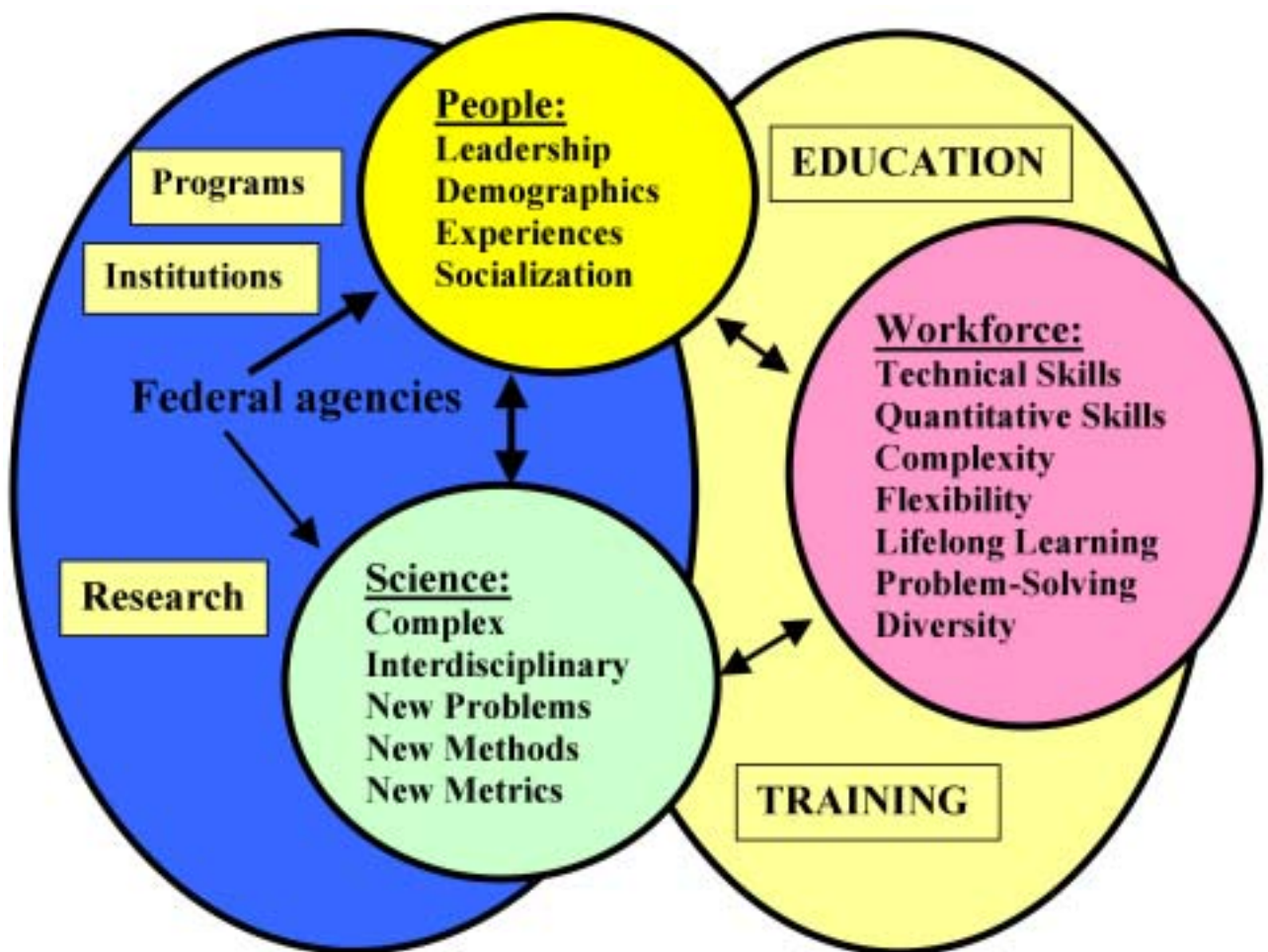

Figure 2: Change requires an integrated view of people, institutions, programs, research and science.

At the beginning of the workshop, the participants were asked to go beyond considering ways to accelerate the progress of existing and proposed programs. They also were asked to identify paradigm shifts that might enable funding agencies, academia, industry, and the broader society to consider the problem of broadening participation in STEM careers in new and different ways. In considering these more fundamental and wide-ranging changes, workshop participants focused on the difference between *building capacity* and *realizing capability*.

For example, the National Science Foundation has defined its goals to be the development of People, Ideas and Tools as they all relate to the scientific enterprise, broadly defined. Typically, people in the STEM workforce are viewed as instruments for building and supporting the research enterprise. Many workshop participants agreed on the necessity to redefine this model, so that the focus of the enterprise is people, and the STEM disciplines are instruments for promoting the health and economic welfare of all people. Ideas and tools are deployed for the full realization of the potential of all people, who in turn generate more diverse and better ideas and tools. Seen in this light, the internal dynamics of the research process are an integral part of the conduct of science, not an afterthought.

It became clear that some groups will need more resources and support than others all along the multiple STEM pathways in order to enjoy full participation in the workforce of the future. In the past, the United States has neglected to engage all sectors of its population in the conduct of science (Committee on Equal Opportunities in Science and Engineering, 2002). The workshop strongly recommends that policy makers encourage the development of a network of pathways that allows students from diverse backgrounds to achieve success in a range of roles, such as researcher, educator, evaluator, industry leader, or entrepreneur.

Realizing the capability of all its citizens requires that the nation's policy makers view the development of human resources as inseparable from the goal of expanding the research frontier. Developing people to their full intellectual potential <u>and </u>developing a vibrant science and engineering enterprise should be seen as a synergistic, two-way relationship, with both aspects being of equal importance and dependent upon each other for success.

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APPENDIX 2: WORKSHOP AGENDA, OCTOBER 24-26, 2003

Friday, Oct 24, 2003

8:00 am   10/24 Panelists, Moderators, Speakers meet with Workshop Leaders

8:30   Continental Breakfast   National Science Foundation, Room 110 Foyer

9:00   *Plenary Session:* Moderator: Gus Roig, *Florida International University*
                Welcome and Purpose (Dianne Martin, *The George Washington University*)
                Introduction of Speaker (Willie Pearson, Jr., *Georgia Institute of Technology*)

9:20   Opening Address
                Dr. Joseph Bordogna (Deputy Director and CCO)
                National Science Foundation

10:00   Q&A

10:30   Break
                National Science Foundation, Room 110 Foyer

10:45   *Plenary Session:* Panel of Program Directors
                Moderator: Paula McClain, *Duke University*
                Gary May, *Georgia Institute of Technology*
                Melvin Webb, *Clark/Atlanta University*
                John Handy, *Morehouse College*
                David Manderscheid, *University of Iowa*
                Rachelle Heller, *The George Washington University*
                Stan Hill, *Winston-Salem Forsyth Co. Schools*

12:00   Q&A

12:30   Buffet Lunch
                National Science Foundation, Room 110 Foyer

1:30   *Break Out Session 1:* Focus on Successful Programs

                Facilitators: *Reporters:*
                1) Room 770: Melissa Herman   Henry Frierson
                Northwestern University   *University of NC-Chapel Hill*

                2) Room 805: Charles Vela   John Brown
                CAHSEE Inc.   *Seltzer Group, LLC*

                3) Room 830: Peter Henderson   Diola Bagayoko
                National Research Council   *Southern University, Baton Rouge*

                4) Room 110: Joan Esnayra   Michael Gaines
                National Research Council   *University of Miami(Florida)*

2:45   Break
                National Science Foundation, Room 110 Foyer

3:00   *Plenary Session:* Report Back. National Science Foundation, Room 110
                Moderator: Norman Fortenberry,
                National Academy of Engineering

4:15   Q&A

4:45   Day 1 Workshop Evaluation / Plans for Day 2
                Workshop Leaders: Pearson and Martin

5:00   Networking – Dinner on Your Own

7:30   10/25 Panelists, Moderators, Speakers meet with Workshop Leaders

8:00   Continental Breakfast
        National Science Foundation, Room 110 Foyer

8:30   *Plenary Session:* Panel on the Status of Research
        Moderator: Carlos Rodriguez, *American Institutes for Research*
        Mary Frank Fox, *Georgia Institute of Technology*
        John Sargent, *U. S. Department of Commerce*
        Eleanor Babco, *Commission on Professionals in Science*
        John Trumpbour, *Harvard University*
        Roberta Spalter-Roth, *American Sociological Association*
        Paula Rayman, *University of Massachusetts, Lowell*

9:40   Q&A

10:00   Break
        National Science Foundation, Room 110 Foyer

10:15   *Break out Session 2:* Focus on the Role of Research

        Facilitators: *Reporters:*
        1) Room 630: Terry Russell   Cheryl Leggon
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        2) Room 730: Jane Lee   Paula McClain
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        3) Room 770: Craig Love   Virginia Valian
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        4) Room 830: Traci Powell   Manuel Vargas
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11:15   *Plenary Session:* Report Back
        Moderator: Joan Burrelli, *National Science Foundation /SRS*

12:00   Q & A

12:30   Buffet Lunch
        National Science Foundation, Room 110 Foyer

1:15	*Plenary Session:* Panel of Stakeholders
	Moderator: Thomas Windham, *University Corporation of Atmospheric Research*
	Todd Clark, *US Department of Energy*
	Cathleen Barton, *INTEL*
	Patrick Antony, *Boeing*
	Joel Oppenheim, *New York University*
	Jim Wyche, *University of Miami - Florida*
	Jane Daniels, *Henry Luce Foundation*
	John Yochelson, *BEST*
2:30	Q&A
3:00	Break
	National Science Foundation, Room 110 Foyer
3:15	*Break out Session 3:* Focus on Integrative Approaches

	Facilitators:	*Reporters:*
	1) Room 630: Robert Lichter	Richard Freeman
	Merrimack Consultants, LLC	*Harvard University*
	2) Room 730: Carlos Rodriquez	Indira Nair
	American Institutes for Research	*Carnegie Mellon University*
	3) Room 770: Bobbie Spalter-Roth	Bill Koonz
	American Sociological Association	*College of Menominee Nation*
	4) Room 830: Manuel Gomez	Luis Echegoyen
	University of Puerto Rico	*Clemson University*

4:30	*Plenary Session:* Report Back, National Science Foundation, Room 1235
	Moderator: Yolanda George, *American Association for the Advancement of Science*
5:00	Q&A
5:30	Day 2 Workshop Evaluation / Plans for Day 3
	Workshop Leaders: Pearson and Martin
5:40	Networking- Dinner on Your Own

8:00	10/26 Panelists, Moderators, Speakers meet with Workshop Leaders
8:30	Full Hot Breakfast National Science Foundation, Room 110 Foyer
9:00	*Plenary Session:* Moderator: Jeanne Pemberton, *University of Arizona* Introduction of Speaker: Dianne Martin, *The George Washington University*
9:10	Judith Ramaley (Assistant Director, Education and Human Resources Directorate) *National Science Foundation*
9:40	Q&A
10:00	*Plenary Session:* Synthesis Panel: Where Do We Go From Here? Moderator: Indira Nair, *Carnegie Mellon University* Daryl Chubin, *NACME* Virginia Valian, *Hunter College* Jane Daniels, *Henry Luce Foundation*
11:00	Q&A
11:15	National Science Foundation Response
11:30	Q&A
11:45-Noon	Day 3 Workshop Evaluation / Wrap up and Next Steps Dianne Martin, *The George Washington University*