NSF GRANT NUMBER HRD-9817536, A002

IN PURSUIT OF A DIVERSE SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS WORKFORCE

RECOMMENDED RESEARCH PRIORITIES TO ENHANCE PARTICIPATION BY UNDERREPRESENTED MINORITIES

American Association for the Advancement of Science

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In Pursuit of a Diverse Science, Technology, Engineering, and Mathematics Workforce:

Recommended Research Priorities to Enhance Participation by Underrepresented Minorities

American Association
for the Advancement of Science

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Executive Summary

Today the United States is the world leader in the global science, technology, engineering and, mathematics (STEM) enterprise, but other countries stand ready to challenge this economic strength. One of the main reasons is a shortage of U.S. workers to fill STEM jobs. Technically skilled workers on H-1B Visas (guest workers) are now making up for the U.S. worker shortfall. This supply of talent could dwindle in the near future as other nations take steps to increase their own STEM productivity. Another reason is that the majority of the current STEM workforce, White, non-Hispanic men, is shrinking. In 1995, the projected percentage of White men in the overall workforce was 36%. By 2050 White males are projected to be 26% of the overall workforce, while in 1997 they represented nearly 70% of the STEM workforce.[1]

In our efforts to sustain U.S. productivity and economic strength, underrepresented minorities (URM) (for the purpose of this paper defined as persons of African American, Hispanic American, and Native American racial/ethnic descent), provide an untapped reservoir of talent that could be used to fill technical jobs. Over the past 25 years, educational diversity programs have encouraged and supported URM pursuing STEM degrees. Yet, their representation in STEM still lags far behind that of White, non-Hispanic men.

To understand the reasons why this is occuring, the American Association for the Advancement of Science Directorate for Education and Human Resources Programs convened a study group meeting in September 2000 of 70 leading educators and researchers in the STEM fields. We examined over 150 research efforts related to choice of college majors, retention in STEM college majors, academic mentoring at both the pre-college and higher education levels, and pursuit of a STEM doctorate, as well as faculty positions. At the study group meeting, we discussed key research, identified gaps, and developed a research agenda for the future. Particular attention was paid to the transition process from one level of academic achievement to the next.

We identified three research priorities for URM in STEM from the high school years to the professoriate:

1. **Improve methodology**. While a substantial body of research is underway on URM in STEM, many of the studies focus on patterns of underrepresentation in STEM or group differences. Also, many studies are small and represent the perceptions of one group of stakeholders in the system, in this case, students, faculty, or program staff. We recommend more comprehensive studies that take into account the interactions of all key players in the system, as well as studies that follow cohorts of students as they move through the higher education years into faculty positions.

2. **Improve research linkages**. Many of the research studies previously conducted are not comparable for a number of reasons, including differences in definitions of terms or data collection practices. For example, in many cases, researchers define URM in different ways. In terms of practices, researchers collected retention rates and graduation rates at different times.

   To improve research linkages, we recommend developing data collection guidelines and definitions, using common research methods and developing models that will permit cross-comparison of findings in a wide range of studies. We also recommend establishing a research consortium.

   In addition, we encourage organizations like the National Science Foundation, and other government agencies to foster STEM education research coordination. We also recommend that these organizations maintain and build databases to provide information about the education and workforce experiences of URM, women, and persons with disabilities in STEM.

In our efforts to sustain U.S. productivity and economic strength, African Americans, Hispanic Americans, and Native Americans provide an untapped reservoir of talent that could be used to fill technical jobs.

3. **Explore new research areas.** Our analysis suggests that STEM education research to date is somewhat limited. Part of our assessment focused on factors that facilitate progression of URM into STEM higher education studies and the professoriate. These include taking high-intensity and high-quality advanced mathematics and science courses during high school, pre-college programs that boost STEM skills, and higher education academic support programs in core mathematics and science. Factors that limit progress include community college STEM curricula that do not adequately prepare students for a baccalaureate program, lack of undergraduate faculty mentoring toward STEM doctoral programs, and low intensity of STEM curriculum at the undergraduate level.

Developing a better understanding of the factors that facilitate or limit URM STEM progress requires:

Continued collection of critical data. Researchers need to continually collect data from higher education enrollment, STEM course taking, and graduation for different groups, as well as data from different types of colleges and universities. Curriculum alignment between community and four-year colleges also should be monitored. Specific attention should be given to monitoring the impact of changes in higher education admissions, retention, and graduation policies at both the state and national levels.

Additional research to better understand factors that facilitate or limit student progression towards doctoral degrees and faculty positions in STEM. We need to study the reasons why able and high achieving URM do not enter STEM college majors or, if they enter, search for the reasons why they do not complete STEM higher education degrees or go on in higher education to pursue doctoral careers in academe. Suggestions for further research include:

- Studies concerning teaching and mentoring URM at the high school, college, and graduate school levels.
- Studies addressing how to create a nurturing institutional and STEM departmental culture that values the knowledge URM bring to this enterprise.
- Studies determining why URM, particularly those with high ability, do not pursue doctoral careers in STEM.

Members of our study group meeting hope that these suggestions will provide guidance, and strategies for policymakers, researchers, educators, and public and private foundation staff who want to build and sustain STEM education research on URM. The better the quality of information we have on what facilitates and what limits URM’s progress towards STEM doctorates, the better equipped we will be to create educational policies and programs to address them.

Introduction

Building a diverse workforce in science, technology, engineering and mathematics (STEM) is increasingly important to sustaining the nation's productivity and economic strength. Evidence already exists that the lack of United States citizens in the STEM workforce is limiting economic growth, and business has looked to H-1B Visas (guest workers) as a way to fill this gap. However, recognizing the connection between sustained economic growth and a technically trained workforce, other nations are aggressively restructuring higher education and workforce policies to keep their nationals at home.[2]

These worldwide education and workforce policy trends can have a negative effect on the nation's economy, particularly if enough guest workers are not technically trained.

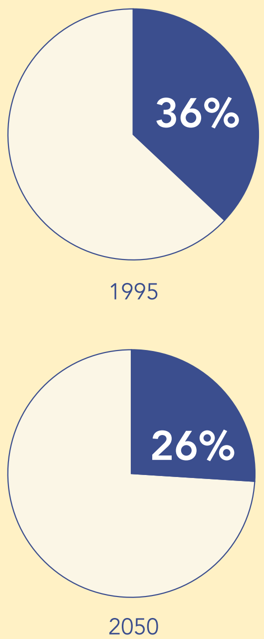
Traditionally, STEM workers have been White, non-Hispanic men. In 1997, the general STEM workforce was comprised of nearly 70% White men.[3] Their numbers, however, as a percentage of the U.S. population are declining. The Census Bureau reports that the population of White, non-Hispanic men is expected to decrease by 11% by the middle of this century.[4] This could leave an enormous gap in the American workforce that must be filled. (See Chart left.)

The United States has an untapped reservoir of talent that could be developed to fill technical jobs. Underrepresented minorities (URM) in STEM (for the purpose of this paper defined as persons of African American, Hispanic American, and Native American racial/ethnic descent), should be encouraged to pursue STEM education from high school to the doctoral level. In 1997, URM comprised just over 6% of the general STEM workforce.[5] URM accounted for only 4.6% of the STEM workforce with doctoral degrees, compared to nearly 80% for White men.[6] (See Sidebars on pages 5 and 6.)

Over the past 25 years, educational diversity programs in STEM have made a difference in bringing URM, women, and persons with disabilities into these disciplines. But new restrictions on these programs, and reluctance on the part of URM to pursue higher education in STEM fields, have kept the percentage of these workers within STEM low.

If a strong U.S. STEM workforce is to be ensured, it is imperative that this nation understand how to encourage and develop the STEM talent of all U.S. citizens, including all racial/ethnic groups, men and women, and persons with disabilities.

Population Projection for White, Non-Hispanic Males in the United States



Source: Day, J. (1996). *Population projections of the United States by age, sex, race and Hispanic origin: 1995 to 2050.* Arlington, VA: U.S. Census Bureau.

Over the past 25 years, educational diversity programs in STEM have made a difference in bringing URM, women, and persons with disabilities into these disciplines.

To address this critical problem, the American Association for the Advancement of Science (AAAS) Directorate for Education and Human Resources Programs convened a study group meeting in September 2000 to discuss current and future research on URM in STEM from the high school years into the professoriate. Seventy educators and researchers from leading universities, representatives of the National Science Foundation, and other leaders in the STEM fields attended. (See Appendix A, for a complete list of participants.)

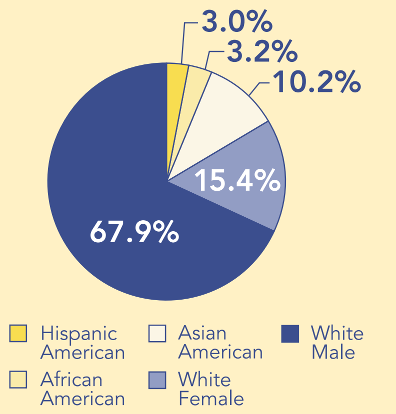
The study group met for seventeen hours, and participants considered a variety of questions based on current STEM research. The goals of the study group were to review current research on STEM education, identify gaps, and recommend research priorities for future studies.

Research Methodology

As preparation for the study group meeting, AAAS staff identified and reviewed over 150 research studies related to STEM student and faculty diversity. These studies were grouped into six categories based on possible educational paths to a STEM doctorate and into the professoriate. Particular attention was given to the transition process from one level of academic achievement to the next. The six categories were:

1. The process STEM undergraduates go through to select these disciplines, especially determining which high school courses may influence their decision to pursue a STEM major.
2. Undergraduate academic achievement and progress in STEM at the associate and baccalaureate levels, including transition from associate to baccalaureate degree programs.
3. Transition to master's programs in engineering and computer science, with consideration of professional or terminal master's programs.

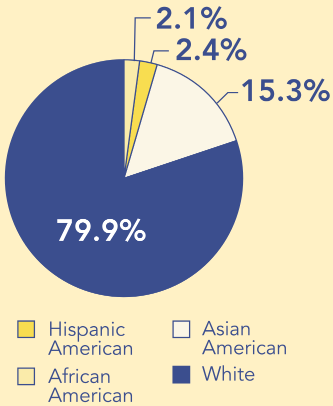
Racial/Ethnic Distribution of U.S. STEM Workforce in 1997



Native American participation was less than 1%.

Source: Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development. (2000). *Land of plenty: Diversity as America's competitive edge in science, engineering and technology*. Arlington, VA: National Science Foundation.

The STEM Workforce with Doctoral Degrees in 1997



**Native American participation was less than 1%.*

Source: *Women, minorities, and persons with disabilities in science and engineering. (2000)*. Arlington, VA: National Science Foundation.

4. Transition to STEM doctoral degree programs, including transition from undergraduate programs, as well as master's to doctoral bridge programs at Research Extensive and Research Intensive universities.
5. Graduate school academic achievement and progress in STEM.
6. Transition from STEM doctoral to postdoctoral positions, transition to tenure track and non-tenure track faculty positions, and issues around promotion and tenure.

Each of the six categories was assigned to an individual study group. The groups examined a selection of key research papers within their assigned categories, that focused on the STEM experiences of URM, women, and persons with disabilities from high school to the professoriate. They also answered questions developed to stimulate discussion and reviewed bibliographies of current research. (See Appendix B for a complete list of discussion questions.) Each study group had an assigned leader who was responsible for producing a written report by the end of the meeting.

The meeting produced several insights into areas of STEM research that call for further exploration as well as three specific research priorities. These recommended research priorities, with regard to URM in STEM from the high school years into the professoriate are:

- Improve methodology.
- Improve research linkages, often referred to as community building.
- Explore new research areas.

In addition to summarizing the findings, this paper first outlines:

- What we know about the existing research.
- Gaps in current research on URM in STEM.

We hope that it will provide guidance to researchers about methodology, areas of study, and the most effective ways to share information. In addition, we hope these suggestions will provide guidance and strategies for policymakers, educational leaders, and public and private foundation staff who want to build and sustain STEM education research on URM.

What We Know from the Existing Research

National and state school educational policies may limit resources for K-12 schools, particularly in science.[8]

The following is an assessment of what we know from the existing research on URM in STEM for the high school, undergraduate, and graduate years, as well as the professoriate. With input from the study group participants, over 300 quantitative and qualitative studies were identified, including ongoing data reporting and studies done by the U.S. Department of Education, the National Science Foundation, private testing groups, and STEM professional associations or groups.

These findings are drawn from large data collection efforts, as well as smaller studies about perceptions of students, faculty, or special program staff. They provide information about URM students as they progress from high school to professional STEM careers. They explain the variables that contribute to successful completion of STEM degrees, the barriers to degree attainment, and, when understood, the reasons for attrition from higher education, as well as barriers to the professoriate. The findings are not necessarily ranked in order of importance.

Findings for the High School Years

- The three most important variables that contribute to bachelor's degree completion are intensity and quality of the secondary school curriculum, test scores, and class rank/grade point average.[7]

- National and state school educational policies may limit resources for K-12 schools, particularly in science.[8]

- Taking mathematics courses beyond Algebra II, such as trigonometry or pre-calculus, is particularly key for African American and Hispanic American students.[9]

- Factors that are associated with racial/ethnic differences on standardized and college admissions tests, as well as entry into STEM majors include:
  - The number of advanced mathematics and science courses taken by students and offered by high schools.
  - Teacher effectiveness.
  - School resources.

- Parental income, wealth, and education.
- Out-of-school opportunities.[10]

- African American and Hispanic college students with high grade point averages and SAT scores above 600 typically do not pursue STEM college majors for reasons including poor teaching in STEM courses, lack of encouragement from teachers or parents, and self-perception of their own inability to be successful in STEM majors.[11]

- Pre-college programs for URM are shown to increase college and university enrollment of students in STEM majors.[12]

Findings for the Undergraduate Years

- URM are more likely to drop out of college for a variety of reasons, including financial difficulties, poor high school preparation, poor college teaching, low faculty expectations, and an inflexible curriculum.[13]

- Examples exist of college and university STEM academic support services and programs that, if implemented with clear learning objectives and appropriate student participation, can increase retention of URM.[14]

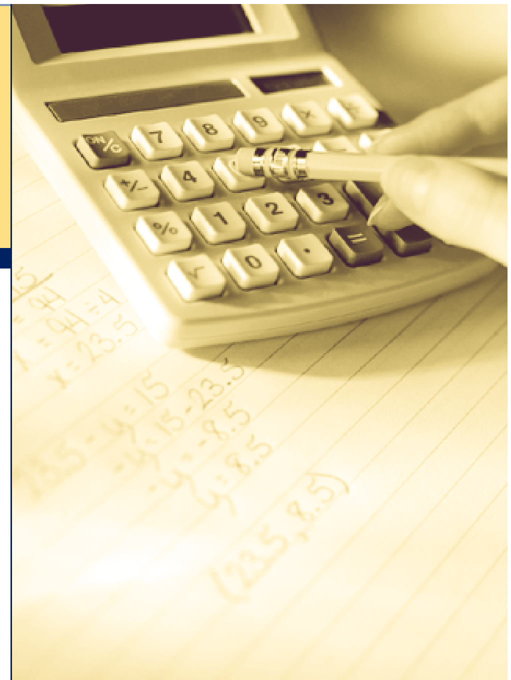
- Data from the 1980s *High School and Beyond* studies indicate that 58% of bachelor's degree recipients attended more than one institution, with dramatic increases in the proportion of students attending more than two institutions. Students starting in highly selective four-year colleges and in open door institutions have the highest multi-institutional attendance for different reasons.[15]

Findings for the Graduate School Years

- Bans on use of affirmative action for graduate admissions had an adverse impact on first-year graduate school enrollments in Research I universities. Enrollments dropped precipitously during the 1997-1998 school year and rebounded in 1998-1999; however, these rates still did not match the 1996 rates.[16]

- Negative variables for progression to graduate school include loans, debt burden, and age; while a negative barrier that affects primarily women is having dependent children.[17]

- Positive variables for progression to graduate school include strong college grade point averages, a bachelor's degree from a highly selective school, a



Underrepresented minorities are more likely to drop out of college for a variety of reasons, including financial difficulties, poor high school preparation, poor college teaching, low faculty expectations, and an inflexible curriculum.[13]

bachelor's degree from a school with large numbers of graduate students intent to go to graduate school, and parents with a high level of education.[18]

- STEM pre-graduate school bridges and undergraduate research programs for minorities and women increased STEM graduate school enrollment.[19]

- The choice of a doctoral career in science (as opposed to careers in medicine, law, and business) may be affected by the burden of educational debt, the opportunity cost of required graduate education, expected remuneration rates in the career, and benefit accumulations, particularly for URM students.[20]

- Positive factors that affect persistence and completion of doctoral degrees in STEM include intellectual capital, financial aid, interactions with faculty, peer support, and minority role models.[21]

Findings for the Faculty Years

Barriers to advancement and retention of URM in post-doctoral and tenure track faculty positions include:

- Fewer interactions with faculty peers.
- A belief that they were hired because of affirmative action and not for their capability to do science.
- Lack of an influential mentor or sponsor.
- Difficulty with securing grants, even with a track record for high-quality research.[22]

Gaps in Current Research

These current research findings provide a snapshot, albeit an incomplete one, of students, faculty, or special program staff within the STEM disciplines. The following is a summary of the factors that *facilitate* or *limit* progress of URM students within STEM. These factors present an overview of current research and can be used to identify gaps and new areas of study.

Factors that *facilitate* progression of URM into STEM post-secondary studies include:

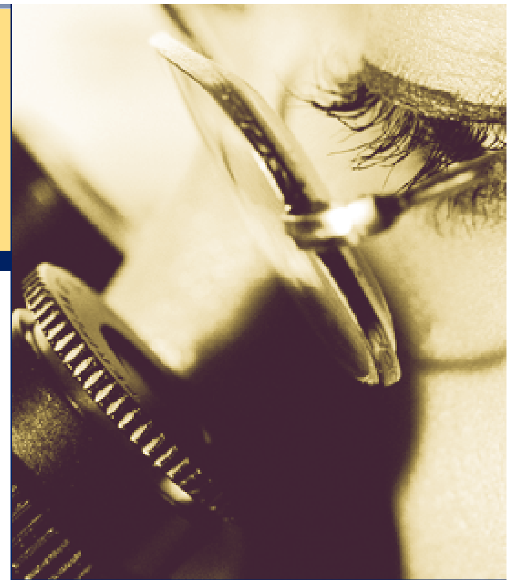
- Taking high-intensity and high-quality advanced mathematics and science courses.
- STEM pre-college programs that include enhanced STEM high school curricula, admissions test preparation, and early introduction to STEM careers.
- Post-secondary STEM support programs, particularly in calculus, chemistry, and physics, that increase undergraduate retention.
- Financial aid packages that reduce debt burden.
- STEM pre-graduate school bridge programs that increase enrollment in Ph.D. programs.

Factors that *limit* the progression of URM students into STEM post-secondary studies and professorial positions include:

- Emerging state policies that impede K-12 reform or bans against use of affirmative action in post-secondary admissions.
- High school STEM teaching that lacks rigor, as well as mentoring toward doctoral STEM careers.
- Community colleges' STEM curricula that may not be aligned with bachelor of science degree-granting colleges and universities.
- College and university STEM teaching that often does not take into account students' different learning styles.
- Lack of undergraduate faculty mentoring towards doctoral STEM careers.
- Low intensity and quality of STEM curricula at the undergraduate level.
- Undergraduate STEM curricula that may not be aligned with graduate school STEM curricula.
- The mistaken belief that race or ethnicity, rather than capability, plays a major role in selection or employment in the higher education sector.

Given the limiting factors to progression of URM in STEM, there is a need to:

- Continually collect data on access of African American, Hispanic American, and Native American high school students to mathematics and science courses needed for post-secondary majors in STEM. Data also should be collected on student access to certified science and mathematics high school teachers and high-quality mathematics and science courses in high school.



- Monitor the annual college and university enrollment and degree attainment of URM in STEM at all educational levels, given evolving state higher educational policies related to bans on use of affirmative action.
- Monitor how community colleges are aligning their STEM curricula with colleges and universities to which students usually transfer.
- Monitor state policies related to STEM curricula alignment between community colleges and bachelor of science degree-granting colleges and universities.

Also there are a number of areas limiting student progression that we need to better understand. They include:

- The teaching/mentoring and learning interactions between high school science and mathematics teachers and African American, Hispanic American, and Native American students, as well as students from different socioeconomic groups.
- The teaching/mentoring and learning interactions between college and university faculty and URM students in STEM.
- How to create an institutional and STEM departmental culture that will nurture and develop the talents of URM students.
- How to create a scientific research culture that will recognize and value the knowledge and perspectives that URM bring to the enterprise.
- How to interest African American, Hispanic American, and Native American students in doctoral careers in STEM, especially those with high ability.

We need to better understand how to interest African American, Hispanic American, and Native American students in doctoral careers in STEM, especially those with high ability.

A 1999 College Board report states that few of the numerous programs to improve academic outcomes of URM have undergone extensive external evaluation.[23]

Improve Methodology in Research on URM in STEM

The current research base provides limited potential for thorough analysis for several reasons. First, there are no established data collection guidelines for researchers who study URM in STEM. In other words, most of the data in this research base is not comparable due to differences in methods, definitions of terms (e.g., retention, URM), and other factors. Also, many of the studies on URM in STEM are sample surveys with differing degrees of validity and reliability.

The studies conducted are particularly limited in terms of disaggregated information about different racial/ethnic groups, as well as different STEM disciplines. As a result, it is hard to discern which factors are generic to all STEM students or faculty, and which are group or discipline specific.

In many studies, information on African Americans and Hispanic Americans is included; however, information on Native Americans or on gender within racial/ethnic groups is not reported. This occurs primarily because the cell size of these populations is too small to report statistically meaningful data. Further, no studies were found on minority students with disabilities in STEM.

The studies also do not examine the full spectrum of colleges and universities. For example, many of the studies are conducted at Research Extensive and Research Intensive universities, with few looking at community colleges, Historically Black Colleges and Universities, institutions serving concentrations of Hispanic Americans, tribal colleges, women's colleges, or colleges and universities that target or serve persons with disabilities.

Much of the research has focused on patterns of group differences or underrepresentation. However, very few of these studies focus on the complexity of the undergraduate or graduate educational experience of URM in STEM.[24]

Recommendations for Improving Methodology

In terms of methodology, the research designed to investigate and explain differences must take into account the complexity of the STEM disciplines. That is, the research should be multivariate and multi-leveled (e.g., path-analysis, structural equations). Researchers should ensure that their attempts to reduce the number of variables and interactions do not oversimplify important research questions.

The research also must be comprehensive, incorporating ecological models that include a complementary set of individual and systemic approaches. Strategies such as cohorting should be used and, ideally, information should be collected from all involved in the

educational process, including students, university administrators, department faculty and staff, and STEM intervention program staff.

Specific recommendations for improving methodology include:

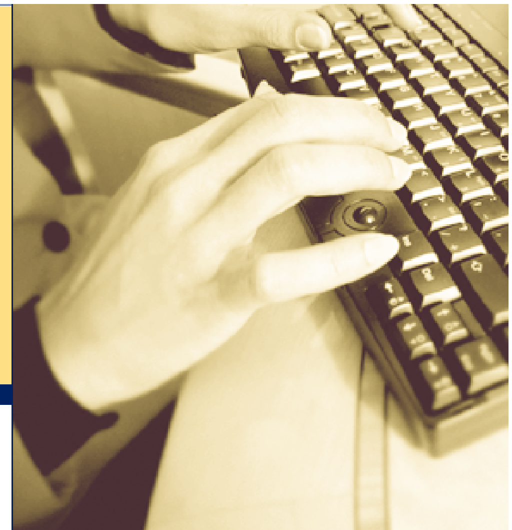
- Research studies should include data that is longitudinal, retrospective, small-scale, institutional-based, critical event, or action-oriented.
- Data should be disaggregated by race/ethnicity, gender and disability within race/ethnicity, college and university types, STEM disciplines, student achievement levels, college persisters and non-persisters, age, and socioeconomic status, where appropriate.
- Comparative studies are needed at the post-secondary level between the different groups of students and faculty so that it can be discerned which problems in STEM are generic, and which are group specific, including gender and disability within racial/ethnic groups.
- Given the open admissions model in community colleges, a different way of looking at the transfer rate is needed, since all students do not go to community colleges with the goal of transferring to a four-year institution.
- Given the degree of institution and field switching by students, new ways of looking at retention and graduation rates are needed.
- More sophisticated outcome evaluations of federal and non-federal intervention programs are needed, including requirements for inclusion of comparison samples, and the use of state-of-the-art social science evaluation models beyond mere tracking.
- Alternatives to the pipeline metaphor to analyze current data are needed to account for “stepping-out” or interruption of post-secondary education degree attainment. These models must account for university and field switching.

Improve Research Linkages and Community Building Among Researchers

One of the biggest problems identified was the lack of data collection guidelines for researchers who are studying human resources in STEM. Also, more opportunities are needed for early communication and information sharing among STEM researchers. Although data are shared in a number of venues upon completion, researchers do not communicate as often during the study development, collection of data and analysis of results phases. Researchers need to communicate more effectively with each other at all stages of the research process so they can share methodology and findings.

Building a community of researchers who confer regularly may help to improve methodology and bring us closer to understanding factors that limit the STEM talent pool. To this end, recommendations for community building include:

- Establish a consortium of researchers studying the STEM experiences and achievements of URM from the high school years to academe.
- Develop guidelines for coordinating both quantitative and qualitative high school and post-secondary school research on URM in STEM to allow cross-research or cross-institutional comparisons. These guidelines should include developing common definitions of enrollment, community college transfer rates, attrition, and types of disability, as well as definitions of who should or should not be counted as a scientist or engineer (e.g., someone with a master's in business practicing in a high tech company, physicians, patent lawyers, etc.). They also should include common sets of data collection protocols across STEM intervention program areas as needed to allow for cross-program analysis.
- Encourage granting agencies to foster research coordination through synergy and to smooth the path for data release from colleges and universities that are their grant recipients.
- Maintain and build National Science Foundation databases on minorities, women, and persons with disabilities that produce disaggregated STEM data by gender, race, and disability, as well as maintain and build the databases of the U.S. Department of Education's National Center for Education Statistics.



Explore New Research Areas

Tables One to Four provide information on addressing the gaps in STEM research. They recommend areas of new and continuing research on the STEM experiences and achievements of URM from the high school years into the professoriate. While all research topics mentioned are important, several study group participants recommended seven specific areas as having the highest priority for funding.

These areas are:

1. The need to understand STEM talent spotting and development in colleges and universities.

Specific data collection activities and research needed in this area include:

- Study institutional and departmental admissions criteria and processes. More needs to be known about undergraduate and graduate school admissions criteria, including the predictive value of admissions tests and grade point averages. Also, we need to better understand educational institutions and STEM departments that have adopted a talent development approach to doctoral recruitment and training. Too many STEM programs are still wedded to a Darwinian concept of doctoral training.
- Collect departmental data by race/ethnicity, gender, and disability. Institutions should provide systematic information by department, including information about their student recruits, enrollees, and degree recipients, including post-degree positions. In addition, data needs to be collected on STEM post-doctoral researchers and faculty recruitment, promotion, and tenure within departments.
- Study departmental policies, programs, and practices. It is at the department level that policies, intervention programs, teaching, and learning take place. Therefore the way departmental organization and culture foster and impede the advancement of URM in STEM fields must be understood.
- Study STEM faculty teaching and mentoring. Studies are needed to examine the impact of STEM faculty teaching and mentoring on students' persistence and STEM degree attainment at both the undergraduate and graduate levels. This includes the extent to which there is faculty understanding, knowledge, and practice of racial/ethnic diversity. Faculty are, perhaps, the single most important influence on students, and

Table 1 – **High School Level**

Topic	Research Exists On	New or Continuing Research is Needed On
Education Policy	• STEM education policy regarding equity of resources, affirmative action, and executive orders. • High school course-taking and achievement.	• New and emerging education policies that limit the size of the STEM pool in post-secondary education, including admissions, financial aid, legislation, and judicial orders. • Differential access to technology and its affect on student achievement in post-secondary education and career choice. • Equity of STEM resources available to all students from different racial/ethnic and socio-economic groups. • Systemic education reform, with particular attention to: ▪ High school course-taking and achievement, as related to courses needed to major in STEM. ▪ How different types of science and mathematics courses offered by high schools impact URM students' decisions to take STEM courses in college.
Teaching Effectiveness	• Factors that affect students' decisions to take STEM courses in high school and college, include: ▪ Courses offered. ▪ Intensity and quality of courses taken. ▪ Attitudes and expectations of teachers and parents in regards to STEM. ▪ Students' aspirations and perceptions of their abilities.	• Continue existing research. • How high school teaching and mentoring affect minority students' entry, persistence, and bachelor's degree attainment in STEM. • How teacher in-service and pre-service programs impact achievement of URM in science and mathematics. • Identify pre-service programs that produce teachers who are effective with students from all racial/ethnic and socio-economic groups. • How to best influence high school students to pursue STEM, including high-ability minority students, and those in low performing schools.

much more needs to be understood about factors related to their impact on students.

2. The need to better understand STEM community college transfers.

Since many URM and students with disabilities begin their college careers in the community college system, we need to better understand the community college transfer process, including STEM-related policies, practices, and courses that are needed to successfully transfer to bachelor of science degree-granting colleges and universities.

3. The need to study STEM curricula and instruction at different types of colleges and universities.

Better understanding of the quality of instruction and

Table 2 – **Undergraduate Level**

Topic	Research Exists On	New or Continuing Research is Needed On
Recruitment and Admissions	• Undergraduate recruitment and admissions policies and practices. • Factors that affect undergraduate and graduate admission test scores.	• How affirmative action bans affect enrollments of and financial aid for URM in STEM. • How new and emerging undergraduate admissions policies affect URM achievement and undergraduate degree attainment in STEM. • Identifying factors that promote or inhibit effective transition in STEM majors from community colleges to bachelor of science degree-granting colleges and universities.
Institutional and Departmental Culture	• Factors that affect undergraduate retention, including instruction, culture, academic support services, and social climate.	• How STEM faculty teaching and mentoring affects undergraduate persistence and degree attainment, and entry of URM into doctoral programs. • How STEM undergraduate faculty understanding, knowledge, and practices of diversity (as related to URM, women, and students with disabilities) affect persistence and degree attainment. • How technology affects teaching and learning.
STEM Intervention and Support Services	• Data collection by colleges and universities of how STEM intervention programs affect undergraduate retention, graduation rates, and graduate school admissions. • Effective practices in STEM intervention programs.	• Continue existing research. • Identifying what aspects of undergraduate STEM interventions increase entry, persistence, and degree attainment. • The extent to which undergraduate education support services and programs contribute to the progress and achievement of URM in STEM.

curriculum at different types of institutions is needed. Studies should be conducted at community colleges, Historically Black Colleges and Universities, institutions serving a concentration of Hispanic Americans, tribal colleges, women's colleges, and colleges and universities that target or serve significant populations of disabled students. In addition, the integration of technology into STEM curricula should be examined.

4. The need to examine the changing culture, structure, and economics of colleges and universities on STEM.

We need a better understanding of the present and future context within academia if URM are to succeed in STEM, including the theory that "multicontextuality" can improve teaching and learning, particularly for Hispanic Americans and other URM.[25] Another topic to be explored in this area includes how hiring URM part-time instructors,

Table 3 – **Graduate Level**

Topic	Research Exists On	New or Continuing Research is Needed On
Pursuit of Graduate Degrees	• Factors that affect bachelor's degree recipients' decisions on whether or not to enroll in graduate school. • How anti-affirmative action initiatives affect first year graduate school enrollments.	• Continue existing research. • How affirmative action bans affect enrollments of and financial assistance for URM in STEM. • Effectiveness of graduate school recruitment strategies and programs. • Graduate school and departmental admissions policies and practices regarding URM, including: ▪ Use of admissions tests. ▪ Expectations and attitudes of faculty. ▪ Centralization or decentralization of admissions. ▪ Foreign student admissions. ▪ Not using ethnic self-identification. • The predictive value of graduate school entrance examinations and undergraduate grade point averages. • How the information technology and the biotechnology revolutions have affected students' progression to graduate school.
Finances	• How financial aid affects persistence in graduate programs. • Debt owed by doctoral recipients.	• Continue existing research. • How differing forms of financial aid affect entry, persistence, and degree attainment. • How debt affects entry and completion of STEM doctorates.
Characteristics and Experiences	• The characteristics and experiences of URM in graduate school in STEM disciplines, with particular attention to doctoral recipients.	• How undergraduate STEM preparation affects graduate school achievement and doctoral attainment, including preparation at minority serving institutions. • How STEM departmental organization and culture affects URM persistence and graduate school degree attainment • The mentoring practices of STEM graduate school faculty, including cross-cultural mentoring. • URM decisions to pursue STEM graduate studies. • The pathways of URM to STEM doctorates. • How institutional restructuring of STEM graduate education affects the number, type, and fields of degrees earned by URM in STEM disciplines, with particular attention to master's certificates, terminal master's, and new fields.

Table 4 – **Faculty Level**

Topic	Research Exists On	New or Continuing Research is Needed On
Commitment to STEM Academic Careers	• Postdoctoral durations. • Recruitment of URM and women into academe in STEM disciplines. • University tenure policies and practices. • Critical mass of women in STEM in academe.	• Continue existing research. • How the changing policies, practices, culture, structure, and economics of research universities and industry affect URM and women in STEM academe, including: ▪ Family and dual career couple issues. ▪ Class backgrounds. ▪ Technology. ▪ Formation of networks. ▪ Research interests. • How the "multicontextuality" approach affects teaching and learning. • The experiences that lead tenured URM and women to drop out of STEM doctoral programs.

adjunct faculty, and research associates affects recruitment and retention into tenured faculty positions in STEM departments.

5. The need to understand the STEM teaching/mentoring and student learning interactions during the high school years.

Since having high-intensity and high-quality advanced mathematics and science instruction is a key factor to successful completion of a bachelor's degree, STEM teaching/mentoring and student learning interactions must be studied and understood. We need to determine if and how STEM teaching/mentoring and student learning interactions vary with different groups of students. Also, we need to better understand the impact on students of having mathematics and science teachers with strong content backgrounds. It is most important to understand the impact of high school science and mathematics teachers on African American, Hispanic American, and Native American students, including high-ability students and those in low-performing schools.

6. The need to monitor college and university STEM pre-service teacher preparation programs for production of teachers who are effective with students from all racial/ethnic and socioeconomic groups.

Pre-service teacher education represents a set of institutional and classroom practices that have intergenerational effects on students of all race/ethnic and socioeconomic groups. We must document which institutions are producing teachers of all race/ethnic groups that are culturally and habitually effective in teaching STEM courses and with getting URM into STEM majors and careers.

7. The need to understand the decisions of URM to pursue doctoral work in STEM and how to best influence these decisions.

We know very little about why URM with doctoral degrees in STEM decided to pursue Ph.Ds. We need to understand what roles parents or family, as well as K-12 and college and university educators and peers, play in their career choice, if any. Also, it is important to determine what makes different STEM disciplines interesting to URM. In addition, we need to better understand the role of industries on influencing doctoral career paths for URM in STEM.

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Appendix B: Study Group Discussion Questions

1. What key research reports or studies are missing?

2. What is the quality of the existing research?

3. How reliable is the existing research?

4. Are research studies linked to performance indicators or degree attainment? [*Note: To enter graduate school or to obtain financial aid, most colleges and universities require applicants to possess, at minimum, a 3.3 grade point average (on a 4-point scale).*]

5. What are strategies to increase data comparability and linkages?

6. What type of research is best conducted by the National Science Foundation's Division of Science Resources Studies?

7. What type of research is best conducted by colleges and universities?

8. What type of research is best conducted by external researchers/evaluators?

9. In addition, participants were asked to identify additional gaps in the research area, direction, and/or the above questions, with consideration for:

- How do questions relate to different racial/ethnic groups, with consideration for gender and disability differences?
- How do questions relate to different STEM disciplines?
- Are questions related to specific types of colleges and universities?

About AAAS

Founded in 1848, the American Association for the Advancement of Science (AAAS) is the world's largest federation of scientific and engineering societies, with over 270 affiliated organizations. AAAS members include more than 138,000 scientists, engineers, science educators, policymakers, and interested citizens. The Association's goals include:

- Furthering the work of scientists and facilitating cooperation among them.
- Fostering scientific freedom and responsibility.
- Improving the effectiveness of science in the promotion of human welfare.
- Advancing education in science.
- Increasing the public understanding and appreciation for the importance of the methods of science in human progress.

AAAS also is the publisher of *Science* magazine.

The Directorate for Education and Human Resources (EHR) seeks to:

- Improve education in science, technology, engineering, and mathematics.
- Foster equal access to these fields for racial/ethnic minorities, women, and persons with disabilities.
- Enhance the public understanding of science and technology.

Its many initiatives and projects include:

- School reform in science, mathematics, and technology.
- Educational research on schools, colleges, universities, and human resources.
- Informal science and mathematics education with community-based organizations.
- Libraries, science museums, and technology centers.

EHR projects and activities include a children's science and mathematics cyber club, science media fellowships, science and technology summer internships in government and business for students with disabilities, and a science radio show.

Any interpretations and conclusions contained in this report are those of the authors and do not represent the views of the AAAS Board of Directors, the Council of AAAS, its membership, or the National Science Foundation.

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