Diversity in the Geosciences and Successful Strategies for Increasing Diversity

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ABSTRACT

Data available from the National Science Foundation Division of Science Resources Statistics demonstrate that since 1966 fewer bachelor's, master's, and Ph.D. degrees have been awarded in the geosciences than in any other STEM field. Data spanning the time period from 1995-2001 indicate that the percentage of bachelor's and master's degrees awarded to members of racial and ethnic groups that are underrepresented in STEM fields was lower in the geosciences than in other STEM fields. The percentage of Ph.D. degrees awarded in the geosciences to students drawn from underrepresented groups from 1995-2001 was similar to the percentage awarded in math and computer science, physical science, and engineering. It appears that the geosciences retain a greater number of students drawn from underrepresented groups during the transition from master's to Ph.D. degree programs, and/or recruit underrepresented students into Ph.D. programs from other STEM fields.

The geosciences have had success recruiting and retaining women since 1966, and the lessons learned in increasing gender diversity in the field may help the geoscience community increase its racial and ethnic diversity in the future. Four strategies that consistently appear to be effective in increasing diversity are: demonstrating the relevance of the field and opportunities for high-paying careers in it; developing partnerships among multiple stakeholders to reduce 'leaks' from the educational pipeline; promoting strong mentoring relationships among students and geoscience professionals, including opportunities for students to conduct research prior to graduate school; and providing financial assistance when necessary.

INTRODUCTION

According to data available from the National Science Foundation, graduates from bachelor's, master's and doctoral degree programs in the geosciences have lower ethnic and racial diversity than do graduates from any other science, technology, engineering, and mathematics (STEM) field. The Directorate for Geosciences at the National Science Foundation considers this problematic for three reasons. First, enrollments in geoscience bachelor's level programs are in decline across the nation and the continued viability of many geoscience departments will depend on their ability to attract additional students in the near future. Second, the public at large does not understand the implications of cutting-edge geoscience research and typically does not consider the results of geoscience research when making decisions that influence the way that humans interact with their environment. Third, the capability of the geoscience community to identify and investigate emerging issues depends on the discipline's ability to attract outstanding scientists who are able to analyze complex problems in innovative ways. All three of these concerns can be addressed by increasing the racial and ethnic diversity of geoscientists.

Students from populations that are currently underrepresented in the geosciences are an untapped reservoir of potential geoscience professionals. Geoscience degree programs that are able to recruit and retain a significant number of students drawn from diverse racial and ethnic backgrounds have the potential to grow in size and are less likely to be threatened with future closure due to low enrollments. An increase in the diversity of students matriculating into geoscience degree programs should eventually lead to an increase in the ethnic and racial diversity of the geoscience workforce, which will have the important benefit of improving the field's ability to communicate information to the public at large. A diverse workforce is able to employ numerous culturally appropriate mechanisms to demonstrate the relevance of scientific findings. A diverse workforce is also able to appreciate the concerns of multiple segments of the population. Topics of concern to different racial, ethnic, and cultural groups are best understood and addressed by members of those groups.

Increasing the diversity of the professional geoscience workforce will likely have substantial additional benefits that will contribute to the vitality and health of the discipline. Scientists from different backgrounds bring different methods, approaches, and perspectives to the problems they study. In the geosciences, problems are often best investigated through the use of a variety of techniques (e.g., field data collection, remote sensing, modeling, and experimentation). Use of multiple analytical tools and integration of diverse geoscience datasets requires extraordinary creativity. Diverse teams of goescientists have the potential to develop innovative strategies to consider issues in the geosciences.

As the issues that face the nation and world become increasingly complex during the 21st century, geoscientists will be trying to solve ever more difficult problems. The future success of the geoscience community in its effort to help society understand and interact with the Earth system will depend on its ability to attract promising young scientists from all racial, ethnic, and cultural groups to the field.

In this paper, strategies that have proven successful in increasing diversity in the geosciences are discussed. These successful strategies were identified by the authors during their involvement with the management of the National Science Foundation's Opportunities for Enhancing Diversity in the Geosciences (OEDG) program. The OEDG program has supported projects intended to increase diversity in the geosciences since 2001. Prior to discussing the successful strategies, we first present and discuss several demographic datasets to document trends and establish benchmarks against which future changes in the diversity of geoscientists can be compared. In the future we anticipate that programs intended to enhance diversity in the geosciences (including the OEDG program) will result in measurable changes in the field's demographics.

DATA ACQUISITION AND ANALYSIS

The primary source of most of the data used in this study is the Integrated Postsecondary Education Data System (IPEDS) Completions Survey by Race. IPEDS was originally established to be the core postsecondary education data collection program at the National Center for Education Statistics (NCES). NCES, located within the U.S. Department of Education and the Institute of Education Sciences, is the primary federal entity responsible for collecting and analyzing data related to education.

IPEDS is a single, comprehensive system of surveys designed to collect data from all primary providers of postsecondary education. The IPEDS system is built around a series of interrelated surveys that collect institution-level data about issues such as enrollments, program completions, faculty, staff, finances, and academic libraries. The Completions Survey is designed to collect information on the number and types of degrees awarded by U.S. postsecondary institutions and to collect information on the characteristics of degree recipients.

The IPEDS survey is completed by institutional representatives. The key variables in the survey are: academic institution, field of degree, field of study, level of degree, race/ethnicity, gender, and type of institution (public versus private). The survey population consists of all accredited 2- and 4-year postsecondary educational institutions in the U.S. and its outlying areas. IPEDS data normally used by the Division of Science Resources Statistics (SRS) at the National Science Foundation (NSF) consist of a census of institutions accredited to award degrees. Data are collected for the survey by mail and through phone interviews. Data are checked for consistency through comparison with prior-year responses. No weighting techniques are used to modify the data. Imputation is used to correct for unit non-response when institutions have previously responded, and this technique results in only slight underreporting. Since the data used by SRS are a census of all U.S. institutions, there is no sampling error. The overall response rates for institutions of higher education range between 85% and 96%. There are some item non-response issues in information reported to NCES. For example, among bachelor's degree recipients in 1997, racial/ethnic data were imputed for 0.6 % of the White, non-Hispanic recipients and for 2.6% of non-resident aliens. Although care must be taken in analyzing trend data because the overall degree field taxonomy has been modified over time, no changes in the geoscience degree field taxonomy occurred during the time span covered by data presented in this study.

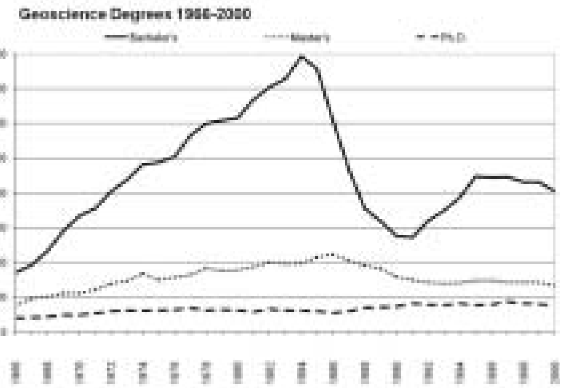
Data from the NSF Survey of Earned Doctorates is used in one figure in this paper. The Survey of Earned Doctorates (SED) began collecting data in 1958. The survey was conducted by the National Research Council of the National Academy of Sciences under contract to SRS from 1957 to 1997. Since then, the National Opinion Research Center (Chicago, IL) has been conducting the survey. The SED continuously documents the number and characteristics of individuals receiving research doctorates from all accredited U.S. institutions. As individuals receive their first research doctorate, they are asked to complete the survey. Each U.S. graduate school is responsible for providing the survey to their graduates and then submitting completed forms to the survey contractor. Responses are grouped by academic year. Because the survey collects a complete college education history, coding of institutions is very important. One-third of doctorate recipients at U.S. universities are from foreign countries. A coding frame developed by the U.S. Department of Education (Mapping the World of Education: The Comparative Database System) has been used by the SED to code the baccalaureate origins of persons who came to the United States to earn their doctorates.

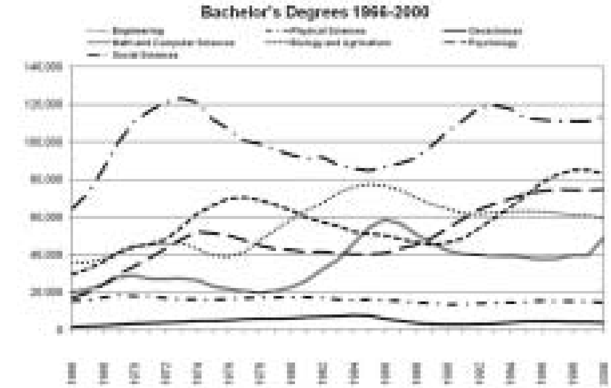
The SED is an extremely accurate source of information about research doctorates awarded in the U.S. Because the SED is a census, which does not require any sampling, weighting is not used to adjust for non-response. Coverage of research doctorates in SED is excellent. In 2004, 91% of degree recipients returned surveys. Data for nonrespondents are constructed based on information collected from commencement programs, graduation lists, and other similar public records. Nonresponses in 2004 were concentrated in certain institutions; graduates from 8 institutions accounted for 30% of nonrespondents. Item nonresponse rates in 2004 for the most frequently used variables ranged from 0.2% for sex to 6.9% for race/ethnicity.

The authors accessed much of the data used in this study via the Computer-Aided Science Policy Analysis and Research (webCASPAR) web portal maintained by SRS. (WebCASPAR is also known as the Integrated Science and Engineering Resources Data System.) The webCASPAR database system contains information about academic science and engineering resources available online. The system also contains information generated from several of SRS's academic surveys plus information from a variety of other sources, including NCES. The webCASPAR system is designed to provide multiyear information about specific fields of science and engineering at specific academic institutions. The system provides users with opportunities to select variables of interest and to specify whether and how information should be aggregated. Information can be output in hard copy form or in Lotus, Excel or SAS formats for additional manipulation.

Most data were analyzed in the webCASPAR system using an analysis variable of Degrees/Awards Conferred by Race (NCES population of institutions) and the classification variables of year, gender (male, female), race and ethnicity (Black non-Hispanic, American Indian or Alaskan Native, Asian or Pacific Islander, Hispanic, White, non-Hispanic, Temporary Resident), academic discipline (broad, standardized) and level of degree or other award. Because a major goal of this study was to compare diversity in the geosciences to diversity in other science and engineering fields, numbers for the Asian or Pacific Islander category were not included in the broad 'minority' category because Asian Americans are not underrepresented in all science and engineering fields, although they are underrepresented in the geosciences.

All of the figures in this paper include the most recent data available at the time of preparation of this manuscript. In some instances the most recent data are several years old. Unfortunately raw data collected by survey instruments require significant processing prior to release. Data processing includes procedures required to ensure that the data are as accurate and complete as possible.





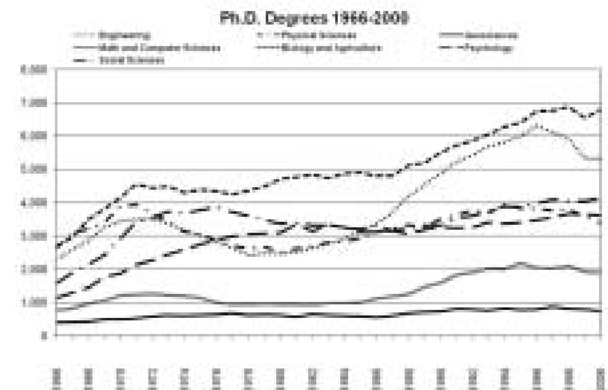


Figure 1 upper left. Bachelor's, master's and Ph.D. degrees in geoscience 1966-2000. Data from Hill (2002), Table 5. Data tabulated by National Science Foundation Division of Science Resources Statistics. Data from the Department of Education National Center for Education Statistics Integrated Postsecondary Education Data System Completions Survey.

Figure 2 upper right. Bachelor's degrees in science and engineering 1966-2000. Data from Hill (2002), Table 5, Table 12, and Table 19. See figure 1 caption for information about the data.

Figure 3 lower left. Master's degrees in science and engineering 1966-2000. Data from Hill (2002), Table 12. See figure 1 caption for information about the data.

Figure 4 lower right. Doctorate degrees awarded in science and engineering, 1966-2000. Data from Hill (2002), Table 19. See figure 1 caption for information about the data.

DIVERSITY DATA

Over the last half century, the overall size of the U.S. science and engineering workforce has increased, but it has not increased as fast as the size of the U.S. population as a whole. In 1966 approximately 237,000 students graduated with a bachelor's, master's, or doctorate in a science or engineering field (Hill, 2002a). In 2000, about 511,000 students graduated with a degree in science or engineering (Hill, 2002a). Over the same time period, the U.S. population grew from 196.6 million to 282.3 million (U.S. Census Bureau, 2003). The fact that increases in the number of scientists and engineers is not keeping pace with the overall size of the population is a concern to government and industry representatives because the economic viability of the U.S. depends on the nation's ability to maintain technological prominence in the global arena.

Degrees Awarded in Science and Engineering - The geosciences (broadly defined as consisting of all atmospheric, ocean, and Earth sciences) comprise only a small portion of the total U.S. science and engineering enterprise (Figures 1-4), but the role of geoscientists in investigating critical issues facing society is significant. The number of bachelor's degrees granted in geoscience fields during the years 1966-2000 was less than the number granted in any of the other science or engineering fields (Figures 1 and 2). The total number of bachelor's degrees awarded in the geosciences rose steadily from 1712 in 1966 to a high of 7925 in 1984, dropped rapidly to 2728 in 1991, rose to a intermediate level of 4478 in 1995, and has fallen steadily but not precipitously since 1995. Only 4047 bachelor's degrees were awarded in the geosciences in 2000, about 1% of the total number awarded in science and engineering in that year. Significantly fewer degrees have been awarded in the geosciences and physical sciences than in the other science and engineering disciplines.

The largest number of bachelor's degrees awarded from 1996-2000 were in the social sciences, but the number awarded fluctuated through time. From 1973 until 1985, the number of social science bachelor's degrees declined steadily, only to increase from 1985 until 1993. Trends in the number of engineering bachelor's degrees awarded from 1996-2000 were out of phase with trends in the number of social sciences degrees. Engineering bachelor's degrees increased in number from 1976-1984 and then decreased from 1984-1995. Trends in the numbers of degrees in biology and agriculture, as well as psychology, were similar to the social sciences trends, although inflection points marking a change from decreasing to increasing or increasing to decreasing numbers of degrees either led or lagged behind the same inflection points in the social science data by one to five years. Trends for mathematics and computer science bachelor's degrees were similar to engineering, but show a one to two year lag behind the inflection points in the engineering data.

Master's degrees awarded in science and engineering fields generally showed a steady increase through time from 1966 to 2000 (Figures 1 and 3). The data shown in Figures 1 and 3 include all students who received a master's degree, including those who continued on to receive a Ph.D. In 2000, the majority of the master's degrees were awarded in engineering (25,736). The number of engineering master's was closely followed by the number of social sciences master's (23,375) in 2000. Other science and engineering fields awarded substantially fewer master's degrees. Math and computer sciences awarded 17,824, psychology awarded 13,708, while biology and agriculture awarded 10,183. Only 3512 master's degrees were awarded in the physical sciences in 2000. The geosciences awarded the smallest number of master's degrees: 1345.

The number of master's degrees awarded in the geosciences was approximately 1.4% of the total number of master's degrees awarded in science and engineering in 2000. The number of degrees awarded in the geosciences rose fairly steadily between 1966 and 1986 when the number reached a maximum of 2234. From 1986 until 1993, the number of master's degrees awarded fell consistently until reaching a value of 1397. After 1993, the number of master's increased to 1487 in 1996 and then fell again to the 1345 value reached in 2000. The data indicate that there were only 586 more master's degrees awarded in the geosciences in 2000 (1345) than in 1966 (759). Only one discipline, physical sciences, saw an overall decline in number of master's degrees awarded between 1966 and 2000, from 4206 to 3512.

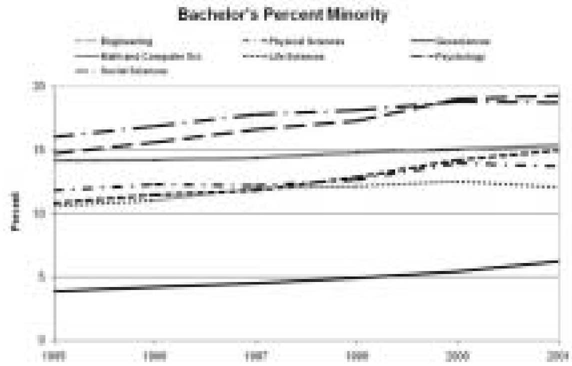
The number of Ph.D. degrees awarded in all STEM fields increased between 1966 and 2000, although the increase was not necessarily monotonic. Biology and agriculture awarded the largest number (6798) of Ph.D. degrees in science and engineering in 2000 (Figures 1 and 4). Engineering awarded the second highest number of Ph.D. degrees (5330). Social sciences, psychology, and physical sciences awarded 4151, 3623, and 3411 Ph.D. degrees respectively. Math and computer sciences awarded significantly fewer degrees, 1909. The geosciences awarded the smallest number (757) of Ph.D. degrees in 2000. This number is 2.9% of the total number of Ph.D. degrees awarded in science and engineering in 2000. In 1966, the geosciences awarded 404 Ph.D. degrees. The largest number of Ph.D. degrees (878) were awarded in the geosciences in 1997.

A Ph.D. is typically required for scientific research, and the number of Ph.D. degrees awarded is used here to estimate the size of the geoscience research community. Based on the data in Figure 1, it is estimated that the maximum possible size of the geoscience research community is on the order of 27,000 individuals. Considering the number and complexity of problems being studied by geoscience researchers, this number seems modest. The rough estimate of the size of the geoscience research community was made assuming that: 1) the number of Ph.D. degrees awarded in the geosciences remained constant from 2001 to 2006 at a level equal to the number awarded in 2000; and 2) geoscientists receive their Ph.D.s at age 30 and retire at age 70. Any changes in these assumptions will result in a change the final estimate. The size of the geoscience research community is estimated here because geoscientists are included in many fields for which employment statistics are tracked by the U.S. Department of Labor. In many cases the categories tracked by the Department of Labor are generalized so that they include research geoscientists, non-research geoscientists, and practitioners from other disciplines. For example, the number of post-secondary Atmospheric, Earth, Marine, and Space Sciences Teachers working in 2005 is reported to be 8810 by the Department of Labor Bureau of Labor Statistics (2007). This number includes post-secondary faculty members who do not have a Ph.D. and are not engaged in research. Similarly, the Bureau of Labor Statistics category of Geoscientists, Except Hydrologists and Geographers, does not include Atmospheric and Space Scientists, and does not distinguish between research and other types of employment.

Race and Ethnicity of Science and Engineering Degree Recipients - Traditionally, geoscience research has been almost exclusively conducted by people who are typically classified by the federal government as White, non-Hispanic U.S. citizens. Through time, students who are members of this racial group have become less involved in science and engineering. This means that the size of the pool from which new geoscience talent has traditionally been drawn is decreasing in size. In order to simply replace the existing geoscience workforce, let alone increase its overall size, it is becoming increasingly important for the geosciences to recruit new practitioners from groups that are currently underrepresented in STEM fields. Unfortunately the geosciences have the lowest diversity of any of the STEM disciplines.

At the bachelor's level, members of groups underrepresented in STEM fields received 6.3% of the geoscience degrees earned in 2001 (Figure 5). Although 6.3% is a small fraction of the total number of degrees awarded, it is important to note that there was a steady increase in the percentage of geoscience bachelor's degrees awarded to underrepresented minorities between 1995 and 2001. In contrast to the 6.3% awarded in 2001, only 3.9% of geoscience degrees were awarded in 1995 to members of groups underrepresented in STEM disciplines. This trend of increasing diversity among bachelor's degree recipients, if continued, could result in dramatic changes in the character of the gesocience workforce.

Despite the increase in the percentage of degrees earned in the geosciences by underrepresented minority students from 1995-2001, members of underrepresented groups received a smaller proportion of the total number of bachelor's degrees in the geosciences than in any other STEM discipline. Because the geosciences awarded fewer bachelor's degrees overall than other STEM fields, the fact that the geosciences awarded the smallest proportion of degrees to minority students means that fewer actual degrees (number rather than proportion) were earned by underrepresented students in the geosciences than in any other STEM field. Looking forward, the small size of the geosciences (relative to other STEM fields) may be an asset. It will be possible to markedly increase the proportional diversity of the field



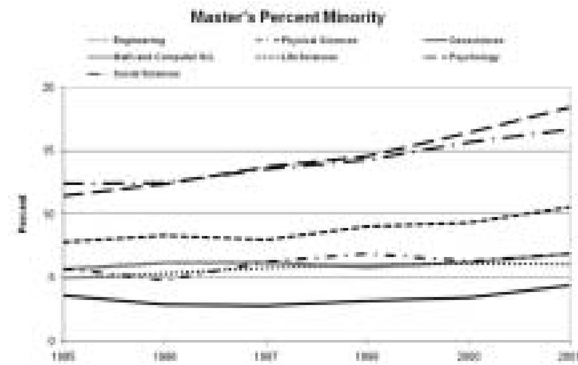


Figure 5 left. Percentage of underrepresented minorities among bachelor's degree recipients in science and engineering fields. In this figure, the category 'minority' includes Black, American Indian or Alaskan Native, and Hispanic bachelor's degree recipients. Individuals belonging to the Asian or Pacific Islander, Unknown, Other, White, Non-Hispanic, and Temporary Resident groups are not included in the broad 'minority' category, but the numbers of degrees received by members of these groups are included in the total number of degrees received (the denominator in the percentage calculation). Asian and Pacific Islanders are not included in the minority category because: 1) they cannot be separated in the webCASPAR system and 2) Asians are not underrepresented in some science and engineering disciplines despite the fact that they are underrepresented in the geosciences. Compiled from the webCASPAR database: http://caspar.nsf.gov. Data from the Higher Education General Information Survey (HEGIS) and the National Center for Education Statistics Integrated Postsecondary Education Data System.

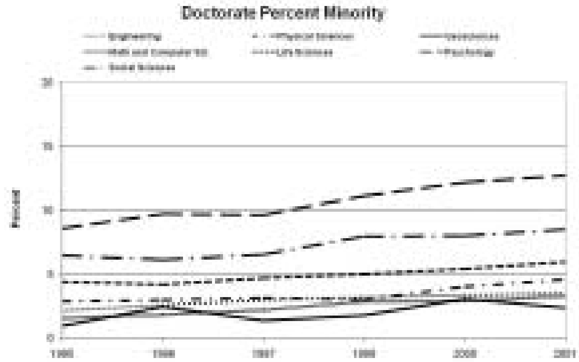
Figure 6 right. Percentage of underrepresented minorities among master's degree recipients in science and engineering fields. See Figure 5 caption for additional information about the data and its source.

by increasing the actual number of degrees earned by underrepresented minority students by only a moderate amount. Increasing diversity at the bachelor's level is likely to have a particularly significant effect on the overall diversity of the geoscience workforce because bachelor's-level programs prepare students for jobs in industry as well as post-graduate study.

Compared to the gesociences, substantially higher proportions and greater numbers of bachelor's degrees were awarded to underrepresented minorities in the two most diverse STEM fields, psychology and social sciences. In these two fields, about 15-20% of the total numbers of bachelor's degrees were earned by members of underrepresented groups. These two fields were the most successful of all the STEM disciplines at recruiting and retaining students from underrepresented groups. Despite their relative success, they were actually quite non-diverse however; bachelor's level degree recipients in psychology and social sciences were dominantly (80-85%) White, non-Hispanic. In the other STEM fields (math and computer science, life science physical science, and engineering), students drawn from underrepresented groups received intermediate percentages (about 10-15%) of the bachelor's degrees awarded from 1995-2001.

All STEM fields were proportionally less diverse at the master's level than at the bachelor's level, indicating that all STEM fields experience higher attrition among students drawn from underrepresented groups than among White, non-Hispanic students. The fields that were most diverse at the bachelor's level (psychology and social sciences) were, however, also most diverse at the master's level (Figure 6). The data shown in Figure 6 include all students who received a master's degree, including those who continued on to receive a Ph.D. In 2001, 19.3% of bachelor's degrees awarded in psychology were received by members of underrepresented groups, while in the same year underrepresented students were awarded 18.4% of the master's degrees. Similarly, 18.7% of bachelor's and 16.7% of master's degrees were awarded to underrepresented students in the social sciences in 2001. In the life sciences, members of groups underrepresented in STEM fields earned 10.6% of the master's degrees (in contrast to 15.0% of the bachelor's degrees). The proportions of master's degrees awarded to underrepresented students in physical science, math and computer science, and engineering were approximately constant (ranging from about 5%-7%) from 1995-2001. In all three of these fields, the proportion of master's degrees awarded to underrepresented students was between 6% and 8% lower than the proportion of bachelor's degrees awarded in the same field during the same year. Physical science, math and computer science, and engineering thus suffered from the highest rates of attrition of underrepresented students. Unfortunately the data analyzed for this study do not indicate whether minority students in these fields primarily left universities immediately after completing their bachelor's degrees, or whether they began post-graduate degree programs and later dropped out prior to completing a master's degree.

As was the case for bachelor's degrees, the geosciences awarded a smaller proportion (3%-5%) of master's degrees to members of underrepresented groups than any other STEM field from 1995-2001. It is interesting to note however that the difference between the proportion of geoscience bachelor's and master's degrees received by underrepresented students in any one year was among the lowest of any of the STEM fields. This suggests either that there was less attrition in the geosciences than some of the other STEM fields, or that the geosciences attracted students into master's programs who previously completed bachelor's degrees in another field. The latter possibility is undoubtedly an important reason for why the geosciences appeared to suffer less attrition than some other fields. The



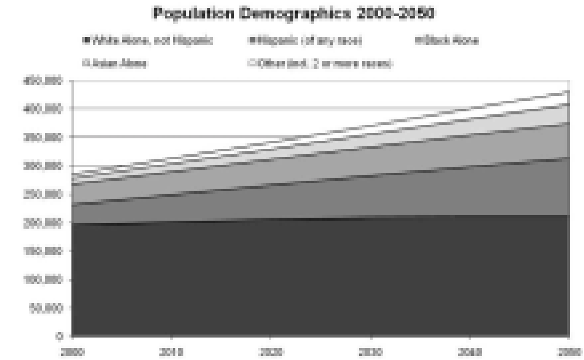


Figure 7 left. Percentage of underrepresented minorities among Ph.D. degree recipients in science and engineering fields. See Figure 5 caption for additional information about the data and its source.

Figure 8 right. Projected U.S. population demographics. Data from U.S. Census Bureau (2004).

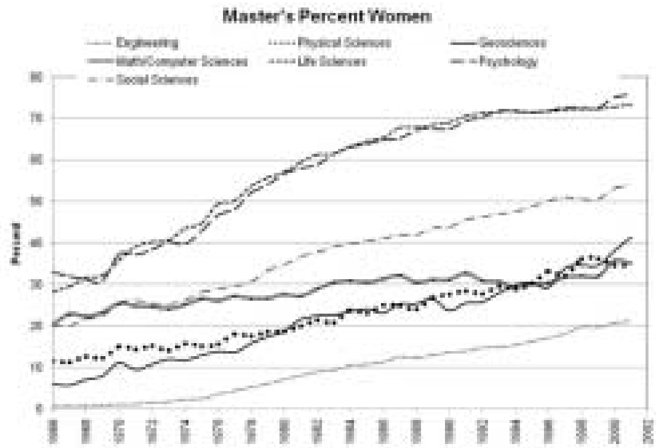
interdisciplinary nature of the geosciences make it possible for students with bachelor's-level training in many different fields (e.g., engineering, math and computer science, physical sciences, or life sciences) to successfully enter and complete advanced degree programs.

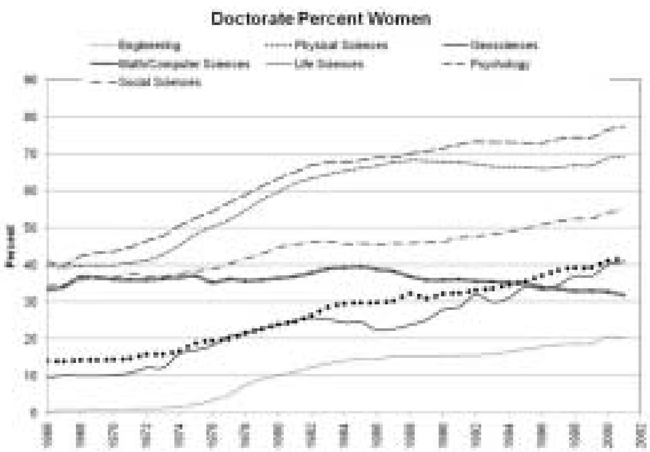
All STEM fields are less diverse at the level of the Ph.D. degree than at the master's level (Figure 7). Students drawn from underrepresented groups are preferentially lost from the academic pipeline between the master's and the Ph.D. as well as between the bachelor's and the master's. In 2001, psychology had higher racial and ethnic diversity than any other STEM field (12.7% of Ph.D.s to underrepresented minority students). The proportion of psychology Ph.D. degrees awarded to underrepresented students in 2001 was, however, substantially lower than the number of master's degrees awarded (18.4%). Similarly, the proportion of Ph.D. degrees awarded to members of underrepresented groups in the social sciences in 2001 was significantly lower than the proportion of master's degrees awarded (8.5% Ph.D. versus 16.7% master's respectively). In 2001, 6.0% of Ph.D. degrees in the life sciences, 4.6% of the Ph.D. degrees in the physical sciences, 3.5% of Ph.D.s in engineering, 3.3% of Ph.D.s in math and computer sciences and 2.4% of Ph.D.s in geoscience were awarded to underrepresented minorities.

As was the case for bachelor's and master's degrees, the geosciences awarded a smaller percentage of the total number of Ph.D. degrees to students from underrepresented groups (ranging from a low of 1.0% in 1995 to a high of 3.1% in 2000) than any other STEM field. In 2001, however, the proportion of Ph.D. degrees awarded to underrepresented minority students (2.4%) was closer in the geosciences to the proportion of master's degrees awarded (4.4%) than in any other STEM field. As was stated above in reference to master's degrees, the geosciences appear to either retain a higher percentage of their underrepresented students during the transition from one degree to the next (e.g., B.S. to M.S., or M.S. to Ph.D.) than some other disciplines and/or they are effective at attracting students from other disciplines to their advanced degree programs.

It is encouraging that advanced geoscience degree programs appear to be attractive to underrepresented students because students who obtain advanced degrees are often viewed as leaders and role models by others. Future increases in the diversity of master's and Ph.D. degree recipients in the geosciences will assist the field in recruiting and retaining additional students at all levels. Given that there have traditionally been so few students obtaining bachelor's degrees in the geosciences, efforts to diversify graduate programs should carefully consider how to attract and retain students who received bachelor's degrees in other fields. The geosciences may offer intriguing opportunities to students who previously received degrees in other areas. By recruiting such students into the geosciences, the discipline may be able to assist in the overall diversification of the science and engineering workforce because the students that are interested in being recruited might otherwise have been lost from the science and engineering workforce due to a lack of engagement in their original field. The contributions that diverse students who are recruited from other disciplines can make to the geosciences are profound. Many current research areas require investigative teams to make use of information and methods traditionally practiced in non-geoscience disciplines. If the geosciences are successful in attracting racially and ethnically diverse students who have strong backgrounds in non-geoscience areas, the discipline may experience a broadening that will ultimately lead to scientific advances, increased relevance to society, and overall growth.

Population Demographics - Examination of projected changes in the demographics of the U.S. population (Figure 8) leads to the conclusion that in the future it will become increasingly important to recruit students from groups that are currently underrepresented in the geosciences because those groups are anticipated to increase in size faster than the White, non-Hispanic group (which is referred to as White Alone, not Hispanic in Figure 8). The size of the U.S. population is expected to increase from approximately 282 million (the population in 2000) to about 420 million during the first half of the 21st century. The Hispanic (of any race) category is expected be the fastest growing segment of the population, increasing from about 36 million to 103 million between 2000 and 2050. In 2050, members of the Hispanic (of any race) category are anticipated to compose 25% of the U.S. population. The Black Alone category is anticipated to be the second fastest growing





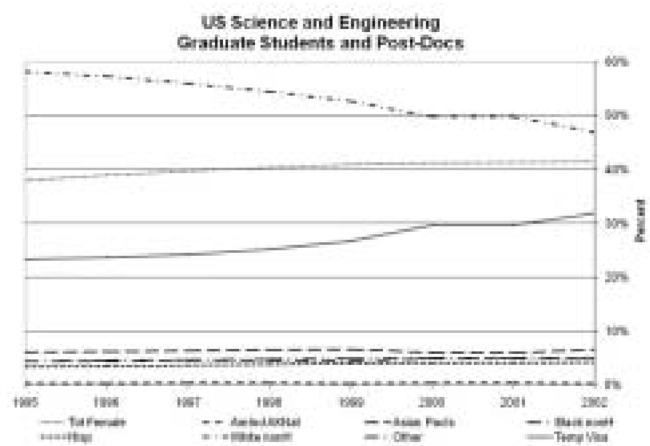


Figure 9. Gender diversity among B.S. recipients from 1966-2001 in STEM fields. Data from NSF webCASPAR database (http://caspar.nsf.gov), derived from IPEDS data. Identical to data presented in Hill (2002).

Figure 10. Gender diversity among M.S. recipients from 1966-2001 in STEM fields. Data from NSF webCASPAR database (http://caspar.nsf.gov), derived from IPEDS data. Identical to data presented in Hill (2002).

Figure 11. Gender diversity among Ph.D. recipients from 1966-2001 in STEM fields. Data from Hill (2002), Tables 21 and 23. Original data tabulated by NSF/SRS and obtained from the NSF/SRS Survey of Earned Doctorates (Research Doctorates).

Figure 12. Demographics of U.S. science and engineering graduate students and post-docs. The categories shown in the graph are: Tot Female = Total Female, including U.S. and non-U.S. citizens; AmIndAKNat = American Indian and Alaskan Native U.S. citizens; Asian PacIs = Asian and Pacific Islander U.S. citizens; Black nonH = Black Non-Hispanic U.S. citizens; Hisp = Hispanic U.S. citizens; White nonH = White Non-Hispanic U.S. citizens; Other = Other U.S. citizens; Temp Visa = Non-U.S. citizens. Note that from 1995-2002 the percentage of White, Non-Hispanic graduate students and post-docs steadily declined, while the percentage of international graduate students and post-docs increased at approximately the same rate. Data from Oliver and Rivers (2005) Tables 14 and 15.

category and is expected to increase from 36 million in 2000 to 61 million in 2050. The Asian Alone category is projected to increase from 11 to 33 million.

Although the absolute size of the White Alone, not Hispanic category is also projected to increase in the future (from 196 in 2000 to 210 million in 2050), it will decrease from 69.4% to 50.1% of the population as a whole. Projections such as these underscore the importance of recruiting and retaining students from segments of the population traditionally underrepresented in STEM fields. Geoscience disciplines, because of their small sizes, have the potential to rapidly change their demographics if successful strategies for attracting and retaining members of underrepresented groups are implemented. As discussed in the following section, the geosciences have been very successful at increasing the number of women in the field, and this is cause for optimism that the geosciences may be successful at increasing racial and ethnic diversity in the discipline.

Gender of Geoscience Degree Recipients - The number of women in the U.S. receiving degrees in STEM disciplines has increased steadily since data were first collected in 1966 (Figures 9-11). The proportion of bachelor's degrees awarded to women in each STEM field (Figure 9) has increased since 1966 for all disciplines except math and computer science. Math and computer science experienced a steady decline in the absolute number (not just proportion) of bachelor's degrees awarded to women from 1987 until 1999. During all years since 1966, women have received a higher proportion of bachelor's degrees in psychology and life sciences than in any of the other STEM disciplines. In fact, women have received more bachelor's degrees than men in psychology since 1974, and have received a greater number than men in the life sciences since 1976. Women have also received more bachelor's degrees than men in the social sciences since 1996.

In all other STEM fields, women received proportionally fewer bachelor's degrees than men for the entire time period shown in Figure 9 (1966-2001). The physical sciences and geosciences have led these remaining fields in the proportion of degrees awarded to women since 1996. In 2001, women received 42% and 41% of bachelor's degrees awarded in physical science and geoscience respectively. Engineering has lagged behind all other STEM fields in terms of the number of bachelor's degrees awarded to women since 1966, with only 20% of the engineering bachelor's degrees awarded in 2001 going to women.

The general increase in proportion of bachelor's degrees awarded to women in STEM fields that has occurred since 1966 is encouraging because it suggests that STEM professionals have taken proactive and effective steps to increase the number of women in their fields. The skills and approaches that have resulted in an increase in the number of women in STEM fields may be useful future efforts to recruit and retain individuals drawn from racial and ethnic groups traditionally underrepresented in STEM fields.

Women have received almost identical proportions of the number of master's degrees awarded in psychology and the life sciences since 1966 (Figure 10). In 2001, the percentage of master's degrees awarded to women in psychology was slightly lower than the percentage of bachelor's degrees awarded in the same field in the same year (76% of master's degrees versus 77% of bachelor's degrees). Also in 2001, the proportion of master's degrees awarded in life science (73%) actually exceeded the proportion of bachelor's degrees awarded that year (69%). Fifty-four percent of the master's degrees awarded in social science in 2001 went to women, only one percentage point lower than the proportion of bachelor's degrees awarded in that field that year.

Women received 41% of the master's degrees awarded in the geosciences in 2001, exactly the same as the percentage of bachelor's degrees received by female geoscientists that year. Women received proportionally fewer master's degrees (35%) than bachelor's degrees (42%) in 2001 in the physical sciences, but the proportion of master's degrees awarded to women in 2001 in engineering (21%) and math and computer science (35%) slightly exceed the number of bachelor's degrees in those fields (20% and 32% respectively). Throughout the 1966-2001 time period for which data are shown in Figure 10, engineering awarded a lower proportion of master's degrees to women than any other STEM field.

It is interesting to note that in all STEM fields except the physical sciences, women received approximately the same proportion of master's degrees as bachelor's degrees. The data presented in Figures 9 and 10 suggest that women who complete bachelor's degrees are just as likely as their male counterparts to successfully complete a master's degree in a STEM field.

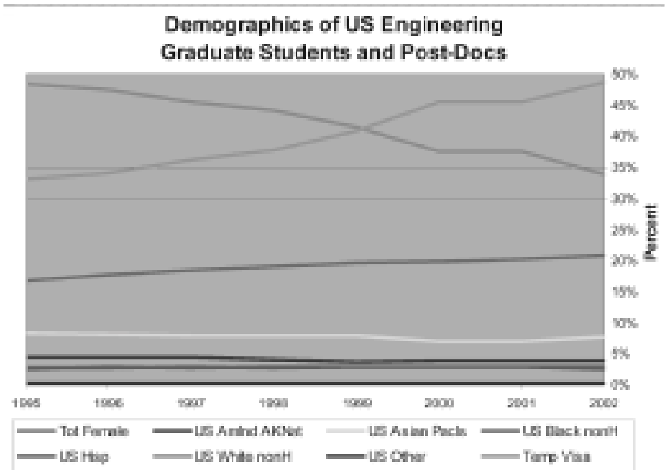
The proportion of Ph.D. degrees awarded to women in any particular STEM field is lower than the proportion of master's or bachelor's degrees awarded each year from 1966 to 2001 (Figure 11). During that time period, psychology awarded the greatest proportion of Ph.D. degrees to women (e.g., 68% in 2001). Although the life sciences awarded a lower proportion of Ph.D. degrees to women (e.g., 49% in 2001), the largest number of degrees were consistently awarded to women in that field (4044 in 2001). Women received 29% of the total number of Ph.D. degrees awarded in 2001 in geoscience fields, a proportion approximately 22 percentage points lower than the number of master's degrees awarded the same year. Only the life sciences showed a greater decrease in the proportions of Ph.D. and master's degrees awarded in 2001 (49% versus 73% respectively). In 2001, the total number of women receiving Ph.D. degrees in the geosciences (156) was approximately 28% of the number receiving master's degrees (564) and about 10% of the number receiving bachelor's degrees (1622). Of the women receiving Ph.D. degrees in geoscience, only a small proportion choose to enter academia and serve as teachers and role models and for future geoscientists (Holmes and O'Connell, 2004).

At the bachelor's, master's, and Ph.D. levels, women receive the greatest proportion and absolute number of degrees in psychology, social science, and life science. All three of these fields are ones in which professional scientists clearly have the opportunity to work with people and conduct research that can have direct benefits for humankind. The number of women in other STEM fields (geoscience, physical science, math and computer science, and engineering) has been growing since 1966, albeit at a very slow rate.

International Degree Recipients - International students have become increasingly involved in the U.S. science and engineering enterprise through time. This is particularly apparent in data collected to document the demographics of the post-graduate STEM population. Growth in the percentage of international graduate students and post-docs at U.S. universities has essentially matched recent decreases in the proportion of White, non-Hispanic males in STEM fields (Figure 12). The geosciences have not attracted as many international students as some other disciplines however (e.g., compare Figures 13 and 14). Increases in the size of geoscience graduate student and post-doc population between 1995 and 2002 essentially occurred because of increased participation by women who were U.S. citizens (Table 1). International students are therefore another segment of the global population that is underrepresented in the geosciences. Participation by international students may become increasingly important in the future if the size of the U.S. geoscience workforce does not keep pace with the needs of government, industry, and academia.

SUCCESSFUL STRATEGIES FOR INCREASING DIVERSITY IN THE GEOSCIENCES

Through its operation and review of the Opportunities for Enhancing Diversity in the Geosciences program, the Directorate for Geosciences at the National Science Foundation has recognized several successful strategies



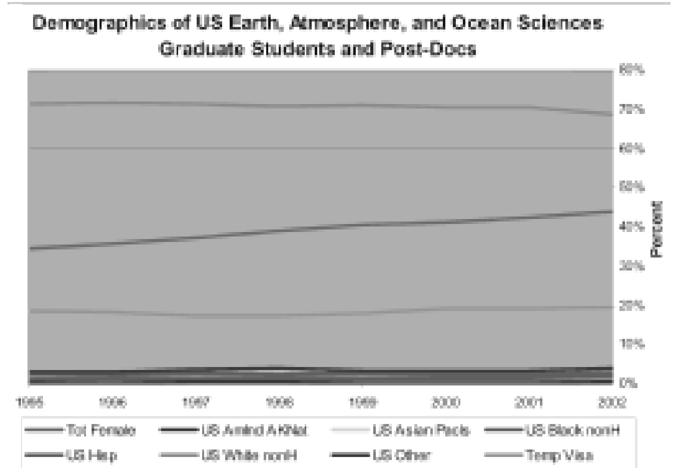


Figure 13. Demographics of U.S. engineering graduate students and post-docs. Note that the percentage of White, non-Hispanic U.S. citizens declined markedly between 1995 and 2002. At the same time, the percentage of international graduate students and post-docs increased at an approximately equivalent rate. See Figure 12 for additional information about the data and its source.

Figure 14. Demographics of U.S. geoscience graduate students and post-docs. Note that although the percentage of White, non-Hispanic graduate students and post-docs decreased between 1995 and 2002, the percentage of women increased. The number of international graduate students and post-docs stayed approximately constant, in contrast to the increasing trend in engineering and for science and engineering fields overall. See Figure 12 for additional information about the data and its source.

for increasing diversity in the geosciences. These strategies are described in this section.

First, geoscience is more interesting to people when it is seen as a relevant field that has numerous applications related to issues faced by society. Geoscientists can no longer be accurately characterized as solitary naturalists who hike through deserts looking for fossils. The modern geoscience workforce dominantly consists of technologically savvy professionals who work in both urban and rural settings throughout the world. The geosciences could benefit from a united effort to publicize traditional and non-traditional career opportunities. Although people typically think of geoscientists as only having potential for employment within the petroleum industry, this perspective is inaccurate. According the U.S. Department of Labor Bureau of Labor Statistics (BLS), 30% of geoscientists are employed in architectural, engineering, and related services, while only 15% are involved in oil and gas extraction (BLS, 2005). Geoscience careers pay well; the median income for geoscientists in 2002 was $68,730, while starting salaries for people with a bachelor's degree averaged $39,365 (BLS, 2005). The geoscience job market is projected to grow more slowly than average (increase from 0-8% between 2004 and 2014), but the small size of the geoscience workforce coupled with an anticipated large number of retirements should result in a generally favorable climate for job seekers in geoscience fields (BLS, 2005). Some geoscience fields that are considered separately by the Bureau of Labor Statistics (i.e., environmental scientists and hydrologists) are expected to grow much faster than average between 2004 and 2014, with the number of jobs increasing by 27% or more (BLS, 2005). Although the Bureau of Labor Statistics projections may be inaccurate because they are based only on behavior of the labor market in the past, their estimates are the best available.

Second, mentoring can enhance efforts to increase diversity. All geoscientists can provide support to one another through development of mentoring relationships among scientists, educators, and students. Mentors who work with undergraduate students participating in Research Experience for Undergraduates programs report feeling personally satisfied as a result of the experience (Russell, 2005). They also report the inclusion of undergraduates in their research allows them to expand their research in significant ways (Russell, 2005).

Third, many students, including those drawn from groups that are currently underrepresented in STEM disciplines, find it difficult to pursue a college education because of financial concerns. The cost of tuition at colleges and universities nationwide is continually increasing. Tuition is only one part of the 'real' cost of attendance for a student who will be forced to reduce the number of hours they spend working at a paying job in order to pursue a degree. Students who are forced to choose between higher education and supporting themselves, and possibly their families, will find it impossible to attain any post-secondary degree without some form of financial aid. Geoscience programs that address economic obstacles faced by students are more likely to be successful in recruiting and retaining students than programs that provide no economic assistance.

Fourth, partnerships that include multiple stakeholders involved with STEM education can reduce the number of 'leaks' from the educational pipeline. Geoscientists should participate in and contribute to the formation of such partnerships. Industry, universities, community colleges, K-12 teachers and guidance counselors, families, communities, and government agencies all have the potential to contribute to a student's academic success. By working together, these stakeholders can reinforce the importance of STEM education and promote understanding of the way that scientists and engineers contribute to society. As a group,

Year	Gender	U.S. Citizens and Permanent Resident						
		American Indian / Alaska Native	Asian / Pacific Islander	Black,non-Hispanic	Hispanic	White,non-Hispanic	Other or unknown	Students with Temporary Visas
1995	Male	31	260	116	223	7200	302	2150
	Female	21	159	99	142	1045	171	797
1996	Male	36	249	115	230	6820	292	1994
	Female	29	160	104	144	4053	185	772
1997	Male	47	253	105	236	6363	332	1796
	Female	35	164	98	163	4039	198	709
1998	Male	44	238	103	202	6033	334	736
	Female	40	186	99	168	4065	247	763
1999	Male	32	208	112	200	5873	270	1663
	Female	31	192	101	200	4134	210	857
2000	Male	33	179	120	186	5612	232	1796
	Female	28	172	100	169	4200	189	896
2001	Male	37	171	125	196	5362	257	1801
	Female	33	170	102	201	4211	194	981
2002	Male	45	158	135	191	5389	319	1756
	Female	36	197	131	222	4410	239	1012

Table 1. Demographics of U.S. geoscience graduate students and post-docs. See Figure 12 for information about the data and its source. Percentages shown for female and male include all U.S. citizens and permanent residents plus all students with temporary visas. Data from Oliver and Rivers (2005) Tables 14 and 15.

these entities have the potential to anticipate, avoid, and address issues that cause students to leave STEM fields.

Although 'leaks' from the STEM and geoscience pipelines occur because of a number of factors, which are generally unique for each student, some generalizations can be made about how partnerships can work together to reduce the size of the 'leaks'. Students who do not initially view a geoscience career as a viable option may reconsider if they learn about people who have rewarding and high-paying jobs in the discipline. Role models who look like or come from similar backgrounds as the students themselves can be particularly effective at transmitting such information. Partnerships made up of K-12 teachers, guidance counselors, university faculty, community leaders, industry representatives, and government agencies can work together to ensure that K-12 students are aware of geoscience career opportunities and how to prepare for them. Partnerships can also provide a mechanism for mentoring and communication among industry, university, K-12 personnel, and students' families and communities so that the interests and needs of students can be effectively identified and met. Once students have entered college, whether or not with a geoscience major, they can be recruited into graduate geoscience programs by faculty members who are active in undergraduate teaching (including community college faculty) who partner with researchers wishing to encourage students to take part in summer research experiences and continue their studies in graduate school. All students, but particularly those whose financial situation makes it difficult for them to attend school full time can benefit from financial aid. Partnerships consisting of educators, industry, and government representatives can identify promising students from diverse backgrounds and provide them the financial support they need to complete their studies and enter the geoscience workforce.

CONCLUSIONS

Like most science and engineering fields, the racial, ethnic, and gender demographics of the geoscience workforce do not match the demographics of the U.S. population at large.

The potential effects of future shortages of scientists and engineers have been discussed extensively by government, university, and industry representatives across the nation. To ensure that the geoscience workforce remains strong, promising new geoscientists must be recruited and retained from all racial and ethnic groups and both genders. To succeed in this effort, geoscientists will have to work as a team to increase the visibility of geoscientists and their work. Americans, particularly those who are members of racial and ethnic groups that are currently underrepresented in the geosciences, have little knowledge of what geoscientists do. Given the fact that geoscience issues are in the news on a daily basis, it should be possible for geoscientists to readily promote exciting, challenging, and high-paying career opportunities in the discipline. Geoscientists work to improve the quality of life for people around the world just as health professionals do; unfortunately this is not widely understood.

Information about geoscience career opportunities and pathways to geoscience careers should be made available to students (and their families) at all educational levels. It is reasonable to expect that students who are aware of geoscience opportunities when they enter college are more likely to major in a geoscience discipline than students who only find out about geoscience when they happen to take a course to fulfill a general education or distribution requirement. Efforts to educate pre-college students about the geosciences and career opportunities in the field will be facilitated by actions that address teachers' and guidance counselors' understanding of the field. A single teacher or counselor will work with many more pre-college students in one week than most geoscience researchers will interact with during their entire careers.

Building strong partnership connections between four-year and community colleges will help the geosciences attract a greater number of students from groups that are currently underrepresented in the field. As the cost of a college education continues to increase, a greater number of students are beginning their post-secondary educations near their homes by matriculating in relatively low-cost community colleges. In the future, the geosciences ideally will have a strong presence at community colleges, and four-year degree-granting geoscience programs will work with two-year colleges to develop clear mechanisms for students to complete bachelor's degrees in the minimum amount of time necessary and at the minimum possible cost. To recruit a greater number of students into graduate programs, geoscientists should increase opportunities for undergraduate research in the field. Participating in a research experience has been shown to increase undergraduates' interest in pursuing a post-graduate degree (Russell, 2005).

The data presented in this paper can serve as a benchmark against which the success of current and future efforts to increase diversity in the geosciences can be gauged. The data indicate that the geosciences exhibit a lower apparent attrition rate for students drawn from underrepresented groups at the transition from B.S. to M.S. and M.S. to Ph.D. levels than other STEM fields. Unfortunately the data do not allow for determination of whether this low apparent attrition rate is real, or whether it instead reflects the fact that graduate-level geoscience degree programs attract students who previously received bachelor's degrees in other STEM fields. Whatever the ultimate cause, the geosciences' ability to either retain or recruit underrepresented students in post-graduate degree programs is reason for optimism. These students are often viewed as leaders, and they have the potential to influence other students' choices of major and career path in the future. If the strategies for enhancing diversity described in this paper and elsewhere (e.g., National Research Council, 2003) are widely implemented, geoscientists should be able to see measurable increases in their community's diversity within the next decade.

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