SRI International

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EVALUATION OF NSF SUPPORT FOR UNDERGRADUATE RESEARCH OPPORTUNITIES: Draft Synthesis Report

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In addition to those SRI staff members listed on the cover, a number of SRI staff provided valuable assistance with various aspects of the study, including obtaining contact information for survey sample members, putting project reports on SRI's Web site, report editing, and project administration. We wish to thank the following current and past SRI staff for their contributions: Catherine Ailes, Denitsa Apostolov, Roland Bardon, Kathryn Baughman, John Benskin, Pernell Brice, Bob Coward, Hal Javitz, Julie Kautz, Klaus Krause, Jongwon Park, Steve Perakis, J. David Roessner, Charles Storey, Lori Szabo, Robin Skulrak, Adrian Tyler, and Lyra Vega.

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The SRI Project Team

CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

A number of studies have assessed undergraduate research opportunities (UROs), but these are either dated or relatively small in scale, generally being focused on one or a few institutions, a single program, or even a single researcher's experiences. To provide a current and more comprehensive picture, NSF contracted with SRI International to conduct a broad-based, nationwide evaluative study of NSF's support for undergraduate research. The purpose of the study was to understand better the demographic and academic characteristics of undergraduates who participate in UROs nationwide, why individuals (faculty as well as students) choose to participate, the characteristics and components of UROs, the effects of UROs on students' academic and career decisions, and whether different kinds of research experiences are more effective with some types of students than with others (e.g., minorities vs. nonminorities, men vs. women).

The study included four Web-based surveys, conducted between 2003 and 2005 and involving almost 15,000 respondents:

- NSF initial survey: an NSF-program participant survey (undergraduates, graduate students, postdocs, and faculty).
- NSF follow-up survey: 2 years later, a follow-up survey of undergraduate participants in the NSF survey.
- STEM survey: a nationally representative survey of individuals ages 22 to 35 who have received a bachelor's degree in a ("hard") science, technology, engineering, or mathematics (STEM).
- SBES survey: a nationally representative survey of individuals ages 22 to 35 who have received a bachelor's degree in a social, behavioral, or economic science (SBES).

Despite the differences in the populations surveyed, the four surveys produced remarkably consistent results. Across the four surveys, four groups of undergraduates proved to have distinctive characteristics for a wide range of study variables.

- NSF researchers. These were the individuals who were undergraduate respondents to the NSF initial survey and who participated in the NSF follow-up survey.
- Sponsored researchers. These were respondents to the STEM and SBES surveys who reported that at least some of their research, as far as they knew, was sponsored by NSF, the National Aeronautics and Space Administration (NASA), or the National Institutes of Health (NIH). Sponsored researchers, especially those in STEM fields, tended to be more similar to the NSF researchers than to their nonsponsored counterparts. Sponsored researchers comprised 7% of STEM graduates and 5% of SBES graduates.
- Nonsponsored researchers. These were respondents to the STEM and SBES surveys whose research was not (as far as they knew) sponsored by NSF, NASA, or NIH. Nonsponsored researchers comprised 46% of STEM graduates and 47% of SBES graduates.

- Nonresearchers. These were respondents to the STEM and SBES surveys who did not participate in undergraduate research. Nonresearchers comprised 47% of STEM graduates and 48% of SBES graduates.

MAJOR FINDINGS

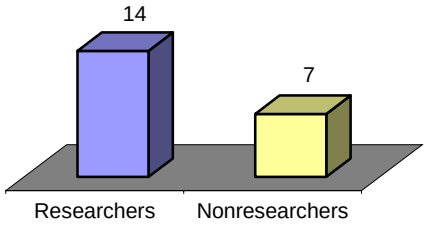
Tracking Undergraduate Researchers

Respondents to the NSF follow-up survey differed significantly from nonrespondents on a number of the questions in the initial survey. For example, compared with nonrespondents, follow-up survey respondents were more likely to be non-Hispanic whites (65% vs. 50%), to expect to obtain a PhD (50% vs. 36%), and to have been interested in STEM since childhood (62% vs. 51%). Fortunately, the high response rate (74%) to the follow-up survey minimized the effect of these differences on the overall profile of undergraduate researchers. These findings point up both the difficulty of obtaining unbiased data in longitudinal studies and the importance of high response rates in minimizing the potentially biasing effects.

Profile of Undergraduate Researchers

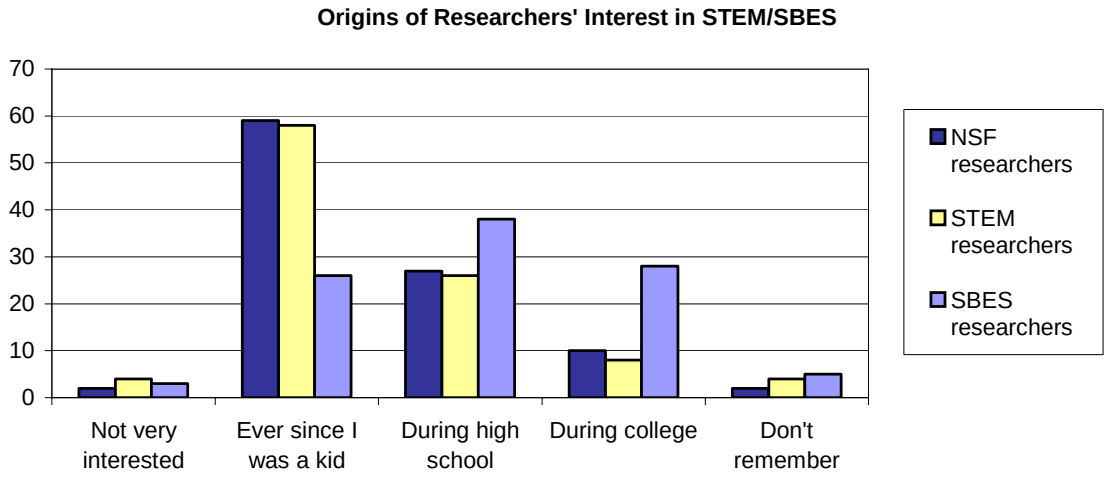
About half of STEM and SBES graduates reported that they participated in hands-on research while they were undergraduates; as noted above, 7% and 5%, respectively, were sponsored researchers. The efforts of NSF and other entities to encourage the representation of historically underrepresented groups, such as women, blacks, and Hispanics/Latinos, appear to have been effective. In all our surveys, SRI found that undergraduate researchers were demographically diverse, with women, blacks, and Hispanics/Latinos represented at rates at least equivalent to their rates in the college population. Also, rather surprisingly, rates of participation (as reported by STEM and SBES graduates) were not very different across the major types of 4-year institutions (doctoral/research extensive, doctoral/research intensive, master's, and baccalaureate). Also, those who began their undergraduate education at a 2-year school were as likely to participate in research as those who started at a 4-year school. There were, however, large differences in research participation rates across the various STEM disciplinary fields: from 34% in mathematics and 37% in computer sciences to 72% in chemistry and 74% in environmental science.

Percentage of STEM Graduates Who Had Pre-College Expectations of Obtaining a PhD



Source: SRI International: STEM survey, 2003.

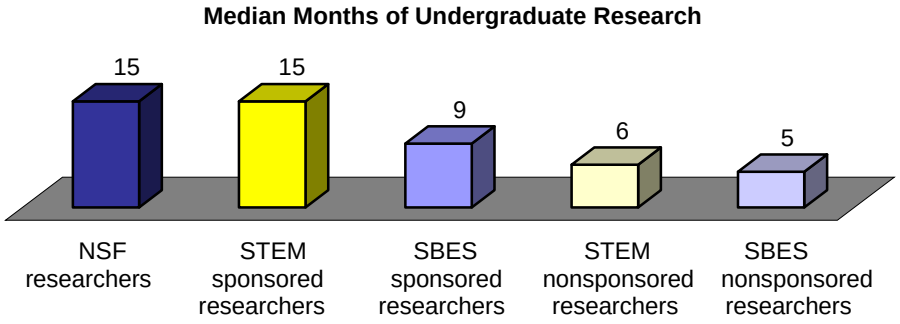
Academically, undergraduate researchers were disproportionately juniors and seniors, and they tended to be high achievers, with relatively high grade point averages and early expectations of obtaining an advanced degree. The STEM survey, for example, found that those who participated in undergraduate research were twice as likely as those who did not do research to have pre-college expectations of obtaining a PhD. STEM and NSF researchers' interest in STEM was likely to have begun in childhood, suggesting that the most effective time to begin attracting students to STEM may well be while they are in elementary school.



Sources: SRI International: NSF initial survey, 2003; STEM survey, 2003; SBES survey, 2004.

Undergraduate Research Characteristics and Activities

NSF and other sponsored research was distinctive in its emphasis on summer research programs in which groups of undergraduates participated in 8- to 10-week summer programs, usually at schools other than their own. Most sponsored researchers also participated in research during the academic year. In contrast, few nonsponsored researchers participated in summer programs, and they were similarly unlikely to have participated in research at some location other than their own college or university. NSF and STEM/SBES sponsored researchers also tended to spend more time engaged in undergraduate research than did nonsponsored researchers and to have participated in a greater variety of activities. Among all groups, common research-related activities/experiences were collecting/analyzing data, having input to research decisions, having a choice of projects, and being able to complete one's project.

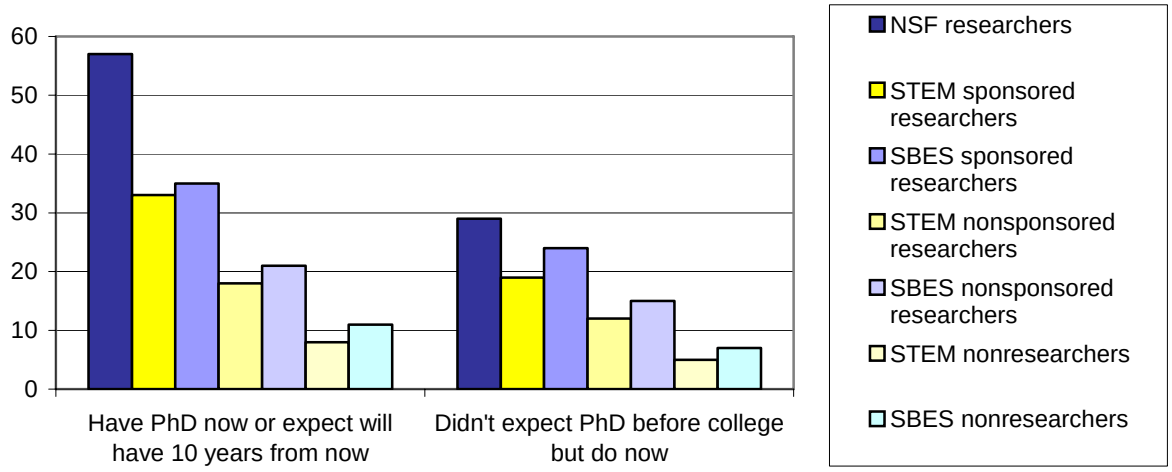


Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

Undergraduate Research Outcomes

The survey findings supported academicians' and researchers' widely held beliefs in the positive effects of UROs. UROs increased the likelihood of obtaining a PhD, and they had strongly positive effects on participants' understanding of the research process, confidence in their research-related abilities, awareness of academic and career options in STEM, and changes in interest in STEM/SBES careers. At the same time, we found support for anecdotal reports of how undergraduate research participation shows some students that research is not what they

Percentage of Each Group Who Have/Expect a PhD



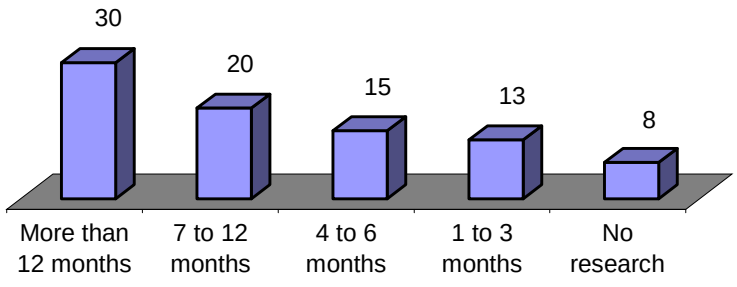
Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

want to do after all: in the NSF follow-up survey, about one in six respondents reported that one of the things they learned from their undergraduate research was that "research is not for me."

In contrast to their very positive reports of the research experiences themselves, researchers tended to believe that they were not very well informed about UROs, especially those at places other than their own school. The NSF follow-up survey also found that, when researchers first enrolled as undergraduates, only half were aware that the school offered undergraduate research, and, of those who were aware, only about half said that UROs were fairly or extremely important in their decision to enroll. These findings suggest that better dissemination of information about UROs is essential if undergraduate research is to achieve its greatest potential impact.

Broadly speaking, students who participated in research because they were truly interested and who became involved in the culture of research—attending conferences, mentoring other students, authoring journal papers, and so on—were the most likely to experience positive outcomes. Not surprisingly, the overall duration of research experiences and the variety of research activities also were strongly related to positive outcomes. For example, in the STEM survey, 30% of researchers with more than 12 months of research experience reported that they expected to obtain a PhD, compared with only 13% of those with 1 to 3 months of research experience.

Percentage Who Expect to Obtain a PhD, by Duration of Undergraduate Research Experiences: STEM Graduates Survey



Source: SRI International: STEM survey, 2003

Although we found little evidence of a relationship between mentors and research outcomes in our structured questions, by far the most common suggestions that students made about how to improve undergraduate research programs concerned increased and more effective faculty guidance. Thus, it seems likely that mentors who are able to combine enthusiasm with interpersonal,

organizational, and research skills play a key role in facilitating positive outcomes.

Key findings with regard to differences in research-experience effects were as follows:

- Effects tended to be stronger among sponsored than nonsponsored researchers. These differences were partly, but not entirely, explained by the longer duration of research participation by the former.
- We found no evidence of a superiority of summer programs over academic-year programs, or vice versa. (Note, however, that for most NSF researchers, this distinction is moot because they participated in research during both the summer and the academic year.)
- There were few appreciable differences in effects among graduates of different types of schools or between those who began their undergraduate education at a 2-year college and those who began at a 4-year school.
- Among racial/ethnic groups, effects tended to be strongest among Hispanics/Latinos and weakest among non-Hispanic whites, but most racial/ethnic-group differences were small. There were almost no differences on any of the study variables between men and women.
- There was no evidence that minorities benefited more from same-race/ethnicity mentors than from those of a different race/ethnicity or that women benefited more from female than from male mentors. However, over time, having a diverse group of mentors (in terms of their race/ethnicity and sex) appeared to be mildly beneficial to all respondents.

Mentor Perceptions

Personal satisfaction—much more than career or research factors—appeared to be the driving force behind most faculty participation in undergraduate research. In the NSF initial survey, about 7 in 10 faculty mentors agreed that "I get a lot of personal satisfaction out of working with undergraduates doing research." In contrast, fewer than 4 in 10 agreed that "Mentoring undergraduates is viewed favorably in my department's tenure/promotion review process." Lack of adequate financial support was seen as the greatest barrier to increasing the number of undergraduate researchers in NSF centers and Research Experiences for Undergraduates (REU) Sites.

RECOMMENDATIONS

Our surveys provide strong evidence that undergraduate research programs help to keep students interested in STEM and SBES careers both inside and outside of academia and to motivate them to pursue advanced degrees. Nevertheless, there remains room for enhancement. Below is a summary of SRI's suggestions.

- Survey findings suggest that the most effective time to begin attracting students to STEM may well be while they are in elementary school. If attempts to increase the U.S. STEM workforce are to be successful, it would appear that increased support of K-12 inquiry-based STEM curriculum and summer activities is essential.
- NSF should work to provide more and better information about UROs to potential participants:

  - Improve the quality, quantity, timeliness, and accessibility of information about NSF-funded UROs that is available on the NSF Web site. For example, consider developing a comprehensive searchable Web-based registry of all NSF-sponsored UROs, classified by discipline, setting, and duration.
  - Encourage colleges and universities to find ways to share information about UROs with their students and students from other schools.
  - Provide information about UROs to NSF programs that target K-12 students, to promote early awareness of UROs.
- Given the strong positive relationship between the duration of research participation and positive research outcomes, we recommend that NSF encourage its PIs to find ways to include college freshmen and sophomores in their research programs.
- SRI's analyses suggest that being an active participant in the culture of research—as evidenced through choosing to participate because it seemed to be fun, gaining independence, attending conferences, understanding the "big picture," and so on—was more strongly related to positive outcomes than having completed assignments such as research proposals, reports, or poster presentations. Accordingly, we suggest that NSF encourage PIs of undergraduate research projects to focus more on generating enthusiasm and involving undergraduates in the *culture* of research than on requiring them to complete specific research-related assignments.
- We suggest that NSF help to make mentoring more effective in several ways:
  - Encourage and fund mentor workshops for both new and experienced mentors.
  - Commission booklets on mentoring that can be sent to all grantees of undergraduate research projects.
  - Sponsor and publicize blogs on mentoring, accessible by all active grantees.
  - Use the Foundation's funding leverage to encourage colleges and universities to recognize mentoring as a factor in promotion and tenure decisions.
- NSF currently encourages REU PIs to evaluate what their participants have learned in their REU experience and how their perspectives on STEM have been expanded. PIs also would be well served by obtaining feedback directly related to how their projects might be improved. Accordingly, NSF should recommend that project evaluations include questions about participants' perceptions of project strengths and weaknesses and requests for suggestions about project improvements.
- NSF currently recommends that REU Site PIs track their participants beyond graduation to find out what effect the REU program had on them. We suggest that NSF discontinue this recommendation, for the following reasons:
  - PI efforts to track past participants are likely to produced biased, unscientific findings because participants who are easy to track are likely to be quite different from those who are more difficult to track.

- Most undergraduate researchers participate in a variety of research activities, so follow-up is unlikely to be able to reliably discern the unique effect of a single project.
- Career path information is better obtained through large-scale studies such as this one, with sample sizes that allow for a variety of multivariate analyses and subgroup comparisons.

I. OVERVIEW

INTRODUCTION

In academic and research circles, it is widely believed that undergraduate research opportunities (UROs) help encourage undergraduates to pursue research and teaching careers in the sciences. Aiding in this process is one way in which the National Science Foundation (NSF) achieves its goal of developing a diverse, internationally competitive, and globally engaged workforce of scientists, engineers, and well-prepared citizens.

There have been a number of other studies assessing UROs, but these are either dated—such as NSF's 1990 assessment of the Research Experiences for Undergraduates (REU) Program[1]—or relatively small-scale studies, generally focused on one or a few institutions, a single program, or even a single researcher's experiences. NSF has also funded a study of UROs at four liberal arts institutions that used both qualitative and quantitative approaches to assess the impact of "effective" undergraduate research experiences on learning, attitude, and career choice.[2] SRI's study differs from these other studies in a number of ways, but most importantly in its greater comprehensiveness in terms of the NSF programs included and the survey sample sizes, and, correspondingly, in the numbers and diversity of institutions included.

Major study questions were:

- What are the activities and characteristics that comprise undergraduate "research experiences"?
- For what reasons do faculty and students choose to participate in these experiences?
- What criteria do faculty use in selecting undergraduates for research activities?
- What effects do research experiences have on undergraduates' academic and career decisions?
- What are the key variables that influence the effects of research experiences? In particular, do the effects differ by whether the experience took place during the summer vs. the academic year (fall through spring), the NSF program sponsoring the experience, the academic field of research, or the student's race/ethnicity or sex?
- Are different kinds of research experiences more effective with some types of students than with others? In particular, are the characteristics of the optimal experience different for minorities vs. nonminorities or for men vs. women?

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[1] National Science Foundation. *NSF's Research Experiences for Undergraduates (REU) Program: An Assessment of the First Three Years* (Report 90-58). May 1990. Washington DC: NSF.

[2] David Lopatto and Elaine Seymour. *Pilot Study to Establish the Nature and Impact of Effective Undergraduate Research Experiences on Learning, Attitude, and Career Choice.* 2004. (National Science Foundation award number 0087611).

URO SURVEYS

The study included four Web-based surveys, conducted between 2003 and 2005 and involving almost 15,000 respondents:

- An initial NSF-program participant survey (undergraduates, graduate students, postdocs, and faculty), conducted in 2003.
- Two years later (2005), a follow-up survey of undergraduate participants in the NSF survey.
- A nationally representative survey of individuals ages 22 to 35 who have received a bachelor's degree in a ("hard") science, technology, engineering, or mathematics (STEM), conducted in 2003.
- A nationally representative survey of individuals ages 22 to 35 who have received a bachelor's degree in a social, behavioral, or economic science (SBES), conducted in 2004.

The NSF initial survey focused primarily on respondents' undergraduate research experiences during summer 2002 or the 2002-03 academic year. The other three surveys asked about research experiences throughout the respondents' undergraduate years. To the extent feasible, given the different survey populations and time frames of interest, survey questions were identical across the four surveys. Each survey is described briefly below.[3]

Initial NSF-Program Participant Survey

This survey was actually a set of surveys, involving approximately 8,000 students and faculty participants in more than 1,000 NSF-funded projects across the following NSF programs:

- Research Experiences for Undergraduates (REU) Sites and Supplements
- NSF-sponsored research centers that include a significant undergraduate research component, identified by NSF as all Engineering Research Centers (n=18), all Materials Research Science and Engineering Centers (n=25), and 16 other centers, laboratories, and observatories
- Research in Undergraduate Institutions (RUI)
- Historically Black Colleges and Universities Undergraduate Program (HBCU-UP)
- Tribal Colleges and Universities Program (TCUP)
- Louis Stokes Alliance for Minority Participation (LSAMP) Program
- Cooperative Activity with Department of Energy's Education Programs (DOE)
- Grants for Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE).

[3] A detailed report on each survey has been submitted to NSF. Pending formal NSF approval, report drafts are available on SRI's Web site at http://www.sri.com/policy/csted/reports/university/index.html#uro.

Generally speaking, the sampling strategy was to obtain a diverse group of awards across the NSF programs. For REU Sites (459 awards), REU Supplements (1,155 awards), and RUI (338 awards), awards were randomly sampled, with stratifications by whether the institution was a primarily undergraduate institution (PUI) and by NSF directorate/division. For the other programs (each of which had fewer than 60 awards), all awards that were active as of September 2002 were included. Within each sampled award, all participants involved with undergraduate research—undergraduates, graduate-student/postdoc mentors, principal investigators (PIs), and other faculty mentors—were included.

Prior to the questionnaire administration, contact information was obtained from the PI of each award. In addition, for each individual named, the PI was asked to specify the time period (summer 2002, 2002-03 academic year, or both) during which the individual had participated in undergraduate research. Participants were then contacted by e-mail and directed to a Web site to complete the appropriate questionnaire. (Participants for whom an e-mail address was not available were surveyed by postal mail.) As an incentive, undergraduates were offered a $20 Amazon.com gift certificate in return for their participation, and all respondents were promised a summary of the survey results. Reminders to complete the questionnaire were sent at approximately weekly intervals over an 8-week period between April and June 2003. Ultimately, completed questionnaires were obtained from 76% of the undergraduates (n=4,560), 80% of the graduate students/postdocs (n=822), 81% of the faculty mentors (n=2,140), and 95% of the PIs (n=616).

Surveys of STEM and SBES Graduates

The STEM and SBES surveys involved nationwide samples of approximately 3,400 and 3,200 individuals, respectively. SRI subcontracted with NFO WorldGroup—now TNS NFO—(NFO) to provide the sample and do the data collection.

For each survey, NFO selected the sample from its Interactive Panel, which comprises 1.2 million households and 3.6 million individuals. The starting samples were composed of individuals ages 22 to 35 with a bachelor's degree or higher. To ensure that the samples were representative, they were balanced to U.S. Census profiles for adults of the specified age and education, with an added oversample of Hispanics/Latinos and blacks. Survey sample members were screened to confirm that they met the age and education requirements. STEM/SBES graduates were identified as those who indicated that they had received their bachelor's degree in a STEM/SBES field. Only those who met all eligibility criteria completed the remainder of the questionnaire and are included in the final data file.

For both surveys, the response rate was 40%. In spite of the low response rates, this approach was preferable to one using institution-based lists of past URO participants because the latter approach tends to produce respondent groups with disproportionately high numbers of individuals who are employed in academia. In a study of the effects of UROs on career and academic decisions, such a bias would have seriously damaged the validity of the results.

NSF Undergraduates Follow-up Survey

The sample for this survey comprised all undergraduate respondents to the initial NSF-program participant survey (henceforth, the NSF initial survey). In the initial survey, we told undergraduate respondents that we would be conducting a follow-up survey in 2005, and we

asked them to provide information to help us locate them at that time: their own personal e-mail address and the name and contact information for someone who would be likely to know how to reach them in 2005. One or more of these pieces of information were provided by 4,367 respondents (96%). Late in 2004, we began a series of contact attempts by e-mail, postal mail, and telephone to confirm/update respondent contact information. These efforts focused mostly on attempting to obtain correct addresses for e-mails that "bounced."

Survey data collection began in early May 2005. Procedures were the same as those used for the initial survey. Seven reminders were e-mailed to nonrespondents over the course of the next 3 ½ months. Ultimately, we received responses from 3,354 individuals, representing 74% of all undergraduates who responded to the initial survey and 80% of those for whom (as far as we knew) we were able to find a valid address.

DIFFERENCES BETWEEN RESPONDENTS AND NONRESPONDENTS TO THE FOLLOW-UP SURVEY

Respondents to the follow-up survey differed appreciably from nonrespondents on a number of the questions in the initial survey, but the two groups were very similar on other items. For instance, compared with nonrespondents, follow-up survey respondents were more likely to be non-Hispanic whites (65% vs. 50%), to expect to obtain a PhD (50% vs. 36%), to be REU Site participants (45% vs. 29%), and to have been interested in STEM since childhood (62% vs. 51%); they had higher self-reported grade point averages (41% vs. 28% had grade point averages of 3.7 or higher); and they were younger (18% vs. 32% were age 23 or older).[4] On the other hand, there were no or small differences on a number of the outcome measures, including gains in confidence, understanding, and awareness; overall satisfaction levels; and changes in interest in a career in research.

Despite the differences between respondents and nonrespondents, because the follow-up survey respondents comprised a large majority of respondents to the initial survey, the differences between the initial respondent group and those who responded to the follow-up survey were small. For example, there was a 16-point difference between follow-up respondents and nonrespondents in the percentages who were REU Site participants but only a 4-point difference between follow-up respondents and initial respondents. These findings point up both the difficulty of obtaining unbiased data in longitudinal studies and the importance of high response rates in minimizing the potentially biasing effects.

REPORTING

All survey results presented in this report are based on weighted data. Comparisons noted in this report are significant at the .05 level of significance. In essence, a difference that is found to be significant at the .05 level has a 95% probability that it did not occur simply by chance. Because of the large numbers of respondents for most of the analyses (which result in very small differences being statistically significant), the practical import of differences rather than the statistical significance tended to be the key driver in reporting findings.

[4] Note that these percentages were calculated with the weights used for the initial survey; follow-up survey percentages reported in subsequent chapters differ slightly from those reported here, because the follow-up survey weights differ slightly from the initial survey weights.

II. PROFILE OF UNDERGRADUATE RESEARCHERS

Overall, 53% of STEM graduates and 52% of SBES graduates reported that they participated in hands-on research while they were undergraduates. This chapter provides a general description of the demographic and academic characteristics of these individuals and their counterparts in the NSF surveys.

KEY SURVEY SUBGROUPS

Across the four surveys, four groups of undergraduates proved to have distinctive characteristics for a wide range of study variables.

- NSF researchers. These were the individuals who were undergraduate respondents to the NSF initial survey and who participated in the NSF follow-up survey.
- Sponsored researchers. These were respondents to the STEM and SBES surveys who reported that at least some of their research, as far as they knew, was sponsored by NSF, the National Aeronautics and Space Administration (NASA), or the National Institutes of Health (NIH). Sponsored researchers, especially those in STEM fields, tended to be more similar to the NSF researchers than to their nonsponsored counterparts. Sponsored researchers comprised 7% of STEM graduates and 5% of SBES graduates.
- Nonsponsored researchers. These were respondents to the STEM and SBES surveys whose research was not (as far as they knew) sponsored by NSF, NASA, or NIH. Nonsponsored researchers comprised 46% of STEM graduates and 47% of SBES graduates.
- Nonresearchers. These were respondents to the STEM and SBES surveys who did not participate in undergraduate research. Nonresearchers comprised 47% of STEM graduates and 48% of SBES graduates.

DEMOGRAPHIC CHARACTERISTICS

Findings from all four surveys indicated that women and traditionally underrepresented minorities were well represented in undergraduate research opportunities (UROs). In the STEM and SBES surveys, Hispanic/Latinos' and blacks' participation rates were equivalent to or slightly higher than those of non-Hispanic whites, and participation rates for men and women were almost identical. Minorities and women were similarly well represented among NSF undergraduate researchers in 2002-03. Similar percentages of participants were men (47%) and women (53%), 10% were black, and 17% were Hispanic/Latino. By comparison, excluding nonresident aliens, 9% of STEM bachelor's degrees in the United States in 1999-2000 were awarded to blacks and 5% to Hispanics/Latinos.[5]

[5] National Center for Education Statistics, *Digest of Education Statistics, 2002*. Data table 255. The relatively high percentage of Hispanics/Latinos in the NSF survey was due partly to the 185 Puerto Rican respondents (most were LSAMP participants), who comprised 30% of all Hispanic/Latino respondents. Mainland U.S. Hispanics/Latinos comprised 10% of undergraduate researchers.

ACADEMIC CHARACTERISTICS

NSF Researchers' Academic Class Level

Undergraduate researchers were disproportionately juniors and seniors. In the NSF initial survey, we asked undergraduates what their academic class level was at that time. More than 6 in 10 reported that they were seniors.[6] Another 27% were juniors, 8% were sophomores, and 1% were freshmen. In the SBES survey, we asked respondents to recall the academic class level(s) at which they participated in undergraduate research. Of those who participated at all, 52% said that they participated as seniors, 54% participated as juniors, 22% as sophomores, and 9% as freshmen. (STEM survey respondents were not asked this question.)

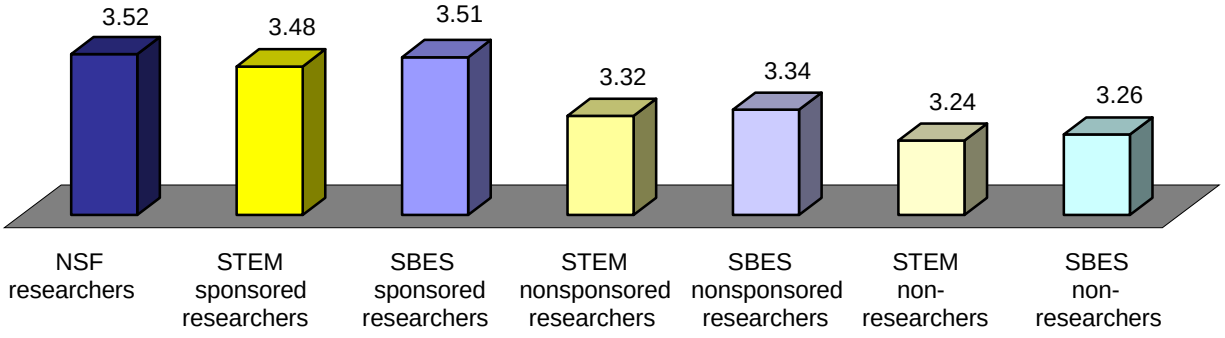
Academic Major

There were substantial differences in research participation rates across the various academic majors, especially in STEM fields. Rates ranged from a high of 74% of those who majored in environmental sciences and 72% of those in chemistry to a low of 28% of those who majored in STEM education. Other majors whose research participation rates were lower than average were computer sciences (37%) and mathematics (34%)—fields in which research activities tend to be atypical. In SBES fields, participation rates ranged from 63% of psychology majors to 38% to 40% of majors in criminology/criminal justice, economics, and political science.

Undergraduate Grade Point Averages (GPAs)

In both the STEM and SBES surveys, we found that researchers' self-reported GPAs tended to be higher than those of nonresearchers, and the GPAs of sponsored and NSF researchers were especially high (Figure II-1).

Figure II-1
Mean Self-Reported GPAs



Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

Pre-College/Pre-Research Degree Expectations

STEM and SBES researchers were twice as likely as nonresearchers to have pre-college or pre-research expectations of obtaining a PhD. (That is, they reported that before they attended

[6] Academic class participation in research includes those who participated in the summer preceding the specified class level. For example, "seniors" includes rising seniors.

college or participated in any undergraduate research, they expected to obtain a PhD.) Overall, 14% of both STEM and SBES researchers had such expectations, compared with 7% of the nonresearchers in each survey. "Early" PhD expectations were related to both research sponsorship and total duration of undergraduate research experiences. For example, 37% of NSF researchers, 26% of STEM sponsored researchers, and 21% of STEM nonsponsored researchers who participated in more than 12 months of undergraduate research had early expectations of obtaining a PhD.

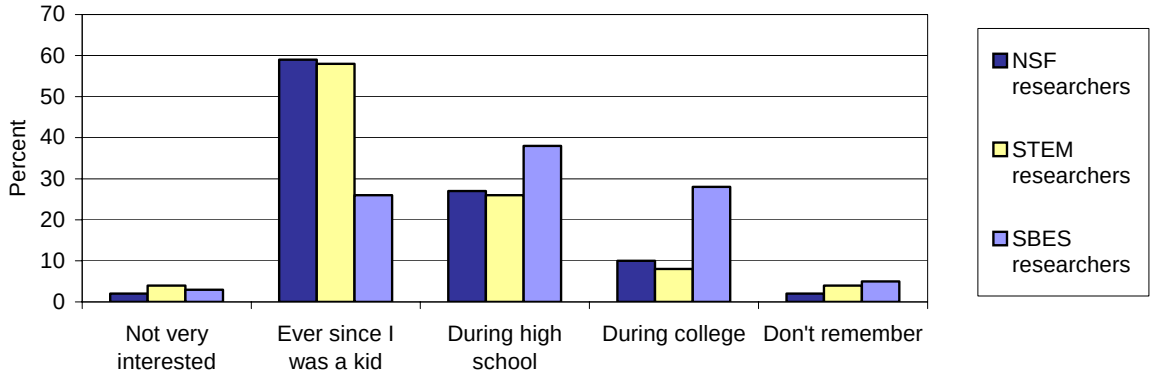
Type of School

Rather surprisingly, the STEM and SBES surveys found that research participation rates were not very different across the major types of 4-year institutions, ranging from 49% among STEM graduates of master's institutions to 57% among STEM graduates of doctoral/research-extensive universities and baccalaureate colleges. There were similar differences in rates of participation in sponsored research: 11% of STEM graduates and 5% of SBES graduates of master's institutions; 17% of STEM graduates and 13% of SBES graduates of doctoral/research-extensive universities. Equally surprisingly, students who had started their undergraduate education at a 2-year college (17% of STEM graduates and 18% of SBES graduates) were as likely to have participated in research as those who had started at a 4-year institution.[7]

ORIGINS OF INTEREST IN STEM/SBES

For STEM and NSF researchers, interest in STEM was likely to have begun in childhood. About 6 in 10 STEM and NSF researchers reported that they had been interested in science/ math/engineering "ever since I was a kid," and only 8% to 10% became interested in college. In contrast, only about a fourth of SBES researchers said they had become interested in SBES in childhood, about the same percentage as became interested during college (Figure II-2). We suspect that the percentage interested in STEM/SBES since childhood is lower for SBES majors than for STEM majors in part because SBES topics are less likely than STEM topics to be

Figure II-2
Origins of Researchers' Interest in STEM/SBES



Sources: SRI International: NSF initial survey, 2003; STEM survey, 2003; SBES survey, 2004.

[7] We did not ask whether students participated in research at 2-year colleges. However, since most undergraduate research occurs during students' junior and senior years, it is likely that in most cases the research was conducted after the student transferred to a 4-year college.

covered in elementary school, so awareness of SBES among elementary school students is relatively low. The low percentage of STEM majors who became interested during college also may reflect the steep learning curve required (or at least perceived to be required) of someone who waits until college to take up a STEM field.

Within the STEM and SBES groups, sponsored researchers were more likely than their nonsponsored counterparts to have developed an early interest in STEM/SBES, and nonsponsored researchers were more likely than nonresearchers to have developed an early interest. Overall, the large percentages who developed early interest in STEM suggest that the most effective time to attract students to STEM may well be while they are in grammar school; it would appear that waiting until college may be too late for many.

OVERVIEW OF UNDERGRADUATE RESEARCHER PROFILE

About half of STEM and SBES graduates reported that they participated in hands-on research while they were undergraduates; 7% and 5%, respectively, reported that they participated in research sponsored by NSF, NASA, or NIH. Rates of participation in undergraduate research generally and in sponsored research were lowest at master's institutions and highest at doctoral/research-extensive universities, but the differences were less than 10 percentage points—much less than the 46-point range in participation rates of the various STEM academic majors.

In all our URO surveys, we found that undergraduate researchers were demographically diverse, with women and traditionally underrepresented minorities represented at rates at least equivalent to their rates in the college population. Academically, undergraduate researchers were less diverse. They were disproportionately juniors and seniors, had relatively high GPAs, and were considerably more likely than nonresearchers to have pre-college or pre-research expectations of obtaining a PhD. Among SBES and STEM graduates, those who participated in sponsored research were especially likely to have high GPAs and early expectations of obtaining a PhD.

For STEM and NSF researchers, interest in STEM was likely to have begun in childhood; very few became interested when they were in college. In contrast, only about a fourth of SBES researchers said they had become interested in SBES in childhood. These findings suggest that the most effective time to attract students to STEM may well be while they are in grammar school; it would appear that waiting until college is too late for many.

III. REASONS FOR PARTICIPATING (OR NOT) IN UNDERGRADUATE RESEARCH

UNDERGRADUATES' PERCEPTIONS

Reasons for Research Participation

During site visits conducted early in the study,[8] we talked with undergraduates about why they were interested in doing research. From these interviews and a review of other surveys about undergraduate research, we developed a list of nine potential reasons for participating in research. We asked undergraduates in the NSF initial survey and STEM and SBES survey respondents to rate the importance of each reason. The percentages of NSF respondents and STEM/SBES sponsored and nonsponsored researchers who rated each reason as extremely important are presented in Table III-1.

Table III-1

Undergraduates' Motivations for Participating in Research:
Percentage of Each Group Who Rated Each Reason as "Extremely Important"
(Listed in descending order of the "NSF Initial Survey" column)

	NSF Initial Survey	STEM Sponsored	SBES Sponsored	STEM Nonsponsored	SBES Nonsponsored
Number of respondents:	*4,541*	*246*	*163*	*1,542*	*1,459*
I wanted to learn more about what it's like to be a researcher.	[62]	44	47	(18)	29
I wanted hands-on experiences to reinforce what I learned in class.	[57]	52	49	(43)	46
I wanted to know if going to grad school in science or engineering [a social/behavioral science] was for me.	[50]	45	43	(17)	29
I thought it would be fun.	[48]	39	42	(31)	36
I thought it would help me get into graduate/medical school [graduate/law/ business school] or get a job.	45	[49]	[49]	(29)	40
Doing research was more appealing than other kinds of jobs.	[45]	42	[45]	24	(22)
I wanted to know if science or engineering [a social/behavioral science] was for me.	28	34	[35]	(16)	30
I needed/wanted the academic credit I could get from doing research.	(8)	21	37	24	[43]
I needed to fulfill my school's/my scholarship's requirements for research.	(6)	15	[31]	20	28

This table shows, for example, that in the NSF initial survey, 62% of respondents reported that wanting to learn more about what it's like to be a researcher was extremely important in their decision to participate in undergraduate research.

Note: A boxed number indicates the group with the highest percentage in that row; a circled number indicates the group with lowest percentage.

Sources: SRI International: NSF initial survey, 2003; STEM survey, 2003; SBES survey, 2004.

[8] Primarily to help guide development of the survey questionnaires, SRI conducted site visits to a diverse group of 20 institutions in the United States that provide research opportunities to undergraduates.

There was considerable variation in the five groups' responses. The only reason that close to half or more of each group rated as extremely important was wanting hands-on experiences to reinforce what had been learned in class. On most of the items, NSF researchers had relatively high ratings, and STEM/SBES sponsored researchers were more like NSF respondents than like their nonsponsored STEM/SBES counterparts. However, there were two rather dramatic exceptions. STEM and, especially, SBES researchers were much more likely than NSF researchers to rate need for academic credit and need to fulfill academic requirements for research as extremely important. These differences reflect, at least in part, the fact that most NSF undergraduate research programs—especially the summer programs—do not provide academic credit. (In the initial NSF survey, only 30% of the undergraduates reported that they received academic credit for their NSF-supported research activities.)

Reasons for Not Participating in Research

STEM and SBES graduates who indicated that they had not participated in research were asked, "Which of the following help to describe why you did not participate in any hands-on research activities when you were in high school or a college undergraduate?" The response options are listed in Table III-2, in descending order of the percentages of STEM graduates who selected them. Overall, it was much more common for students to *choose* not to participate in research than to be *unable* to participate (that is, unable either because research opportunities

Table III-2

Undergraduates' Reasons for Not Participating in Research: Percentage of Each Group Who Cited Each Reason (Listed in descending order of the "STEM Nonresearchers" column)

	STEM Nonresearchers	SBES Nonresearchers
Number of respondents	*1,456*	*1,575*
(1) I didn't have time	37	34
(2) I was not interested in doing research	37	32
(3) Research opportunities were not available to me (or I didn't know about them)*	28	38
(4) It never occurred to me to do research	18	23
(5) It didn't pay well enough (or at all)	13	7
(6) The research opportunities that were available to me weren't interesting	11	8
(7) Faculty did not conduct research at the school I attended	9	7
(8) My grades were not good enough	3	2
(9) I applied/asked about doing research but was turned down	2	1
(10) Other reasons	1	<1

This table shows, for example, that 37% of STEM nonresearchers reported that "I didn't have time" helped to describe why they did not participate in any hands-on research activities when they were in high school or a college undergraduate.

*The parenthetical clause was included only in the SBES survey.

Sources: SRI International: STEM survey, 2003; SBES survey, 2004.

were not available or because the respondent was turned down): 80% of STEM nonresearchers and 73% of SBES nonresearchers selected one or more of the "choice" options (options 1, 2, 4, 5, and 6); 39% of STEM nonresearchers and 44% of SBES nonresearchers selected one or more of the "unable" options (options 3, 7, 8, and 9).

Interestingly, the perception of availability of research opportunities did not increase appreciably over the 15 years covered by the surveys, but the awareness of research as a personal option did: the percentage who selected "it never occurred to me" decreased over time: 31% of SBES majors who graduated between 1989 and 1992, 24% of those who graduated between 1993 and 1997, and 20% of those who graduated between 1998 and 2004. In the STEM survey, a parallel trend was observed, but the percentages were slightly smaller.

MENTORS' PERCEPTIONS

Benefits of Undergraduate Research

During the site visits, we talked with faculty and graduate students about why they chose to involve undergraduates in their research and what the benefits and drawbacks were. From these interviews, we developed a number of agree-disagree items for the initial NSF survey, reflecting many of the views that were expressed. Overall, responses to these items suggest that it was personal satisfaction much more than career or research factors that was the driving force for most mentors. Three of the four most commonly agreed-to items related to personal motivation. For example, 75% of faculty mentors (including PIs) and 64% of graduate-student/postdoc mentors agreed that "I get a lot of personal satisfaction out of working with undergraduates doing research." Other factors appeared to be weighted somewhat *against* undergraduate research. For instance, among those to whom the items applied, only about 4 in 10 faculty mentors agreed that mentoring undergraduates enables them to expand their research avenues (37%), is viewed favorably in their department's tenure/promotion review process (38%), or (among those who have graduate students) is a good way to recruit the undergraduates to be graduate students in their lab/department (43%). Predictably, the faculty mentors who were at primarily undergraduate institutions (PUIs)[9] tended to have more favorable views of undergraduate research than did those at non-PUIs. This was particularly true with regard to how mentoring undergraduates is viewed in the tenure/promotion review process. On this item, 61% of those at PUIs to whom the item applied agreed that mentoring is viewed favorably, compared with 32% of those at non-PUIs.

Potential Barriers to Increased Undergraduate Research

NSF center and REU Site PIs were asked their perceptions of a variety of potential barriers to increasing the number of undergraduates involved in their center/site. The most commonly perceived barriers were related to financial support. Seventy-five percent agreed or agreed somewhat that they would include more undergraduates if they had financial support for more undergraduates. The only other factor perceived to be a barrier by more than half of the respondents was insufficient faculty or researchers available/willing to be mentors (60% agreed or agreed somewhat).

[9] There were relatively few PUI faculty mentors in the sample—they comprised only 16% of all faculty mentors.

OVERVIEW OF REASONS FOR PARTICIPATING (OR NOT) IN UNDERGRADUATE RESEARCH

Undergraduates' reasons for participating in research differed considerably among NSF, STEM, and SBES respondents and between the sponsored and nonsponsored groups in the STEM and SBES surveys. Across all groups, wanting hands-on experiences to reinforce what had been learned in class was important. Needing academic credit and needing to fulfill academic requirements for research were much more important motivators for STEM and, especially, SBES researchers than for NSF researchers. In contrast, wanting to learn what it's like to be a researcher was much more important for NSF and STEM/SBES sponsored researchers than for STEM/SBES nonsponsored researchers. STEM and SBES graduates who did not participate in undergraduate research were much more likely to have chosen not to participate than to have been unable to participate.

For mentors, personal satisfaction—much more than career or research factors—appeared to be the driving force in their inclusion of undergraduates in their research. The most commonly perceived barriers to including undergraduates were related to financial support.

IV. CHARACTERISTICS AND ACTIVITIES OF UNDERGRADUATE RESEARCH EXPERIENCES

In this chapter, we summarize the characteristics of undergraduate research experiences and the activities that comprised those experiences. The relationships between research activities/ characteristics and URO effects are discussed in subsequent chapters.

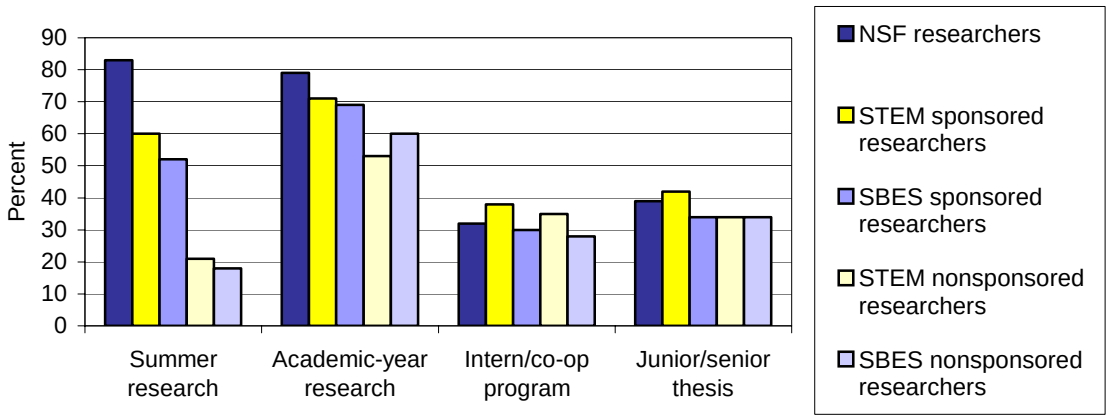
TYPES OF RESEARCH EXPERIENCES

The surveys focused on four major types of undergraduate research experiences, described in the questionnaires as follows:

- Summer research, other than intern or co-op program. A full-time hands-on research project for the summer with a professor or researcher.
- Hands-on research with a professor during one or more academic terms, while enrolled in classes.
- Intern or co-op program that involved hands-on research as its main component. Usually, a company or other organization pays you for working on a research project at their site. Sometimes you receive academic credit at your school for this research. May happen any time of year.
- A junior or senior thesis that involves hands-on research (other than library research) as its main component.

NSF undergraduate research programs are distinctive in their emphasis on summer research. As shown in Figure IV-1, respondents to the NSF follow-up survey were considerably more likely than STEM and SBES sponsored researchers and much more likely than STEM and SBES nonsponsored researchers to have participated in summer research. NSF and STEM/SBES sponsored researchers also were more likely than nonsponsored researchers to have participated in academic-year research, but the differences were not nearly as large. There were only small differences in rates of participation in intern/co-op programs and junior/senior thesis research.

Figure IV-1
Rates of Participation in Major Types of Undergraduate Research

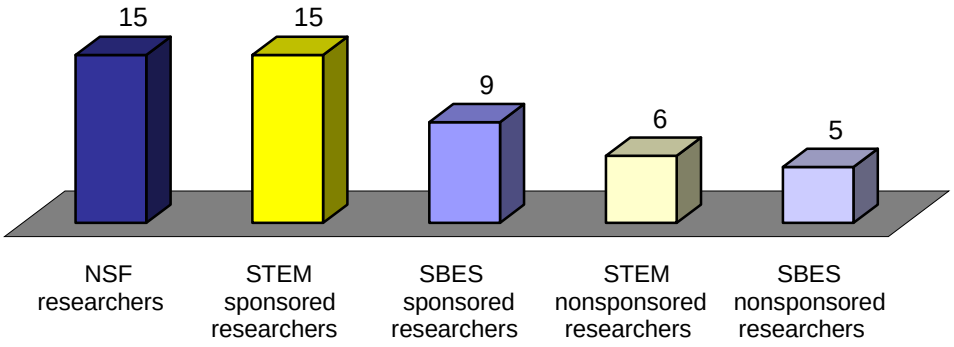


Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

RESEARCH DURATION

NSF and STEM sponsored researchers tended to spend considerably more time engaged in undergraduate research than did STEM nonsponsored or SBES researchers (Figure IV-2).

Figure IV-2
Median Months of Undergraduate Research



Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

Among SBES researchers, the sponsored group averaged more time in research than those who were not sponsored, but the difference was not nearly as large as that between STEM sponsored and nonsponsored students. In all of these groups, those who reported that they either had a PhD or expected that they would have one in 10 years tended to have more research experience than those without PhD expectations. For example, among NSF follow-up survey respondents who had received their bachelor's degree, 40% of current graduate students expecting a PhD participated in research for at least 24 months, compared with 28% of other graduates.

RESEARCH LOCATIONS

By far the most common location of undergraduate research was the respondent's own college or university. Among each of the five researcher groups that we have been discussing, between 80% and 90% of respondents participated in research at their own school. Rates of research participation at some other college or university were highest among NSF researchers, at 41%; 18% and 13% of STEM and SBES sponsored researchers did so; only 6% and 4% of STEM and SBES nonsponsored researchers did so. The five groups' rates of participation at other types of entities—for-profit companies, nonprofit organizations, and government facilities—ranged between 6% and 22%.

RESEARCH ACTIVITIES

Table IV-1 shows the percentage of each of the five researcher groups who reported engaging in each of 19 research-related activities/experiences. Only five activities were reported by more than 50% of all groups:

- Collected and/or analyzed data or information to try to answer a research question
- Had input to or responsibility for decisions about what to do next
- Had a choice of projects to work on

Table IV-1

Undergraduate Research Activities and Experiences Reported in the NSF Follow-up, STEM, and SBES Surveys

(Listed in descending order of the "NSF Follow-up Survey" column)

	NSF Follow-up Survey	STEM Sponsored	SBES Sponsored	STEM Nonsponsored	SBES Nonsponsored
Number of respondents:	*3,278*	*246*	*163*	*1,542*	*1,459*
Collected and/or analyzed data or information to try to answer a research question	[88%]	84%	(61%)	79%	81%
Understood how my work contributed to the "bigger picture" of research in that field	[76]	66	52	57	(49)
Had input to or responsibility for decisions about what to do next	76	[81]	77	71	(68)
Delivered an oral presentation describing my research and results	[73]	59	(35)	44	39
Had a choice of projects to work on	72	76	[78]	(65)	67
Prepared a final written research report describing my research and results	[70]	63	(47)	58	60
Gained increasing independence over the course of the research	[69]	59	45	43	(35)
Had input to or responsibility for decisions about research techniques/materials	65	73	[76]	64	(63)
Prepared/presented a poster presentation describing my research and results	[64]	44	27	21	(18)
Was able to complete my project	58	65	(51)	66	[67]
Provided input to designing my project	58	[64]	53	47	(41)
Attended student conference(s) that included students from other colleges	[44]	36	21	14	(13)
Wrote a proposal describing the research I planned to do	(41)	52	[53]	42	47
Went on research-related field trip(s)	37	[39]	na	(21)	na
Attended professional conference(s)	[36]	32	21	(15)	16
Had primary responsibility for designing the project that I worked on	(33)	40	[41]	37	38
Authored or co-authored a paper that was submitted for publication in a professional journal	[30]	29	13	10	(8)
Mentored other students conducting research or led a student research team	24	na	na	na	na
Did little or nothing that seemed to me to be real research	(6)	7	[13]	7	(6)

This table shows, for example, that in the NSF follow-up survey, 88% of respondents reported that they collected/analyzed data as part of their research experience.

Notes: A boxed number indicates the group with the highest percentage in that row; a circled number indicates the group with lowest percentage.
na = not asked.

Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

- Had input to or responsibility for decisions about research techniques/materials
- Was able to complete my project.

There was considerable variation among the five groups in the percentages who engaged in the various activities, but NSF researchers tended to have relatively high participation rates and SBES nonsponsored researchers tended to have relatively low rates. Activities with the largest differences among the groups were:

- Preparation of a poster presentation (high: 64% of NSF researchers; low: 18% of SBES nonsponsored researchers)
- Delivery of an oral presentation (high: 73% of NSF researchers; low: 35% of SBES sponsored researchers)
- Gained increasing independence (high: 69% of NSF researchers; low: 35% of SBES nonsponsored researchers)
- Collected/analyzed data (high: 88% of NSF researchers; low: 61% of SBES sponsored researchers)
- Understood how work contributed to "bigger picture" (high: 76% of NSF researchers; low: 49% of SBES nonsponsored researchers).

NSF researchers were also the most likely of the groups to have prepared a final written report (70% did so) and attend a professional conference (36%). They and STEM sponsored researchers were more likely than others to have authored or co-authored a journal paper (30% and 29%, respectively). Interestingly, NSF researchers were the least likely to have written a research proposal (41%) and to have had primary responsibility for project design (33%).

Differences between sponsored and nonsponsored groups tended to be larger and were more consistent among STEM researchers than among SBES researchers. Sponsored vs. nonsponsored differences probably were due in large part—although not entirely—to the fact that sponsored researchers tended to participate in research longer than did nonsponsored researchers.

OVERVIEW OF UNDERGRADUATE RESEARCH CHARACTERISTICS AND ACTIVITIES

Relative to undergraduate research in general, NSF programs are distinctive in their emphasis on research conducted during the summer and at other institutions than the student's home college. NSF researchers were the most likely, and nonsponsored researchers by far the least likely, to have participated in summer research programs, and there were corresponding differences in the percentages who participated in research at some location other than their own college or university. NSF and STEM/SBES sponsored researchers tended to spend more time engaged in undergraduate research than did nonsponsored researchers and to have participated in a greater variety of activities. Differences between sponsored and nonsponsored groups tended to be larger and were more consistent among STEM researchers than among SBES researchers. Among all groups, common research-related activities were collecting/analyzing data, having input to research decisions, having a choice of projects, and being able to complete one's project.

V. PERCEPTIONS AND OUTCOMES

The questionnaires included a variety of topics related to the respondents' opinions of their research experiences, as well as their academic and employment characteristics. All four surveys included questions about perceptions of gains made on various dimensions, perceptions of effects of their experiences on their interest in several STEM/SBES-related careers, and academic degree expectations. Other outcome-related topics were covered in only some surveys.

SATISFACTION WITH UNDERGRADUATE RESEARCH

Satisfaction with undergraduate research experiences overall (assessed in the NSF surveys) tended to be high: 64% of NSF follow-up survey respondents said they were very satisfied, and another 30% said they were somewhat satisfied; half (48%) reported that it was "one of the best experiences of my life"; and 43% wished they had done more undergraduate research, whereas a mere 2% said they wished they had done less.

In contrast to the high levels of satisfaction with conducting undergraduate research, NSF follow-up survey respondents tended to be only moderately satisfied with how well informed they were about the UROs at their own college or university (36% were very satisfied, 38% somewhat satisfied) and less so with how well informed they were about UROs at places other their own school (23% were very satisfied, 37% somewhat satisfied). A number of respondents' suggestions for how to improve UROs related to wider and more effective dissemination of information about UROs.

PERCEPTIONS OF INCREASED UNDERSTANDING, CONFIDENCE, AND AWARENESS

All surveys assessed perceived gains by asking respondents to rate how much they thought they had gained in each of a number of areas as a result of their research experiences. Variables that correlated with one another were aggregated into indices, which we labeled "understanding," "confidence," and "awareness." The components of each index are outlined below.

Increased understanding about:

- How to formulate a research question
- How to plan/conduct a research project
- How to deal with setbacks, "negative results," etc.
- How STEM knowledge is built
- The nature of the job of a researcher (in index only in NSF surveys)

Increased confidence in:

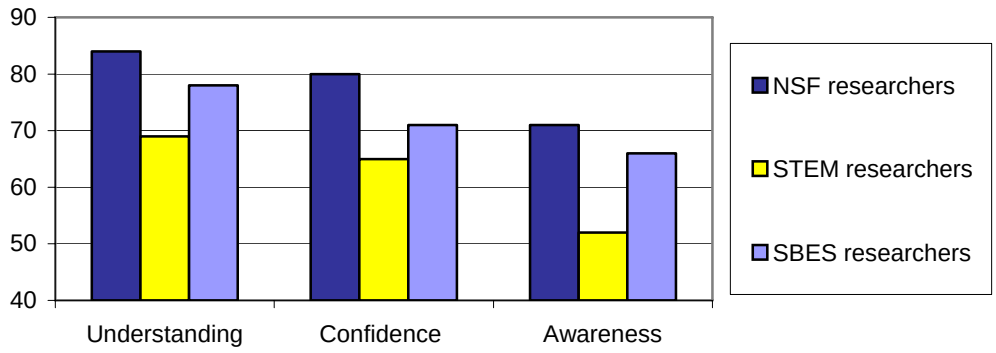
- Research skills
- Ability to succeed in grad school
- Qualifications for jobs in related fields

Increased awareness of:

- What graduate school is like
- STEM/SBES career options
- Variety of STEM/SBES fields available
- Faculty career paths.

In all surveys, most respondents reported gains of a fair amount or a great deal on all three dimensions, although more so on understanding and confidence than on awareness (Figure V-1). Overall, NSF researchers tended to have the highest scores, followed by SBES researchers and then STEM researchers. Among SBES and STEM researchers, those who were sponsored tended to have higher scores than those who were not.

Figure V-1
Mean Percentage of Each Group Who Rated Gains as "A Fair Amount" or "A Great Deal"



Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

In the NSF initial survey, graduate-student/postdoc and faculty mentors and PIs were asked how much they thought that the undergraduates they mentored during summer 2002 (or the 2002-03 academic year) developed on each of the dimensions that the students were asked about. For the most part, faculty tended to believe that undergraduate gains were greater than the undergraduates themselves believed, and PIs tended to have somewhat more positive perceptions than mentors. The particularly positive ratings by PIs probably reflect the fact that they are the ones who obtained the grants to involve undergraduates and whose responsibility it is to show positive effects.

IMPORTANCE OF UNDERGRADUATE RESEARCH IN ACADEMIC AND CAREER DECISIONS AND INTERESTS

Choice of Baccalaureate School

As noted in Chapter IV, the vast majority of undergraduate researchers participated in undergraduate research at their own college/university. The NSF follow-up survey found that, when these researchers first enrolled as undergraduates, only half were aware that the school offered undergraduate research. Of those who were aware, 55% said that UROs were fairly or

extremely important in their decision to enroll. Thus, overall, UROs were important in the decision to enroll for only a fourth of the respondents.

Graduate School Decisions

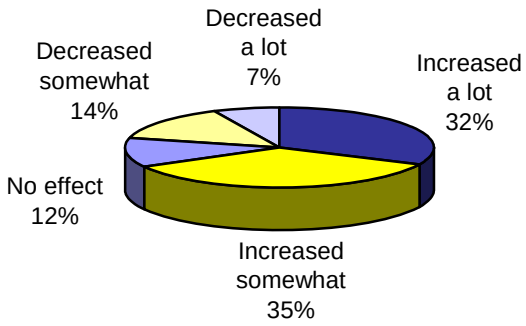
Although undergraduate research was unlikely to play a role in decisions about undergraduate schools, it did help inform graduate school decisions. About 8 in 10 graduate students who expected to obtain a PhD reported that their undergraduate research experiences were fairly or extremely important in their decision to attend graduate school, their decision about what field to study in graduate school, and their acceptance into graduate school. Six in 10 also indicated that their undergraduate research experiences were important in helping them decide where to apply.

Career Decisions

Regardless of whether they expected to obtain a PhD, almost all follow-up survey respondents (89%) reported that their undergraduate research experiences were fairly or extremely important to their career decision. Sponsored researchers in the STEM and SBES surveys gave similar ratings; nonsponsored researchers' ratings were lower (70% and 62% of STEM and SBES nonsponsored researchers said their undergraduate research experiences were fairly or extremely important).

Changes in Interest in Various Careers

Figure V-2
Change in Interest in a Career in Research as a Result of Undergraduate Research Experiences: NSF Follow-up Survey Respondents



Source: SRI International: NSF follow-up survey, 2005.

In all surveys, about half or more of the respondents reported that their undergraduate research experiences increased their interest at least somewhat in careers in STEM/SBES and in research. In the NSF follow-up survey, 67% said their interest in a research career increased, and 21% said it decreased (Figure V-2). Percentages whose interest increased were somewhat lower among STEM and SBES researchers than among NSF researchers, but STEM and SBES sponsored researchers' responses were equivalent to those of the NSF follow-up respondents.

Interestingly, among all groups, larger percentages reported a *decreased* interest in a career in research than in a career in STEM/SBES.[10] For example, compared with the 21% of NSF follow-up survey respondents who reported a decreased interest in a research career, only 8% reported a decreased interest in a STEM career. Similarly, 17% of follow-up survey respondents reported that one of the things they learned from their undergraduate research was that "research is not for me." Thus, the surveys found support for anecdotal reports of how

[10] Although the survey item referred to simply "a career in research," it is likely that most respondents interpreted this to mean research in academia, since academia was where almost all of them conducted their undergraduate research.

undergraduate research participation shows some students that research is not what they want to do after all.

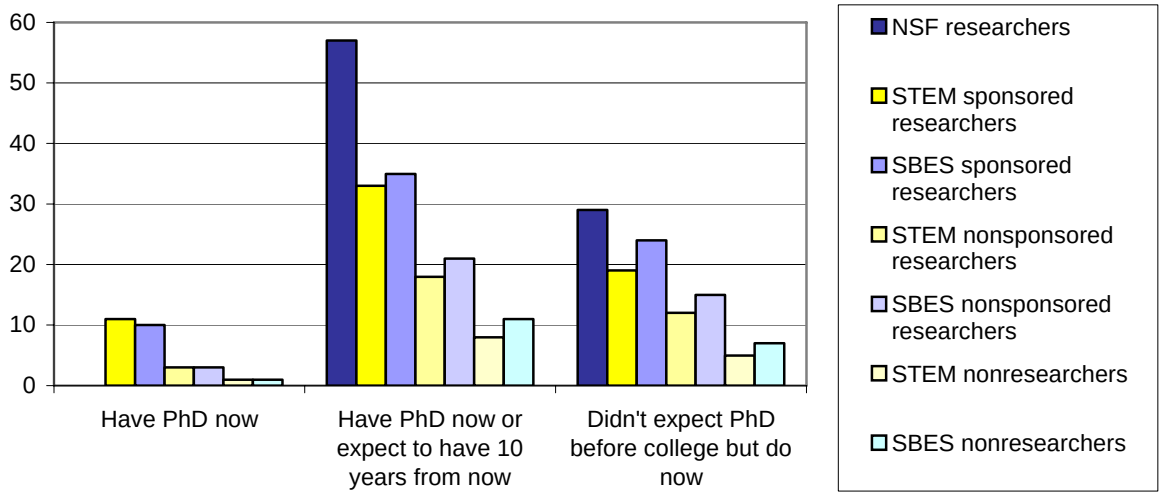
Use of STEM Knowledge in Jobs

The use of STEM knowledge in one's job is not limited to those with PhDs. Eight in 10 NSF follow-up survey respondents who were no longer students reported that their job was at least somewhat related to their (STEM) undergraduate major, 75% said that they used skills learned doing undergraduate research in their job, and 64% said that their job involved science/math research or engineering.

HIGHEST DEGREE EXPECTATIONS AND ATTAINMENT

In Chapter II, we reported that undergraduate research tends to attract those with high degree expectations. We found that it also encourages such expectations. In both the STEM and SBES surveys, researchers were more likely than nonresearchers to have obtained a PhD, to have current expectations that they would have a PhD in 10 years (that is, at the time of the survey, they expected they would obtain one), and to have new expectations of obtaining a PhD (that is, before they started college or did undergraduate research, they did not expect to obtain one, but now they do have such expectations). Consistent with other findings, sponsored researchers and NSF researchers were especially likely to have or expect to obtain a PhD (Figure V-3).[11]

Figure V-3
Percentage of Each Group Who Have/Expect a PhD



Sources: SRI International: STEM survey, 2003; SBES survey, 2004; NSF follow-up survey, 2005.

[11] As Figure V-3 shows, no NSF researchers had obtained a PhD. The reason is that, at the time of the follow-up survey, they were at most 2 years beyond their bachelor's degree. In contrast, STEM and SBES respondents were ages 22 to 35, so many of them had had ample time to complete advanced degrees.

OVERVIEW OF PERCEPTIONS AND OUTCOMES

Overall satisfaction with undergraduate research experiences tended to be high, and most respondents reported gains of a fair amount or a great deal on a set of items about the effect of their research experiences on their understanding of the research process, confidence in their abilities, and awareness of academic and career options in STEM. (Interestingly, faculty mentors, especially PIs, gave the students even higher gain ratings than did the students themselves.) Most researchers also reported that their research experiences were important to their career decision and that their interest in STEM-related careers increased as a result of their research participation. Researchers were more likely than nonresearchers to expect to obtain a PhD and to have new expectations of obtaining a PhD. On all these measures, the positive effects were more pronounced among STEM and SBES sponsored researchers and NSF researchers than among STEM and SBES nonsponsored researchers.

Among NSF follow-up survey respondents who were in graduate school and expecting a PhD, a large majority reported that their undergraduate research experiences were fairly or extremely important in their decision to attend graduate school, their decision about what field to study in graduate school, and their acceptance into graduate school. And of those who were no longer students, about two-thirds said that their job involved science/math research or engineering.

In contrast to their very positive reports of the research experiences themselves, researchers tended to believe that they were not very well informed about UROs, especially those at places other than their own school. The NSF follow-up survey also found that, when researchers first enrolled as undergraduates, only half were aware that the school offered undergraduate research, and, of those who were aware, only about half said that UROs were fairly or extremely important in their decision to enroll. These findings suggest that better dissemination of information about UROs is essential if undergraduate research is to achieve its greatest potential impact. They also suggest that UROs might well be used as a recruiting tool by colleges and universities.

VI. CORRELATES OF UNDERGRADUATE RESEARCH OUTCOMES

The preceding chapter discussed a number of outcome measures. In this chapter, we focus mostly on three of those measures: gains in confidence, increased interest in a career in research, and current expectations of obtaining a PhD. These measures were quite strongly related to some motivations for participating in research and to some of the characteristics and activities that comprised research experiences. They also were related to one another to varying degrees. However, there were only small differences in outcomes among racial/ethnic groups and essentially no differences between men and women. Each group of relationships is discussed below.

RELATIONSHIPS BETWEEN OUTCOMES AND REASONS FOR PARTICIPATING IN RESEARCH

Respondents for whom needing help with an academic or career decision was an important reason for participating in research and those for whom personal enthusiasm/interest was important[12] tended to report higher gains, be more likely to have an increased interest in a research career, and be more likely to expect to obtain a PhD than did those for whom these were not important motivations. For example, among STEM researchers:

- 59% of those for whom needing help with an academic or career decision was very important were "high gainers"[13] on the confidence index, compared with 16% of those for whom needing help with a decision was not important.
- 47% of those for whom needing help with a decision was very important said their interest in a research career increased a lot, compared with 5% of those for whom needing help with a decision was not important.
- 37% of those for whom needing help with a decision was very important expected to obtain a PhD, compared with 12% of those for whom needing help with a decision was not important.

In contrast, engaging in undergraduate research to meet academic requirements tended not to be as strongly related to the outcome measures and was actually slightly negatively related to expectations of obtaining a PhD. These findings suggest that research participation is most likely to be an effective motivator when it is done voluntarily and out of a genuine interest and that requiring research experiences for undergraduates may be counterproductive.

All research motivations were less strongly related to expectations of obtaining a PhD than they were to increased interest in a research career or to gains in confidence. Also, in most cases, the relationships between motivations and outcomes were much stronger among STEM and SBES respondents than among NSF respondents, probably because the motivation questions

[12] These were indices created from questions in the NSF initial, STEM, and SBES surveys that asked respondents to rate the importance of each of various factors in their decision to participate in undergraduate research. See Table III-1 on page 9 for a list of the factors.

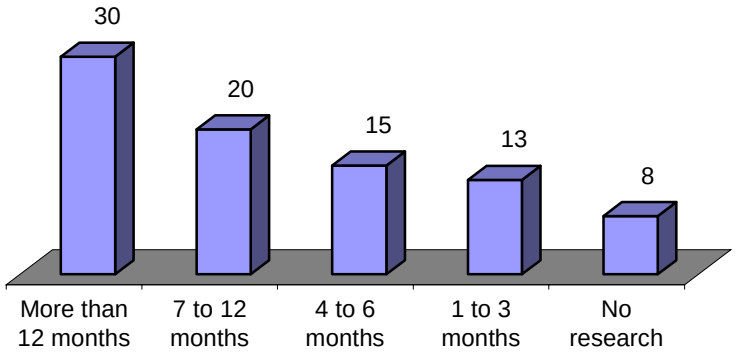
[13] For each index, respondents were grouped into four approximately equally sized categories on the basis of their mean ratings in that index. "High gainers" are those with scores in the top category.

were structured somewhat differently in the STEM and SBES surveys than in the NSF survey rather than because of any substantive difference among the survey groups.[14]

RELATIONSHIPS BETWEEN OUTCOMES AND RESEARCH ACTIVITIES

As with research motivations, the number of research activities in which the student engaged (listed above in Table IV-1) and the total duration of the student's undergraduate research experiences were strongly related to research outcomes. Figure VI-1 shows, for example, the relationship between research duration and PhD expectations for STEM graduates.

Figure VI-1
Percentage Who Expect to Obtain a PhD, by Duration of Undergraduate Research Experiences: STEM Graduates Survey



Source: SRI International: STEM survey, 2003.

Among the specific research activities, those that were the most strongly related to research outcome measures are listed below, in approximate descending order of the strength of their relationship with outcome measures in the several surveys.

- Having authored/co-authored a paper that was submitted for publication in a professional journal
- Having attended professional or student conferences
- Having mentored other student researchers or led a student research team (asked in NSF follow-up survey only)
- Having gained increasing independence

Characteristics of the research experiences that tended to be only weakly (if at all) related to outcomes were (again, in approximate descending order of the strength of their relationship with outcome measures):

- Involvement in project decision-making
- Having delivered an oral presentation about one's research
- Having collected/analyzed data to try to answer a research question

[14] We asked STEM/SBES respondents why they participated in undergraduate research, whereas we asked NSF respondents why they participated in research last summer/last year.

- Having prepared a final written report about one's research
- Having had a choice of projects.

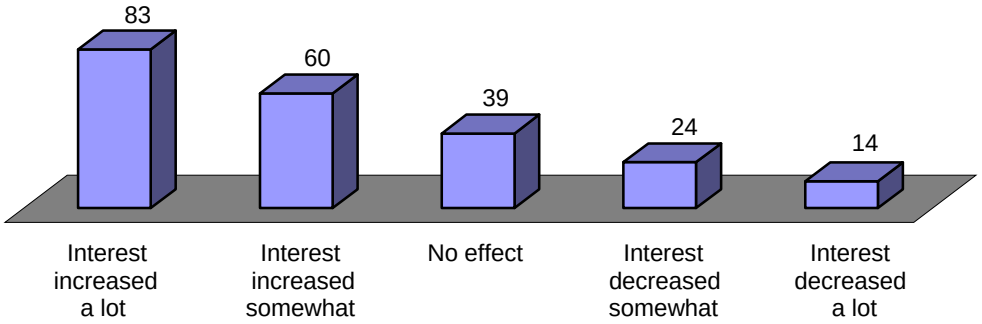
It appears to us that the central difference between the two lists is that the activities that were more strongly related to outcome measures tend to connote a more substantive involvement with the process and culture of research. Together with the finding that research seems most effective if it is done voluntarily, these findings suggest that it is not research activities *per se* that draw students into STEM/SBES careers. Rather, it is the development of interest and curiosity followed by an acculturation process that appears most likely to succeed.

As with research motivations, research activities tended to be more strongly related to perceived gains in confidence and understanding and increased interest in research and STEM careers than to PhD expectations, and almost all variables were more strongly related to current PhD expectations than to new PhD expectations. For instance, 36% of NSF follow-up survey respondents who reported that they gained increasing independence over the course of their undergraduate research experiences were high gainers on the confidence index, compared with only 15% who did not report increasing independence—a difference of 21 percentage points. By comparison, 60% of those who reported increasing independence expected to obtain a PhD, compared with 49% of those who did not report increasing independence—a difference of only 11 percentage points.

RELATIONSHIPS AMONG OUTCOME MEASURES

As one might expect, current and new expectations of obtaining a PhD were strongly related to increased interest in STEM and research careers. The relationship was particularly strong among NSF follow-up survey respondents: 83% of those whose interest in a research career increased a lot expected to obtain a PhD, compared with only 14% of those whose interest in a research career decreased a lot (Figure VI-2). Increased interest in STEM-related careers also was strongly related to gains in confidence and understanding: among STEM researchers, 70% of those whose interest in a research career increased a lot were high gainers on the confidence index, compared with a mere 9% of those whose interest in a research career decreased. In contrast, gains in understanding, confidence, and awareness were only moderately related to PhD expectations.

Figure VI-2
Percentage Who Expect to Obtain a PhD, by Effect of UROs on Respondent's Interest in a Career in Research



Source: SRI International: NSF follow-up survey, 2005.

RELATIONSHIPS BETWEEN OUTCOMES AND RESPONDENTS' DEMOGRAPHIC CHARACTERISTICS

The relationships between outcomes and respondents' race/ethnicity varied somewhat across the several outcome measures and surveys, but broadly speaking the differences tended to be small (typically, less than 10 percentage points difference between high and low groups). Where there were differences, most often it was Hispanics/Latinos who showed the greatest gains and non-Hispanic whites who showed the smallest gains. Differences between men and women on the several outcome measures were even smaller than those among the racial/ethnic groups, and on most measures, their ratings were almost identical.

RELATIONSHIPS BETWEEN OUTCOMES AND RESPONDENTS' TYPE OF SCHOOL AND ACADEMIC MAJOR

Type of school. Interestingly, in the NSF follow-up survey, undergraduate researchers at doctoral/research-extensive universities tended to report somewhat lower gains in confidence, understanding, and awareness and less increased interest in STEM-related careers than did undergraduate researchers at other types of schools, but there were no differences across types of schools in terms of researchers' PhD expectations. In contrast, the STEM and SBES graduates surveys found no appreciable differences in gains or career interests, but graduates of doctoral/research-extensive universities were slightly more likely than others to have or expect to obtain a PhD. In sum, it appears that no one type of school had any particular advantage over the others in terms of research outcomes. There also were no appreciable differences on any of the outcome measures between those who started their college career at a 2-year school and those who started at a 4-year school.

Academic major. Relationships between outcomes and respondents' academic major varied across surveys and outcome measures, reflecting methodological differences among the surveys as well as differences among the majors in career options and the nature of undergraduate research. The most interesting finding was that, despite substantial variation in the percentages in each major who had early expectations of obtaining a PhD and current expectations of obtaining one, there was little variation in the percentage who had new expectations. In other words, it appears that the ability of undergraduate research to recruit new PhD aspirants is relatively constant across academic majors.

ROLE OF MENTORS IN UNDERGRADUATE RESEARCH OUTCOMES

The NSF surveys included several items assessing amount of undergraduate researchers' interaction with mentors and perceptions of the mentors' supportiveness, technical guidance, and so on. None of these items was appreciably related to our research outcome measures. We believe that the absence of strong relationships on these items reflects the complexity of the mentor's role rather than its unimportance. That is, because the role is complex, unidimensional survey items are unable to capture it. As evidence of the centrality of the mentor's role, in response to an open-ended question about how to improve undergraduate research programs, follow-up survey respondents' most common suggestions—by a considerable margin—related to increased and more effective faculty guidance. One respondent's comment summarized the suggestions nicely: "Finding faculty who are not only bright people and good researchers but who also have excellent interpersonal skills is the most crucial aspect to making these programs successful."

DIFFERENTIAL GROUP NEEDS IN UNDERGRADUATE RESEARCH

One of the initial study questions was whether different types of students—in particular, different racial/ethnic groups or men vs. women—benefit differentially from different kinds of mentoring or different research environments. Our analyses found no patterns of differential relationships among research characteristics and outcomes across the racial/ethnic groups or between men and women. Similarly, in our survey of PIs and mentors, only 4% identified differences in needs between men and women, and a mere 2% specified differences by racial/ethnic group. Thus, from the perspective of mentors, the answer to whether there should be different mentoring approaches or research environments for different types of students appears to be a resounding "no."

Some participants and observers of undergraduate research believe that it is important for students, especially for women and minorities, to have mentors who are like themselves, and some studies of targeted programs have supported these beliefs.[15] We explored this hypothesis in the initial and follow-up NSF surveys, not by asking students what they thought about it, but by comparing research outcomes for those who had different types of mentors. We found that women who had some female mentors or all female mentors were no more likely than those who had no female mentors to expect to obtain a PhD or to have new expectations of obtaining a PhD, and the findings with regard to targeted minorities (blacks and Hispanics/Latinos) were parallel. Not only were none of the differences statistically significant, but those that did exist were not in the hypothesized direction.

Overall, on more than 100 comparisons made with regard to the various respondent groups, types of mentors, and outcome measures, there were statistically significant differences in outcomes on only about half. Where there were statistically significant differences, respondents who had both male and female mentors or both same- and different-race/ethnicity mentors tended to have slightly "better" outcomes (e.g., higher confidence gains) than did those who had either only "same" or only "different" mentors. However, statistically significant differences were as common among men as among women and more common with non-Hispanic whites than with minorities. Thus, in brief, our findings suggest that having a mix of mentors (in terms of their sex and race/ethnicity) has a mildly beneficial effect across *all* students, not just women and minorities.

OVERVIEW OF CORRELATES OF UNDERGRADUATE RESEARCH OUTCOMES

Participation in undergraduate research seems most likely to have positive outcomes (e.g., increased confidence in one's abilities, interest in a STEM-related career, expectations of obtaining a PhD) if it is done voluntarily and out of a genuine interest; research that is done because it is required is less likely to lead to positive outcomes. Specific activities appear to be less important than a long-term, multifaceted experience that draws the undergraduate into the culture and process of research. It is likely that talented mentors play a central role in making this happen.

We found no patterns of differential relationships among research characteristics and outcomes across types of schools, summer vs. academic-year programs, racial/ethnic groups, or

[15] See, for example, Baine Alexander and Julie Foertsch, *The Impact of the EOT/PACI Program on Partners, Projects, and Participants: A Summative Evaluation.* 2003. University of Wisconsin-Madison: LEAD Center. Available at http://www.eot.org/Summative.pdf.

between men and women. There also was no evidence that minorities benefited more from same-race/ethnicity mentors than from those of a different race/ethnicity or that women benefited more from female than from male mentors. However, having a diverse group of mentors (in terms of their race/ethnicity and sex) appeared to be mildly beneficial to all respondents.

VII. RECOMMENDATIONS

SRI's four surveys were consistent in their findings of a variety of positive effects of undergraduate research experiences. Even highly effective programs and activities, however, can be more effective. SRI's suggestions for achieving this end follow.

- Most STEM majors, especially those who participated in undergraduate research, reported that they had become interested in STEM during childhood. These findings suggest that the most effective time to begin attracting students to STEM may well be while they are in grammar school. For many, college is too late. If attempts to increase the U.S. STEM workforce are to be successful, it would appear that increased support of K-12 inquiry-based STEM curriculum and summer activities is essential.
- At the time they enrolled, many undergraduates who ultimately participated in research did not know whether their college offered UROs. At the time of the follow-up survey, many NSF researchers did not feel very well informed about opportunities available to them at their own school, and they felt even less informed about opportunities at other schools. We recommend that NSF help to remedy this situation:
    - Improve the quality, quantity, timeliness, and accessibility of information about NSF-funded UROs that is available on the NSF Web site.
    - Encourage colleges and universities to find ways to share information about UROs with their students as well as those from other schools.
    - Provide information about UROs to NSF programs that target K-12 students, to promote early awareness of UROs.
- One of the strongest predictors of increased interest in STEM and research careers and expectations of obtaining a PhD was overall duration of research activities. This suggests that those who begin participating in research early are more likely to stay involved. Yet most NSF undergraduate researchers are seniors, and there are very few freshmen or sophomores. We recommend that NSF encourage its PIs to find ways to include freshmen and sophomores in their research programs.
- NSF should encourage PIs of undergraduate research projects to focus more on generating enthusiasm and involving undergraduates in the *culture* of research—including gaining increasing independence, understanding the context of one's research, mentoring other student researchers, attending conferences, and authoring or co-authoring a paper submitted for publication in a professional journal—than on requiring them to complete specific research-related assignments, such as writing reports.
- Talented, committed mentors almost certainly play a key role in creating positive undergraduate research outcomes. A significant commitment of time, enthusiasm for mentoring, organizational skills, and an ability to develop or help students develop interesting and doable projects most likely are central elements in effective mentoring. We suggest that NSF help to make mentoring more effective in several ways:
    - Encourage and fund mentor workshops for both new and experienced mentors.

- Commission booklets on mentoring that can be sent to all grantees of undergraduate research projects.
- Sponsor and publicize blogs on mentoring, accessible by all active grantees.
- Use the Foundation's funding leverage to encourage colleges and universities to recognize mentoring as a factor in promotion and tenure decisions.

- The section on project evaluation and reporting in the 2005 REU program solicitation implied that the evaluation should focus on measures of what students have learned and how their perspectives on STEM have been expanded. Although this information may be useful to meet Government Performance and Results Act (GPRA) requirements, the PIs themselves would be better served by obtaining feedback more directly related to how their projects might be improved. Accordingly, NSF should recommend that project evaluations include questions about participants' perceptions of project strengths and weaknesses and requests for suggestions about project improvements.
- The 2005 REU program solicitation states that "it is highly desirable to have a structured means of tracking participating students beyond graduation, with the aim of gauging the degree to which the REU Site experience as been a lasting influence in the students' career paths."[16] We recommend that NSF discontinue this suggested activity, for the following reasons:
  - Respondents to the NSF follow-up survey differed significantly from nonrespondents on a number of the questions in the initial survey, including the percentage who expected to obtain a PhD (50% vs. 36%). Although the high response rate (74%) minimized the effect of these differences on this study's overall profile of undergraduate researchers, the differences between nonrespondents and respondents point up the difficulty of obtaining unbiased data when trying to track students beyond graduation. When such efforts are made by, for example, REU Site PIs who have many other demands on their time, the results are likely to suffer from serious biases in favor of those students who have remained in academia. Such biases in turn may serve to perpetuate the under-appreciation of the importance of nonacademic STEM careers.
  - Most undergraduate researchers participate in a variety of research activities, so follow-up is unlikely to be able to reliably discern the unique effect of a single project.
  - Career path information is better obtained through large-scale studies such as this one, with sample sizes that allow for a variety of multivariate analyses and subgroup comparisons.

[16] http://www.nsf.gov/pubs/2005/nsf05592/nsf05592.htm#pgm_desc_txt