THE PIPELINE

Benefits of Undergraduate Research Experiences

Surveys indicate that undergraduate research opportunities help clarify students' interest in research and encourage students who hadn't anticipated graduate studies to alter direction toward a Ph.D.

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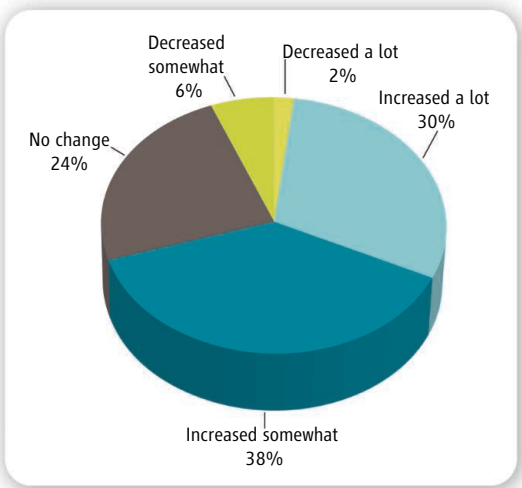
Undergraduate students' participation in hands-on research is widely believed to encourage students to pursue advanced degrees and careers in science, technology, engineering, and mathematics fields. SRI International conducted a nationwide evaluation of undergraduate research opportunities (UROs) to understand who participates, what effects the experience has on them, and what factors favor positive outcomes. Our study included four Web-based surveys, conducted between 2003 and 2005 and involving almost 15,000 respondents. The survey instruments, detailed data tables, and analytical reports are available online (*1*).



Raising interest. UROs often increase a student's interest in STEM careers.

Respondents to the first survey were approximately 4500 undergraduates and 3600 faculty, graduate student, and postdoc mentors who participated during 2002 or 2003 in UROs funded by any of eight NSF programs with a substantial undergraduate research component. Two years later, about 3300 individuals who were undergraduates in the initial survey responded to the follow-up survey.

In 2003, we surveyed a nationally representative sample of individuals (ages 22 to 35) who had received a bachelor's degree in science, technology, engineering, or mathematics (STEM) ($n = 3400$); in 2004, we conducted a parallel survey of individuals who had received a bachelor's degree in a social, behavioral, or economic science (SBES) ($n = 3200$). Of the STEM and SBES survey respondents, some (sponsored researchers) knew their research to be sponsored by NSF, NIH, or NASA. Others (nonsponsored researchers) did research that was not (as far as they knew) sponsored by NSF, NIH, or NASA. A third group (nonresearchers) did not participate in UROs.

About half of STEM and SBES survey respondents had participated in UROs. For about 1 in 15, this research was sponsored by NSF, NIH, or NASA. The experiences and outcomes reported by sponsored researchers in the STEM and SBES surveys proved to be similar to those of the NSF-participant surveys.

Profile of Undergraduate Researchers

The efforts of NSF and other entities to encourage the representation of groups historically underrepresented in STEM fields appear to have been effective. In all of our surveys, undergraduate researchers were demographically diverse, with women, blacks, and Hispanics/Latinos represented at rates at least equivalent to their rates in the overall college population. Those who began their undergraduate education at a 2-year college were as likely to participate in research as those who started at a 4-year college or university. However, URO participation rates differed across various disciplinary fields. In the STEM survey, participation rates ranged from 34% in mathematics and 37% in computer sciences to 72% in chemistry and 74% in environmental sciences. In the SBES survey, rates ranged from 38% in economics and political science to 63% in psychology.

Undergraduate researchers were mainly juniors and seniors, and they tended to have relatively high grade point averages, reflecting the competitive nature of many undergraduate research programs. They also were more likely than nonresearchers to expect to obtain an advanced degree (*2*). The STEM survey found that those who participated in UROs were twice as likely as those who did not to have pre-college expectations of obtaining a Ph.D. (14% versus 7%) (*3*). Interest in STEM was likely to have begun in childhood: 59% of NSF researchers reported that they had been interested in STEM "since I was a kid," and another 29% said they became interested when they were in high school. This suggests that an effective time to attract students to STEM may well be while they are in elementary school (*4*). In contrast, interest in SBES was most likely to have developed during high school or college.

Undergraduate Research Outcomes

We found that UROs increase understanding, confidence, and awareness (*5*–*8*). Most (88%) of the respondents to the NSF follow-up survey reported that their understanding of how to conduct a research project increased a fair amount or a great deal, 83% said their confidence in their research skills increased, and 73% said their awareness of what graduate school is like increased.

UROs also clarify interests in STEM careers (*9*). Of respondents to the NSF follow-up survey, 68% said their interest in a STEM career increased at least somewhat as a result of their URO (see figure above).

Finally, UROs increase the anticipation of a Ph.D. (*10*). Of respondents to the NSF follow-up survey, 29% had "new" expectations of obtaining a Ph.D.—that is, they reported that before they started college they did not expect to obtain a Ph.D., but now (at the time of the survey) they did expect to obtain one. In the STEM survey, "new" expectations of obtaining a Ph.D. were reported by 19% of sponsored researchers, 12% of nonsponsored researchers, and only 5% of nonresearchers (see figure, page 549).

Students who participated in research because they were truly interested and who became involved in the culture of research—

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Published by AAAS

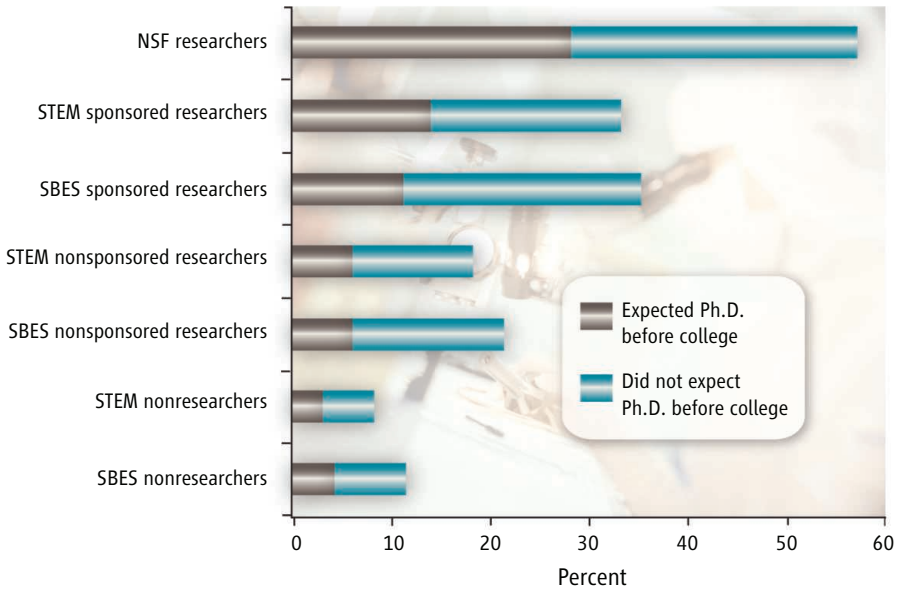
attending conferences, mentoring other students, authoring journal papers, and so on—were the most likely to experience the "positive" outcomes noted above, such as increased interest in a STEM career. The overall duration of research experiences and the variety of research activities also were related to positive outcomes (*11*). For example, in the STEM survey, 30% of researchers with more than 12 months of research experience reported that they expected to obtain a Ph.D., compared with only 13% of those with 1 to 3 months of research experience and 8% of those with no research experience. However, some of the commonly assigned research activities—preparing written final reports, in particular—tended to be unrelated to positive outcomes. The time of year in which the research experience took place (summer versus academic year) also was largely irrelevant.

We found little evidence of a relationship between mentoring characteristics and positive outcomes in responses to our structured (multiple-choice) questions. For example, neither involvement in decision-making nor perceived adequacy of mentor guidance was very strongly related to positive outcomes. However, in response to an open-ended question, by far the most common suggestions that students made about how to improve undergraduate research programs concerned increased or more effective faculty guidance. We suspect that the absence of strong relationships on the structured questions reflects the complexity of the mentor's role rather than its unimportance. Respondent comments, as well as other research (*12*), suggest that mentors who are able to combine enthusiasm with interpersonal, organizational, and research skills play a large role in facilitating positive outcomes.

Differential Group Needs

Among racial/ethnic groups, effects of UROs tended to be strongest among Hispanics/Latinos and weakest among non-Hispanic whites, but most racial/ethnic-group differences that were statistically significant were nevertheless relatively small (typically less than 10 percentage points). Our surveys found almost no differences between men and women on any of the study variables, supporting observations of gender similarities in mathematics and science (*13*). Similarly, in our survey of NSF principal investigators (PIs) and mentors, only 4% identified differences in needs between men and women, and only 2% specified differences by racial/ethnic group.

We also explored whether it is important for women and minorities to have mentors who are similar to themselves (*14*). 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 Ph.D. or to gain new expectations of obtaining a Ph.D. The findings with regard to blacks and Hispanics/Latinos similarly showed no statistically significant differences. Across many comparisons, all groups—men, women, minorities, and nonminorities—who had both male and female mentors or both same- and different-race/ethnicity mentors tended to have slightly "better" outcomes (e.g., greater gains in confidence) 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 among non-Hispanic whites than among minorities. Thus, our findings suggest that having a mix of mentors (in terms of their sex and race/ethnicity) is likely to have a mildly beneficial effect for all students, not just women and minorities.



Ph.D. expectations. Participation in undergraduate research opportunities affects expectations of obtaining a Ph.D.

Conclusion

The large number and variety of students surveyed represented a variety of colleges and universities. Many types of undergraduate research experience fuel interest in STEM careers and higher degrees. No formulaic combination of activities optimizes the URO, nor should providers structure their programs differently for unique racial/ethnic minorities or women. Rather, it seems that the inculcation of enthusiasm is the key element—and the earlier the better. Thus, greater attention should be given to fostering STEM interests of elementary and high school students and providing UROs for college freshmen and sophomores.

References and Notes

1. Survey instruments, survey data, and analytical reports for all four surveys are available online (www.sri.com/policy/csted/reports/university/index.html#urosynthesis). An executive summary of the synthesis report also is available at that location as a subset of the overall synthesis report.
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3. All differences cited here are significant at $P < 0.05$.
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9. A. Zydney *et al.*, *J. Eng. Educ.* **91**, 151 (2002).
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11. A. Zydney *et al.* (*9*) also found that participants' subsequent ratings of the benefits of UROs increased with the amount of time spent engaged in them.
12. A. Hunter *et al.*, *Sci. Educ.* **91**, 36 (2007); available online (http://www3.interscience.wiley.com/cgi-bin/jhome/32122).
13. J. S. Hyde, M. C. Linn, *Science* **314**, 599 (2006).
14. B. Alexander, J. Foertsch, *The Impact of the EOT-PACI Program on Partners, Projects, and Participants: A Summative Evaluation* (Univ. of Wisconsin, Madison, WI, 2003); available online (www.eot.org/Summative.pdf).

15. This work was conducted under contract to NSF, Directorate of Education and Human Resources, Division of Research, Evaluation and Communication (REC-9912172 and GS-10F-0554N). Any opinions, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. Government.

Supporting Online Material

www.sciencemag.org/cgi/content/full/316/5824/548/DC1

10.1126/science.1140384