

Science Undergraduates' Perceptions of Learning from Undergraduate Research Experiences

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In the last few years, undergraduate research experiences (UREs) have become an increasingly common component of undergraduate science curricula. However, researchers have only recently undertaken empirically-based assessments of the benefits that accrue to students participating in UREs (Bauer & Bennett, 2003; Hunter, Laursen, & Seymour, 2007; Kardash, 2000; Lopatto, 2004; Seymour, Hunter, Laursen & DeAntoni, 2004; Zydney, Bennett, Shahid, & Bauer, 2002). For example, based on their review of 54 published articles and reports that addressed how UREs presumably benefit the students who participate, Seymour et al. found only four research articles and five evaluations that, in their estimation, provided carefully documented evidence supporting the various authors' claims about the benefits of UREs.

Given Seymour et al.'s (2004) findings, it is clear that the degree to which the hypothesized benefits of UREs actually accrue to participating students remains largely unknown. In an attempt to shed some light on the benefits of UREs to both the students who engage in them and to their faculty mentors, Seymour and her colleagues (Seymour et al., 2004; Hunter et al., 2007) interviewed 76 students in eight science disciplines at four liberal arts institutions. Students commented on the extent to which they experienced 24 hypothesized benefits of UREs that Seymour et al. had identified in their literature review and indicated any other gains they had achieved that were not on Seymour et al.'s checklist. Seymour et al. classified the benefits and gains mentioned by students into seven categories. Students mentioned "personal and professional gains" and "thinking and working like a scientist" most frequently, with each category accounting for 28% of all gains mentioned by students. Categories of gains mentioned less frequently were gains in skills, clarification and confirmation of career/

education path, enhanced career/graduate school preparation, and changes in attitudes toward learning and working as a researcher.

We were unaware of Seymour et al.'s (2004) evaluation efforts when, in 1996, we began our evaluation of the effects of UREs on a variety of student outcomes, including student-identified benefits of participation in UREs. In fact, we found little in the way of published accounts of the effects of UREs that could guide our efforts. Because the literature on UREs that did exist at the time focused exclusively on the outcomes that faculty mentors and program directors expected participants would acquire, it seemed important to collect data regarding students' perceptions of the benefits associated with participation in UREs. The present chapter summarizes students' perceptions of what they considered to be the most important things they learned from their URE internship.

Method

Description of the URE and Participants

Participants in our evaluation efforts were undergraduate science students at the University of Missouri-Columbia, a research -extensive university. Monies from the National Science Foundation-Research Experiences for Undergraduates (NSF-REU) and the Howard Hughes Medical Institute (HHMI) provided support for UREs in biology, biochemistry, chemistry, mathematics, and physics. Students participated in theoretical, field, or laboratory research with faculty mentors in any of these disciplines during an 8-week summer session, or during the entire academic year. Students who participated in the summer URE worked 40 hours per week in their mentors' laboratories for an 8-week

period. Their URE culminated with poster presentations of their work on the university's campus. Students who participated in the academic-year URE worked 12 hours per week in their mentors' laboratories for a 32-week period. Their URE culminated with oral presentations of their research projects at a statewide science conference in the spring.

In the present study, we report data provided by 72 students from among a total sample of 189 students who participated in UREs during the time period from summer 1996 until summer 1999. The 189 juniors and seniors comprised 113 women (59.8%) and 76 men (40.2%). Of these 189 students, 146 (77.2%) received funding from HHMI and 43 (22.8%) from NSF-REU. One hundred seventy two students provided the following information regarding ethnicity: Caucasian (71.4%), African American (12.2 %), Asian Pacific Islander (5.3%), Native American (1.6%), and international (0.5%).

Materials and Procedures

On the last day of their respective UREs, students responded in writing to several open-ended questions designed to elicit their overall perceptions of the research internship experiences. The specific questions asked at the end of each internship varied somewhat, with not all questions being asked each semester. We asked 107 students, "What are the most important things you learned from the internship?" We present below the responses of the 72 students who answered this question..

Scoring of Open-Ended Questions

We first examined students' responses to each open-ended question for recurring responses and themes, and formed preliminary categories on that basis (Strauss & Corbin, 1998). The first and second authors coded all participant responses by assigning individual responses to the preliminary categories. We resolved disagreements between us by consensus, leading to successive refinements of the categories. We reduced the preliminary categories produced in response to each question by taking into account both the frequency with which certain responses fell into a particular category and also by a logical analysis of the similarity among the various categories (Berg, 1998).

Examination of responses to each question revealed that students frequently listed phrases or terms that they viewed as unique descriptors, but that

we viewed as belonging to the same category. For example, one student wrote that the URE made him more "objective," "dispassionate," and "unbiased." Each of these terms fell into our "open-mindedness/objectivity" category. We designated all three terms with the same category number and counted them just once to eliminate redundancies that would otherwise produce spuriously high frequencies for that category.

Results

Responses to Open-Ended Questions

What are the most important things you learned from the research internship? Forty-four female and 28 male students responded to this item. Table 1 displays the categories of students' responses. Students mentioned most often the acquisition of scientific dispositions and habits of mind. Within this category, students emphasized the importance of patience, keeping focused, persisting, and maintaining a positive attitude in the face of long and difficult periods before realizing the gains of one's labor. They recognized that respecting and getting along with others is critical to the work of science, and that credit should be given to those who do the work. They noted that logistical planning and anticipating potential problems are key to accomplishing tasks efficiently. Interns expressed the importance of remaining dispassionate about one's results and accepting data that don't confirm one's hypotheses. They commented on the ability to self-motivate out of love for and commitment to the discipline. Such motivation and commitment included the need to stay current with technological advances and information in the discipline.

Roughly 50% of the students mentioned gains in research skills and insights into the research process and life of a research scientist. Within this category, students most often mentioned increases in their ability to think like a research scientist. This included a developing understanding of the nature of scientific truth and the means by which truth claims are validated, as well as a working knowledge of how to problem solve and conduct scientific experiments. Others simply mentioned research skills in general or learning about the lifestyle of scientists. Yet others mentioned an increase in their ability to effectively communicate their ideas using jargon appropriate to their field. Some students mentioned less positive gains.

Table 1***Students' Perceptions of Most Important Things Learned from the URE***

Categories	Percent of Students Mentioning Category
Gains in scientific dispositions and habits of mind	
Patience and focus	19.4%
Persistence and perseverance	13.9%
Teamwork	11.1%
Organization and planning ahead	8.3%
Objectivity, open-mindedness and skepticism	6.9%
Motivation, dedication, and commitment	5.6%
Lifelong learning and keeping up with advances in the field	4.2%
Learning from mistakes and accepting setbacks	2.8%
Attention to detail	1.4%
Seeing the big picture and goal-oriented thinking	1.4%
Honesty and ethical behavior	1.4%
Time management	1.4%
Total	77.8%
Gains in research skills and insights into the research process	
Increased ability to think like a scientist	12.5%
Increased research skills and experience	11.1%
Increased insight into the unpredictability and frustration associated with the process of research	8.3%
Increased communication skills	8.3%
Increased appreciation for research and insight into the lifestyle of research scientists	6.9%
Insight into monotonous and tedious nature of benchwork	4.2%
Total	51.4%
Gains in general knowledge and skills	
Content knowledge	16.7%
Laboratory skills	9.7%
Critical thinking and problem solving abilities	9.7%
Making cross disciplinary connections and linking theory to real-life experiences	4.2%
Total	40.3%
Career clarification	
Provided information to aid in career decision-making	20.8%
Increased likelihood of choosing a research science career	6.9%
Decreased likelihood of choosing a research science career	6.9%
Total	34.7%
Gains in perceived self-efficacy and independence	
Perceived self-efficacy and pride in accomplishments	13.9%
Think independently	9.7%
Work independently	1.4%
Total	25.0%

Table 1 (continued)***Students' Perceptions of Most Important Things Learned from the URE***

Categories	Percent of Students Mentioning Category
Personal and professional gains	
Sense of enjoyment, fun and passion	11.1%
Collegial relationships with faculty and peers	6.9%
Resume builder	2.8%
Potential for publications	2.8%
Total	23.6%
Negative experiences and insights	
Learning about the pressure on faculty to write grants	4.2%
Lack of administrative support for faculty	4.2%
Long hours in the laboratory	4.2%
Competitive colleagues	2.8%
Not finishing research project due to problems with laboratory equipment	1.4%
Problems with faculty mentor	1.4%
Low pay	1.4%
Learning about the pressure on faculty to publish	1.4%
Total	20.8%

They commented on the frustration experienced when the results of their studies failed to support their hypotheses, or expressed frustration with the amount of repetitive and boring detail required by bench work.

Approximately 40% of the students mentioned significant gains in knowledge and skills as the most important learning outcomes of the URE. In this category, gains in content knowledge specific to a discipline were mentioned most frequently. Some students noted they were able to attach new meaning to previously learned information by seeing it applied in a research setting. Others stated that the experience enhanced their understanding of the interrelatedness of the various fields of science. Fewer students mentioned gains in laboratory skills and critical thinking and problem solving abilities.

Almost 35% of the students listed career clarification as the most important thing learned from the experience. Many indicated that some aspect of the research experience enabled them to think of a science career in a new or unanticipated way. Others indicated that the experience helped them to gain a clearer picture of what they desired from a career, especially a science career. Yet others viewed the experience as a means of trying out a science career before committing to it. For a small number of students, the experience was as likely to decrease as

to increase their interest in a career in research science.

For 25% of the students, the internship resulted in substantial gains in perceived self-efficacy and in their self-reported ability to think independently. Several students commented on the pride they took in their accomplishments. Many expressed a willingness to tackle questions or problems with a new sense of confidence and boldness, as well as willingness to make a claim or take a stance and adhere to it. Yet others noted that the experience increased their sense of self-direction and personal responsibility.

About 24% of the students mentioned personal and professional gains. Several students referred to the sheer enjoyment and fun associated with conducting research. Other students viewed the development of collegial relationships, talking with others about science, and networking as important aspects. Only a few students viewed the program as a means of increasing their chances of getting into medical or graduate school.

Interestingly, almost 21% of the students listed negative experiences and insights as the most important things they had learned from the internship. As seen in Table 1, these insights covered a wide range of experiences. Some students commented on the amount of pressure placed on

faculty to write grants, and noted how this decreased their interest in a research science career. Others commented on the following barriers to conducting research and writing grants: lack of monetary support for faculty laboratories, administrators' requests for faculty to do things other than research, political or social issues that interfered with faculty's ability to conduct research, and lack of recognition for faculty's efforts. Similar numbers of students remarked on the long hours required by laboratory work and how that decreased their interest in a research science career.

Discussion and Conclusions

Involvement of undergraduate students in meaningful research with faculty mentors is a powerful instructional tool. Among the outcomes that faculty expect students to acquire from UREs are the acquisition of knowledge, research skills, and the attitudes of scientists. How consistent are these faculty-identified hypothesized benefits of UREs with student-identified benefits? Our study and Seymour et al.'s (2004) study are among the first to address this question. Findings from both studies generally confirm the hypothesized benefits of UREs. Namely, participation in UREs confers the following benefits: increases in students' understanding of the processes and acquisition of the dispositions involved in scientific research; increases in students' general knowledge and understanding of science, and in their ability to apply that knowledge to research problems; increases in students' self-confidence in their ability to do research and to contribute meaningfully to the scientific enterprise; development of collegial and collaborative relationships with faculty mentors and others; and increases in communication skills, especially oral ones. In addition, data from both studies reveal that students tend to be very positive about their UREs. We are presently collecting longitudinal data to investigate whether these positive feelings result in participants eventually choosing research science careers. What is clear from both studies, however, is that UREs play an important role in clarifying interns' career-related thinking.

Other benefits, although mentioned, appeared with less frequency in both studies. These included increases in written communication skills, changes in students' views about the nature of scientific knowledge, and career-enhancing outcomes (e.g., a "resume builder"). It is noteworthy that only a relatively small percentage of students reported increases in the development of higher-order inquiry skills. The point is not that these skills were rarely achieved by participation in UREs. Rather, the point is that improvements in these particular skills have

been widely touted as hypothesized benefits from participation in UREs (Seymour et al., 2004). Data from both our study and Seymour et al., on the other hand, indicate that the degree to which these skills are enhanced, at least compared to other student-identified benefits and gains, has been somewhat less than expected. These results support previous findings that UREs seem more successful at promoting the acquisition of basic scientific skills (e.g., observing and collecting data) rather than the higher order inquiry skills underlying critical scientific thinking (Kardash, 2000). However, it is important to recognize that this was the first URE in which our students had participated. It is likely that students who chose to participate in additional UREs offered during the academic year and subsequent summer would be given more opportunities to engage in higher order skills such as identifying specific questions for investigation, designing theoretical tests of hypotheses, and reformulating hypotheses based on one's results. Moreover, the fact that the students did not list these skills does not mean that they did not acquire them. It may be that these skills were simply not the ones that came to mind when students listed what they considered to be the most important things they learned from their UREs.

One of the most significant and striking aspects of the present study is the remarkable similarity between its findings and those reported by Seymour et al. (2004), despite marked differences in the conduct of the two studies. Seymour et al.'s sample comprised 76 students from four liberal arts schools; the sample in the present study comprised 72 students from one large, Midwestern, research-extensive institution. Seymour et al. used a checklist format with individual and focus group interviews to investigate whether students had indeed experienced a number of hypothesized benefits/gains from their UREs. By contrast, interns in the present study responded in writing to open-ended questions and a number of close-ended items. (Responses to other open-ended questions and close-ended items are reported in Kardash, Wallace, and Blockus, in press.) Seymour et al. reported their findings in terms of percentages of total observations; we reported our data in terms of percentages of students who wrote particular comments or phrases. Despite these differences, findings from both studies are very similar with respect to the gains and benefits students reported as a result of their participation in UREs.

It is important to note that our findings concerned student majors in the natural and physical sciences and mathematics. That raises the question of whether our findings would generalize to psychology students. As a reviewer of this article noted, the tools of the natural and physical sciences and of math are

more complicated than are those of psychology in many cases, but psychology involves more complex conceptual constructs. Despite this important distinction, we believe that the benefits and gains mentioned by our science and mathematic students would be similar to those acquired by psychology students involved in UREs. As an example, the scientific dispositions and habits of mind mentioned by our students are desirable ones for all researchers regardless of discipline and would be as likely modeled by faculty in the social sciences as those in the natural and physical sciences.

In sum, our findings lead us to conclude that the student-identified benefits resulting from participation in UREs are generally consistent with the benefits that UREs are presumed to provide. Those students who subsequently choose to enter research-oriented graduate programs will bring to those programs a realistic view of what is entailed in those programs, a set of dispositions appropriate to the conduct of research, and a set of basic research skills. Based on our findings, we believe further that UREs provide substantial benefits even for those students who choose not to pursue research science careers. We expect that those students will, at a minimum, enter their chosen careers with a renewed sense of self-direction, independence and confidence in their abilities to successfully tackle what lies before them. They will also undoubtedly display a deeper appreciation for research than would have been the case had they not participated in UREs.

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