



Undergraduate Research as a High-Impact Student Experience

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The positive effects of an undergraduate research experience on student learning, attitude, and career choice have passed from anecdote to systematic data. Many educators, particularly in the sciences, have come to see the potential for authentic undergraduate research to be a high-impact educational practice for achieving excellence in liberal education. In the past decade research on these student experiences has revealed the extensive array of professional and personal benefits. Initial efforts to understand these benefits started with evaluation of the relatively clear experience in which a student spent a summer working exclusively on research as an apprentice to a faculty scholar, typically in the sciences. Many students in summer science research programs —usually about ten weeks in duration, free of regular coursework—evaluate their experience by completing the Summer Undergraduate Research Experience (SURE) survey, an online assessment instrument. An advantage of the SURE is that a standard set of potential learning gains are offered for evaluation by each student respondent. These gains include the research skills and personal development items described here.

The general taxonomy of benefits include student-reported gains on a variety of disciplinary skills, research design, information or data collection and analysis, information literacy, and communication. Student respondents also evaluate their professional advancement through opportunities such as scholarly publication, becoming part of a learning community, and relationships with mentors and peers. Professional development items include clarification of a career path, understanding the research process in the field, and understanding how scientists think. In addition,

students evaluate gains in personal development, including the growth of self-confidence, independence of work and thought, and a sense of accomplishment (Lopatto 2006). Although studied independently of any of the Association of American Colleges and Universities' initiatives, these benefits of undergraduate research align well with the essential learning outcomes that emerge from initiatives such as Liberal Education and America's Promise (see Kuh 2008).

Student results from the SURE survey indicate that most research experiences enhance intellectual skills such as inquiry and analysis, reading and understanding primary literature, communication, and

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teamwork. Some skills are positively correlated with program components. Students in programs that provide instruction in research ethics report higher gains in this area than other students; students in programs that require written and oral communication report higher gains in these areas. These gains are potentially portable within and beyond the sciences. Even more ubiquitous are the variety of personal gains reported by undergraduates. Undergraduate researchers learn tolerance for obstacles faced in the research process, how knowledge is constructed, independence, increased self-confidence,

and a readiness for more demanding research. These benefits are an advantage in any career path.

Less clear is the effect of the research experience on the student's choice of career. In science, it has long been believed that a research experience compels the student's interest in a science career. The evidence for this belief is equivocal. Most undergraduate research experiences are undertaken by third- and fourth-year students who have already declared a science major. Many of these students have been interested in science since high school. They find the undergraduate experience interesting and useful, but its effect on their career plans is subtle. Sometimes students will use the research experience to fine-tune their career plans. For example, at the conclusion of a summer research program, about 15 percent of students who initially thought of themselves as pre-medical students migrate toward planning for science PhD programs. For students already interested in science, undergraduate research has the benefit of adding to the student's credentials for being admitted to graduate school, so the experience has instrumental value in continuing the student's career trajectory. To expand recruitment beyond the upper-level students, a recent trend in undergraduate research programs is to recruit younger students — including first-year college or even high school students — on the premise that an early research experience will capture the interest of a student who has not yet decided on a career. Evidence for the success of this strategy has not yet accumulated, and there are grounds for skepticism. Young students who have not committed to a career track may feel a strong desire to keep their options open and sample among a variety of valuable experiences, such as travel or internship experiences.

The SURE survey provides a picture of short-term student evaluations of the research experience. As with any research

program, the success in describing the benefits of undergraduate research was accompanied by new questions. Questions about the generalizability of the initial findings, based on students enrolled in liberal arts colleges, were answered when the survey results were replicated in a larger array of colleges, including master's institutions and research universities. Now additional questions about the role of mentoring, the long-term effects of the research experience, and the adaptation of research experiences to courses within the regular curriculum drive new inquiries into the undergraduate research experience.



THE RESEARCH COMMUNITY

Many educators, as well as employers, feel that contemporary undergraduate researchers have a better experience if they work with other undergraduates as teammates or peer mentors. The SURE survey asks the student if he or she works with a team of researchers. The variations in team structure are difficult to characterize. Some research teams work closely on one project; others divide their

labor among separate but related projects. Some undergraduates work only with peers, while other work in diverse groups of undergraduates, graduate students, and other researchers. Given the complexity of the phrase “work with others,” perhaps the most interpretable response option is “I work alone.” About 25 percent of student survey respondents report that they work alone. They may be missing something. Working with other undergraduates on research is evaluated as either moderately or significantly enhancing the research experience by almost 80 percent of students who work in teams. Most student teams are composed of undergraduates who work as equal partners; only one group in ten reports that an undergraduate has assumed the role of peer mentor. The peer mentor is an undergraduate student, typically older and more experienced than the other students in the research group, who is formally or informally given the responsibility of teaching, supporting, and helping the other members in the group. Recent survey results indicate that although peer mentors rarely receive formal training, most rate their experience as positive or very positive, and nearly all would choose to mentor again if they could. Peer mentors report that they enjoy the teaching aspect of the role and the responsibility assigned to them. They seldom report that they were on their own too often or were given responsibility beyond their experience. Peer mentors report many benefits for themselves as a result of the mentoring experience. They gain confidence as researchers, increase their motivation to work on the research, deepen their understanding of the research project, and improve their communication skills. When asked to evaluate their experience on the list of standard learning gains in the SURE survey, peer mentors as a group evaluate their gains as greater than the gains reported by a comparison



cohort of students who had no peer mentoring in their research experience.

How do students react to the presence of a peer mentor? The SURE survey provides an opportunity for these students to evaluate this experience. Most students who worked with a peer mentor evaluated the experience as positive. Over 80 percent of these students agree or strongly agree with the assertions that the peer mentor “helped me appreciate the significance of the research;” “understood my concerns about doing research;” and “had a significant positive impact on my research experience.” Most of these respondents disagreed that the use of peer mentors enabled the faculty or graduate mentors to ignore them, so the presence of a peer mentor does not mean that the research supervisor is absent from the group. Students who were not peer mentors but had access to a peer mentor in their group also reported higher learning gains than students who had no peer mentoring in their experience. The survey data supports the conclusion that the inclusion of peer mentors in research groups enhances the experience of both the mentors and the mentored.

Every undergraduate researcher has a graduate, postdoc, or faculty supervisor functioning as a mentor, and some have more than one. Recent survey data indicate that about 66 percent of undergraduate researchers work primarily with faculty mentors, about 12 percent work primarily with graduate student mentors, 9 percent work with postdocs, and the rest work with other professionals such as industry researchers at a commercial or government site. Students at primarily undergraduate institutions are most likely to have faculty mentors. A great deal of responsibility is placed on the shoulders of the research mentor. Mentors are described as teachers, coaches, career advisers, and gatekeepers to the community of scholars. But does mentoring really matter? The SURE survey permits student respondents to evaluate their

mentor. This evaluation may be correlated with other responses. In each year of SURE data, the report of learning gains correlates directly with the evaluation of the student’s mentor. The majority of the evaluations are positive, and over the last three years we have accumulated over 5,000 cases that permit a statistical analysis. When we examine the students’ reported learning gains, we find a clear almost step-wise relation between the students’ opinion of the mentor and the pattern of student learning gains. Students who rated their supervisor as an “outstanding mentor” reported significantly higher gains than those who rated their supervisors “above average,” who in turn reported higher gains than students who rated their supervisors as

opportunities occur during the academic year as independent study, honors work, or paid positions. The SURE survey asks students to evaluate the relative benefits of doing research during the summer or during the academic year, when research time competes with courses and other activities. Students recognize the tension between research time and class time during the academic year. Almost two-thirds of survey respondents report that it is difficult to balance research and coursework. More than half characterize research as more interesting than coursework, and only about 18 percent report learning more from courses than from their research experience. Despite the tension caused by competing demands on their

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“average,” and so on. As impressive as this pattern is, the quantitative approach does not capture the range of benefits of good mentoring. The social relationships among research group members have a strong impact on the undergraduate researcher’s plans for continuing her education in the research field. As one student wrote on her survey, “These interpersonal relationships are just as important to me as the research itself.” The observation occurred in the context of explaining that she was leaving her planned science career path because of poor mentoring (Lopatto 2009).

RESEARCH AND THE CURRICULUM

As the epitome of the undergraduate research experience, the summer research program offers a refined look at the benefits of the experience, but other forms of the experience exist. Many research

time, students report learning gains from academic-year research experiences in much the same way they report learning gains from summer experiences.

There is one more benefit of a good research experience that may be simply stated: a research experience helps one to be a better student. The presence of undergraduate researchers in a science course after they have had research experience may enhance their course experience. The effect of experienced undergraduate researchers on subsequent science course behavior is one of many questions to be explored through assessment. As a follow up to the SURE research, students who had completed the survey shortly after completing a summer experience were contacted again nine months later and asked to complete a follow-up survey. The results indicated that the students’ longer-



term recollection of the experience slightly magnified their short-term evaluation of the learning experience. For students who enjoyed the experience, a reevaluation of learning gains yielded slightly higher mean scores than did the original SURE responses; for students who did not enjoy the experience, a reevaluation of learning gains yielded slightly lower mean scores than the original SURE responses. An encouraging result of the summer experience is that a majority of the students, reflecting on courses they had taken in the intervening months, reported that they felt that they were better able to think independently and formulate their own ideas, that they were more intrinsically motivated to learn, and that they had become more active learners. One student commented, “I became more driven to do well in my science classes, since I saw more meaning to them.”

Students benefit from academic-year research experiences and carry the benefit into the classroom. Another variation on the research experience is to embed the experience in an existing course. How do students benefit from research or “research-like” experiences embedded in the course curriculum? There is wide variety in the approaches to infusing research experiences into courses, ranging from precise focus on one aspect of the research experience (such as reading primary literature or analyzing data) to complete immersion in research as the central activity (such as the “phage hunters” courses supported by the Howard Hughes Medical Institute). With a variation on the SURE called the CURE (Classroom Undergraduate Research Experiences), we have been able to survey a variety of undergraduate science courses that exhibit more or less research-like quality. Although high research-like courses differ from traditional courses to the degree that they employ activities such as group work, reading primary literature, and

data collection and analysis, the signature distinction is that in high research-like courses, undergraduate students conduct research in which the outcome is not known (even to the course instructor) and have at least some input into the research topic and design of the methodological approach. Students in high research-like courses report learning gains similar in kind and degree to gains reported by students in dedicated summer research programs. Students in high research-like courses often report higher gains than summer researchers in those areas that might be covered more completely in a class setting, such as skill in science writing, learning ethical conduct, and understanding primary literature. Most of the reported learning gains by this group are higher than gains reported by students in traditional lecture and lab courses. Traditional courses are not without advantages: students in those courses rate their learning gains higher than students in high research-like courses on a few familiar items, including listening to lectures, reading a textbook, and taking tests.

FUTURE DIRECTIONS

As current research questions are explored and answers emerge, still more questions occur. Interdisciplinary coursework and research experiences, either between the scientific disciplines or between science, social science, and humanities, are becoming more frequent. The SURE survey data from ostensibly interdisciplinary research areas—neuroscience or bioinformatics, for example—indicates that undergraduate researchers working in interdisciplinary areas report benefits similar to undergraduate researchers working in the traditional disciplines. The prototypical interdisciplinary research experience is elusive in that students may not realize they are “having” an interdisciplinary experience. One student engaged in a neuroscience project, a nominally

interdisciplinary area, was asked if her work was interdisciplinary and replied, “No, it’s neuroscience.” In an effort to capture the essential features and the benefits of interdisciplinary experiences, a collaboration involving a group of liberal arts colleges and funded by the Howard Hughes Medical Institute is studying interdisciplinary course work in the sciences. A branch of this effort is the Research on the Integrated Science Curriculum (RISC) survey, an outgrowth of the SURE and CURE survey work. In a preliminary study, course instructors complete a version of the RISC that provides a list of items related to course goals and pedagogies. Later in the term, students evaluate their learning experience on the same items. Preliminary results indicate a correspondence between the instructor’s emphasis on interdisciplinary problems and students’ reports of interdisciplinary learning. A cluster of course characteristics, including learning to ask “big questions,” reading literature from multiple disciplines, working on a problem that requires integrating two or more disciplines, and learning that disciplines may approach problems in different and sometimes conflicting ways, are emphasized by instructors and reported as learning gains by students. It is too early to tell if this approach will help us understand interdisciplinary research and course experiences, but the effort illustrates that the high-impact practice of undergraduate research still provokes interesting questions for research on student learning. ■

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