ASSESSMENT AND EVALUATION OF THE UNDERGRADUATE RESEARCH EXPERIENCE

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> *We operate on the principle that undergraduate research is not only the essential component of good teaching and effective learning, but also that research with undergraduate students is in itself the purest form of teaching.* (James N. Gentile in *Academic Excellence,* Michael P. Doyle, Editor, Research Corporation, Tucson, AZ, 2000)

Claims about the value of undergraduate research are lofty, indeed, and faculty and student accounts of the experience are overwhelmingly positive. But surprisingly few well-designed studies researching or measuring the benefits of undergraduate research are available. An overview of the papers and reports that *are* available will be provided here, and results from several of the studies will be summarized.

Overview of the literature

The literature on research, assessment, and evaluation of undergraduate research was recently surveyed (Seymour, Hunter, Laursen, DeAntoni, 2003, in press). A typology was described that divided the literature into two main types: 1) papers and reports where the benefits of undergraduate research are both claimed and well-supported and 2) papers and reports where the benefits are simply described without supporting evidence, or where the methodology is not completely described or there are design limitations. Seymour and co-workers list only nine papers, reports, or conference proceedings for the first type. These include four formal research studies on the benefits to students of the undergraduate research experience, and five well-designed program evaluations, three of which were done by the Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center at the University of Wisconsin-Madison. Several of these papers and reports will be described in more detail in this paper. The second type of paper or report in the typology includes program evaluations and a large number of descriptive accounts written by faculty, students, and program administrators that simply describe undergraduate research and its perceived benefits.

Selected report summaries

It is worth examining several of the papers and reports on undergraduate research in detail in order to begin to understand what is known about 1) the benefits of undergraduate research to students, faculty, and institutions, and 2) the program characteristics that lead to successful outcomes. This is particularly important at a time when there is national interest in expanding undergraduate research opportunities, and when many claims are being made about the benefits of undergraduate research.

Kremer and Bringle (1990) studied a group of “talented” psychology students who participated in a summer undergraduate research program. A control group of students who had also applied to the program but were not accepted was used for comparison. The

researchers used several measures (undergraduate GPA and GRE scores, for example) to show that the study group and control group were well matched. In follow-up interviews, the research students reported greater gains in research skills, greater research productivity (as measured by papers and presentations) and stronger interest in research as a career choice than students in the control group. The research students were also accepted and attended graduate programs rated higher in research productivity than the control group of undergraduates. This is one of the first published studies on undergraduate research that used a carefully selected control group and demonstrated specific benefits to students.

Kardash (2000) developed a list of fourteen research skills and asked students to self-assess their skill level before and after their research experience. While gains were reported in all of the skills, the gains were stronger in what Kardash termed "lower-order" skills such as oral communication or observing and collecting data, while only modest gains were reported in "higher-order" skills such as developing a research question and hypothesis, designing a way to test the hypothesis, and using the data acquired to reformulate the hypothesis. It would be interesting to learn if there are connections between the amount of intellectual freedom the student has in the design and the direction of the research project and the development of higher order skills. It would also be useful to know more about the types of experiences that help students develop higher-order skills.

Rauckhorst and Czaja (2002) at Miami University did not look at specific skills as Kardash did, but instead studied the general intellectual gains students made during their research experience using Baxter Magolda's Epistemological Reflection Model (1992). Baxter Magolda's model is similar to Perry's scheme. Her stages of intellectual development are called *absolute knowing, transitional knowing, independent knowing,* and *contextual knowing.* Her work has shown that most college students are in the *transitional knowing* stage during the college years, where knowledge is believed to be both certain and uncertain, and emphasis is placed on being able to understand and apply knowledge. It is similar to Perry's *multiplicity* stage. Rauckhorst and Czaja showed that about one-third of the undergraduate researchers moved from transitional to independent knowing, whereas none in a comparison group exhibited this shift. In the independent knowing stage, knowledge is believed to be uncertain and everyone has his or her own beliefs, and emphasis is placed on independent thinking. It is similar to Perry's *relativism* stage. This is an important result because few studies have tried to examine the intellectual gains provided by a research experience. The application of models of intellectual development, such as Baxter Magolda's, to the study of undergraduate research is an exciting and important development.

One of the commonly stated goals of undergraduate research is to improve retention and increase the number of students pursuing careers in science, especially minority students. A study of the Undergraduate Research Opportunity Program (UROP) at University of Michigan (Nagda, Gregerman, Jonides, von Hippel, Lerner, 1998) looked specifically at student retention. The UROP program, initially open to underrepresented minority students only, is now open to all first and second year students in nearly all disciplines.

The goal of UROP is to "broker intellectual relationships between faculty and first-year and sophomore undergraduates through research partnerships." There are many more applicants to the program than there are positions available, so the researchers were able to study 613 participants and a matched control group of 667 non-participants. The researchers divided the students into three subgroups: Hispanic, African American, and White. In general, the UROP program was shown to increase student retention, but it is interesting to exam the details of the results. For first year participants, White and Hispanic students showed no difference in retention rates compared to the control group, whereas African American students showed improved retention, albeit not of statistical significance. For students participating in UROP as sophomores, all three groups showed improved retention, with African American students showing the strongest and statistically significant improvement. In order to examine how retention differs as a function of GPA, students were divided into low and high GPA groups. The low-GPA African American students appeared to benefit most strongly from the UROP program. Their attrition rate was 15.3% compared to 27.1% for the control group. The study raises two questions that would be of interest to pursue further. Why are the benefits stronger for sophomores than for first year students, and why do African American students show the strongest benefit with respect to retention?

The LEAD Center at the University of Wisconsin-Madison, has carried out program evaluations on several undergraduate research programs. The reports are available on the LEAD Center's web site (http://www.cae.wisc.edu/~lead/pages/internal.html). In an evaluation of UW-Madison's Summer Undergraduate Research Program (SURP), the LEAD Center found that the program was an effective tool for recruiting students to graduate school at UW (Foertsch, Alexander, & Penberthy, 1997, June). Importantly, because the summer research program was aimed at minority students and students from institutions without research programs, it proved to be an effective way to recruit minority students to UW. Altogether, slightly more than one-third of the SURP students returned to UW for graduate or professional school.

In an evaluation of the Spend a Summer with a Scientist (SaS) program at Rice University, the LEAD evaluators clearly documented the effectiveness of the program with respect to the recruitment of minority undergraduates into graduate school and the retention of minority graduate students at Rice University (Alexander, Foertsch, & Daffinrud, 1998, July). More importantly, the evaluators were able to delineate the specific characteristics of the program that led to its success. These characteristics are described in a well-documented list of *essential elements*, which might be used to replicate the program at other institutions. For example, students were asked about which parts of the program influenced their decision to attend or remain in graduate school. The top three responses were: interactions with the program director, being in the company of other minority students, and interactions with other students in the program. The report then goes on to give significant detail about what each of these mean. The report provides rich insight into *how* a successful program works. This is one of very few documents that links specific program characteristics to desired outcomes.

The University of Delaware carried out an extensive alumni survey (Zydney, Bennett, Shahid, Bauer, 2002) to study the impact of undergraduate research at Delaware. They divided the respondents into three groups: students who had participated in research through the "official" Undergraduate Research Program (URP), students who self-reported research involvement but did not use the services of URP, and students who had not done research. Undergraduate research participants reported greater enhancement of several important cognitive and personal skills. They also reported higher satisfaction with their undergraduate education and higher rates of going to graduate school. It should be noted, however, that while research participants and non-participants in the study were matched by major, year of graduation, and GPA, the study does not account for the possibility that students who went on to graduate school may have been predisposed to participate in research as undergraduates.

Works in progress

Elaine Seymour (Colorado) and David Lopatto (Grinnell) are carrying out a large research study on the nature and impact of the undergraduate research experience. The goal is to "clarify and estimate the relative importance to students of the benefits of 'good' undergraduate research experience and the processes whereby these are achieved, in a sample of science disciplines and from the viewpoints of participating and non–participating undergraduates and faculty." Seymour and Lopatto are collecting data at four liberal arts colleges.

Early in the study, Lopatto (2003) asked faculty and students about the benefits to students of an undergraduate research experience. Both students and faculty ranked clarifying career plans, learning a topic in depth, and developing research and laboratory skills highly. One difference between faculty and student responses was that faculty rated developing oral and written communication skills as one of the top benefits, whereas students did not. Interestingly, Lopatto noted that student responses indicated a stronger emphasis, relative to faculty responses, about the benefits derived from a good student/research mentor relationship. It will be interesting to learn more about the role and the value of this relationship as this work proceeds.

In the first report from the Seymour group (Seymour, Hunter, Laursen, DeAntoni, 2003, in press), seventy-six undergraduate research students were interviewed from eight science disciplines at four liberal arts colleges. The interviews were transcribed and coded with the following results. The student comments were "overwhelmingly positive" with 91% of student statements referring to gains they had made. The top two reported gains were described in the report as "personal/professional gains" and "thinking and working like a scientist" gains. Within the personal/professional gains category, three-quarters of the student statements referred to their increased confidence to "work as a scientist." The "thinking and working like a scientist" category included statements about gains in the ability to apply knowledge and skills, gains in understanding the scientific process and the process of research, and general gains in science knowledge and understanding. As with the LEAD Center study of the SaS program at Rice, this study has the potential to describe in detail the links between specific program goals, activities, and outcomes.

One of the largest evaluations of the undergraduate research experience is underway presently. NSF is sponsoring SRI, International (S. Russell, personal communication, June 24, 2003) to survey thousands of undergraduate student researchers and faculty, post-doc, or graduate student mentors about their experiences with undergraduate research. There are additional study components planned, such as site visits and follow-up surveys. The objective of the study is to better understand the types of research experiences students have, why faculty and students choose to participate in undergraduate research, and how the experience influences the students' academic and career decisions. The study includes students and faculty from REU programs, NSF-sponsored research centers, RUI institutions, and several other programs such as the Louis Stokes Alliance for Minority Participation (LS-AMP), Tribal Colleges and Universities Program (TCUP), and Historically Black Colleges and Universities Undergraduate Program (HBCU-UP). The student survey included questions about factors in the decision to do research, activities during research, kinds of things learned (how to plan a research project, problem-solving skills, etc.), best and worst aspects of the research experience, and perceived effects of the research experience, including effect on academic major and career choices.

There are many other descriptive accounts of undergraduate research and several program evaluations that were not described here. For example, in 2001, REU site directors held a workshop and produced a report that is full of valuable recommendations (N. Levinger, personal communication, June 25, 2003). With respect to assessment, they emphasized the importance of showing whether or not undergraduate research students were better prepared for careers as scientists or entered such careers with more frequency than comparable students who did not participate in research. It was pointed out that this type of comparison remains difficult because of the problem of trying to both define and locate a "matched" control group of students, and the difficulty of tracking REU students for many years after their participation in research. The study by the Seymour group contains a control group of non-participating students and will undoubtedly provide insight into the question. The SRI, International study also has plans to address the problem by using an available "random" national database, from which they hope to examine the effects of undergraduate research on career choice and success.

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