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Alumni Perceptions Used to Assess Undergraduate Research Experience

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ABSTRACT

On a survey of 986 alumni from a research-extensive university, respondents with undergraduate research experience, when compared to those with no research experience, reported greater enhancement of important cognitive and personal skills as well as higher satisfaction with their undergraduate education. They were also more likely to pursue graduate degrees.

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Introduction

Along with a rapid increase in government funding for academic research in the 1960s came concerns that research activities of faculty in American universities were becoming not only enlarged, but separated from, and elevated far above, their teaching. Clark Kerr (1963) influentially warned against the development of the "federal grant university," and it became widely argued that there exists an inherent conflict between research and education (Sample, 1972). Over the decades, several national reports and academic publications urged greater attention to undergraduate teaching (Astin, 1977; Boyer, 1987). In the world outside of academia, citizens and their legislators sometimes reduced the discussion to counting the number of hours per week spent by faculty in the university classroom (Cage, 1991).

At the same time, defenses of the research endeavor were mounted to argue not only that academic research is important in itself, but also that researchers make good teachers (Ableson, 1967; Jencks & Riesman, 1968). Attempts were made to validate these claims by studying such subjects as relationships between faculty research productivity and student course evaluations (Feldman, 1987; Hoyt & Spangler, 1976). Unfortunately, the initial positing of a conflict between research and teaching had an effect contrary to that intended by those who were calling for reform. The need to defend and uphold the research endeavor itself diverted the potential agents of educational change—the faculty and leadership of research universities—away from re-envisioning the undergraduate experience. As a result, although many faculty-driven inquiry-learning experiments have been initiated (Duch, Groh & Allen, 2001; Monk-Tutor, 2000; Rhem,

1998), basic structures and methods of undergraduate instruction in the nation's research universities have remained largely unchanged.

Integrating Research and Education: Undergraduate Research

The publication in 1998 of the report of the Boyer Commission in effect announced a fundamental shift in the decades-old discussion of "research vs. teaching." The Boyer Report's immediate forerunner was a competition sponsored by the leadership of the National Science Foundation inviting America's research universities to apply for a new kind of grant, a "Recognition Award for the Integration of Research and Education (RAIRE)." Acknowledging that NSF's own portfolio "divide[d] rather clearly into research . . . on the one hand, and . . . education . . . on the other," the Foundation wanted to reshape the old debate (Lane, 1996). Aimed to dislodge the old phrase "research vs. teaching" was the new call for "integrating research and education (IRE)"; IRE has been offered to the U.S. Congress and the public as a "core strategy" of the Foundation itself and for education nationally (National Science Foundation, 2000; National Science Foundation, 1999). IRE is intended, without reducing universities' commitment of faculty effort and of governmental and institutional resources to research, to turn that very research activity into an advantage for the education of undergraduate students who attend such universities.

Reinventing Undergraduate Education, the report produced shortly thereafter by the Boyer Commission, was designed to be a guide, a "blueprint" for the way forward into IRE; the way toward "reinvention," the report says, is to "make research-based learning the standard" for undergraduate education at research universities (Boyer, 1998, pp. 15-16). Historically, research and education have been closely integrated for

undergraduates who collaborate with faculty to conduct research, and this practice underlies the "model" that the Boyer Commission proposes, with "scholar-teachers" who "would treat the sites of their research as seminar rooms in which not only graduate students but undergraduates observe and participate in the process of both discovery and communication of knowledge" (Boyer, 1998, p. 18). Undergraduate research is now held by many academics in the sciences and engineering as the touchstone against which other efforts at IRE should be judged (National Science Foundation, 1989).

Assessment of Student Learning Through Undergraduate Research

Claims for the special educational efficacy of undergraduate research are, however, somewhat suspect, as reflected in this newspaper headline: "Research by Undergraduates Proliferates, But Is Some of It Just Glorified Homework?" (Reisberg, 1998). This article points out that the pressure on universities to offer undergraduate research programs is not only political and ideological, but also economic, as the ability to offer undergraduate research experience is perceived to give an institution "an edge in recruiting" (Reisberg). It would be helpful for faculty and administrators, as well as the general public, to know whether the considerable costs of undergraduate research programs, both in funds and in faculty time, can be justified in terms of value added to the education of the undergraduates who participate in these programs. If other efforts to integrate research and education are to take the presumed benefits of the undergraduate research experience as their goal, it would be good to identify what these benefits are and, if possible, to document their existence.

Before the late 1980s, only a few universities had committed significant resources to institution-wide undergraduate research programs that involved the institutions' faculty

in regular research collaborations with undergraduates. The first institution-wide program was founded by the late Margaret L.A. MacVicar at MIT in 1969 (http://web.mit.edu/urop). Additional research universities with early institution-wide programs were Stanford (http://uro.stanford.edu/uro), Cal Tech (www.its.caltech.edu/~surf) and the University of Delaware (www.udel.edu/UR). Student and faculty participants in undergraduate research at these and other institutions frequently report high levels of satisfaction with learning achieved by undergraduates through collaborative research with faculty (Mabrouk & Peters, 2000; Hakim, 1998; Manduca, 1997); however, efforts at formal assessment of learning outcomes attained through the undergraduate research experience are just beginning.

One approach has been to ask participants in intensive summer research experiences to rate their learning of specific research skills, e.g., literature review, research design, data collection, statistics/computer, scientific writing (Kremer & Bringle, 1990; Kardash, 2000). However, the focus on assessing research-specific skills is somewhat limiting if the undergraduate research experience is to be taken as a model for other forms of IRE, where the goal is not primarily to produce professional scientists but to increase the development of a broad range of cognitive and personal abilities in all undergraduates. Further limitations in these approaches have included small sample size (22 psychology students in Kremer & Bringle, 57 science students in Kardash) and the absence of a control group (Kardash).

Graduate school attendance rates have been examined in earlier studies for which the question has been whether a research experience affects undergraduates' decisions to pursue graduate study in science and engineering (Kremer & Bringle, 1990), especially

for underrepresented minorities (Foertsch, Alexander & Penberthy, 1997; Alexander, Foertsch & Daffinrud, 1998). Although pursuit of graduate study is a desired outcome for talented undergraduates, studies that use data concerning graduate school attendance to demonstrate value-added by the undergraduate research experience have been hampered by failures in their research designs that left them unable to demonstrate that undergraduate research experiences were the cause of continuance to graduate school (Mabrouk & Peters, 2000; Sabatini, 1997; Manduca, 1997; Strassburger, 1995; De La Garza, Anderson & Lee, 1991; Fortenberry, 1990).

In a study of an undergraduate research program for first- and second-year underrepresented minority students, Nagda, Gregerman, Jonides, von Hippel, & Lerner (1998) did demonstrate that this program succeeded in increasing retention rates for some students, especially African American sophomores. A methodological strength of this study was its use of students who had applied to the program but had to be denied admission due to funding limitations; these students were assigned at random to a control group. However, this undergraduate research program's focus on minority student retention limits its applicability to institution-wide programs.

In designing an assessment, it is desirable to match a comparison group of students who have not participated in undergraduate research to a group of undergraduate research participants to be studied. However, it may not be desirable to limit the number of applicants who can benefit from an educational program in order to create a control. Another way to identify a comparison group for participants in a voluntary educational program such as undergraduate research is to study alumni, matching a set of program

participants to a set of individuals who resemble the participants except for the fact that they did not participate in undergraduate research.

Alumni studies have traditionally been used primarily for fund raising from alumni and development of alumni associations. However, colleges and universities are increasingly calling upon alumni to "provide critical assessments of the institution's performance in preparing students to lead productive and rewarding lives," and it is now recognized that there is a "vast alumni research domain to be explored" (Pettit & Litten, 1999, p. 1). Alumni opinions of their undergraduate achievements have been found to correlate well both with their perceptions of these achievements as undergraduates and with faculty opinions about those same achievements (Pace, 1979). Thus, alumni judgment of undergraduate experience can be an accurate measure of undergraduate achievement. A further advantage of studying undergraduate research alumni is that informants will not be tempted, as they might have been while students, to try to ensure continued funding for their research scholarships by skewing their comments in an effort to present the most favorable possible picture of the program. In addition, alumni have a perspective on their undergraduate experience provided by their years of graduate study and/or employment, as is recognized by faculty, for whom alumni surveys generally hold high credibility (Banta, Lund, Black, & Oblander, 1996).

Research Questions

The purpose of the present study was to develop a methodology and instrument that could reliably use alumni perceptions as one measure of the value added by the undergraduate research experience to baccalaureate education. To assess the

effectiveness of undergraduate research as a vehicle for IRE, answers were sought to the following research questions:

1. How do alumni value undergraduate research in comparison to other out-of classroom educational experiences? And, a related question, does a commitment to undergraduate research limit participants' involvement in other aspects of undergraduate curricular and co-curricular activity?
2. Do alumni with undergraduate research experience perceive themselves to have attained higher levels of important general cognitive and personal abilities and skills than comparable alumni with no undergraduate research experience perceive themselves to have gained from their undergraduate education? In addition, do undergraduate research alumni express higher overall satisfaction with their undergraduate education than that expressed by comparison alumni?
3. When examined for differences by research participation, do results differ according to field of study or gender? Most previous studies have been conducted in the sciences; however, benefits of IRE should pertain to all disciplines at a research university. Female undergraduates involved in scientific research have reported lower confidence than male students in their ability to formulate a research question (Kardash, 2000). From their perspective as alumnae, do women with research experience show the same levels of self-confidence in higher cognitive skills as men with research experience?
4. Does the length of time spent on undergraduate research activities affect the perceived benefit of the research experience? The related policy question is

whether students' research experiences could be planned for shorter periods, such as one semester, so as to accommodate more student participation without subtracting significantly from the benefit of the experience to the participants.

5. Does undergraduate research experience increase the likelihood of students' pursuing graduate study and successfully completing doctoral degrees? The answer to this question is of particular interest to potential financial sponsors of undergraduate research programs, especially in high-need areas of engineering and the sciences and in efforts targeted at women and underrepresented minorities.

Method and Instrument

A survey was mailed in Spring 1998 to 2,444 alumni of the University of Delaware, a mid-sized, research-extensive university that has operated a formal, institution-wide undergraduate research program since 1980. Because of its long-established Undergraduate Research Program (URP) and a related, institution-wide practice of problem-based classroom learning, this University received one of the National Science Foundation's ten RAIRE awards.

Characteristics of the Undergraduate Research Program

Undergraduate research at the University of Delaware is defined as "collaboration" between undergraduates and their faculty research sponsors. This means that faculty must give undergraduate researchers a significant role in all phases of the research process. Although undergraduate research students are not exempted from performing the relatively low-skilled tasks of a technician, they must also experience a steady progression in their abilities to develop a research hypothesis, design and carry out

an investigation and analysis of results, contextualize their work within the scholarly literature, and present their work orally and in writing.

Undergraduate Research Program services, which are open to all interested undergraduates, include maintenance of a directory of faculty research projects inviting undergraduate involvement, initial advisement of students and referral either directly to potential faculty mentors or to a faculty liaison in their major department. Consultation is available for new faculty on involvement of undergraduates in their research. The Undergraduate Research Program provides supply-and-expense funding for collaborations, summer research scholarships for students, numerous opportunities for students to present ongoing work, and a university-wide senior thesis program through which students prepare a research proposal, make oral presentations of research-in-progress to other students and faculty, establish a formal thesis committee, and give an oral defense of their thesis.

Over 66 per cent of the University's approximately 950-member faculty regularly participate in undergraduate research, including over 90 per cent of the faculty in the sciences and engineering. From 600 to 700 students are estimated to be engaged in undergraduate research at any one time. Students can begin research at any point in their undergraduate careers; however, normal starting time is mid-sophomore year. Student involvement generally lasts for one to two or more calendar years, usually including one or more summer or winter terms in addition to the academic semesters. Students are advised that they should plan to be involved in research for at least a year even though their commitment is made one term at a time. During the academic year, students usually register for academic credit as undergraduate researchers although those with financial

need can earn work-study money doing undergraduate research. During the summers and, for some students, the five-week winter session, about 200 full scholarships and 20-30 additional partial scholarships, in addition to salaries paid by faculty, enable full-time or a substantial amount of time for work on research.

Selection of the Sample

The 2,444 alumni surveyed for this study included 865 graduates of the Undergraduate Research Program (URP), each of whom was matched as closely as possible with two alumni who shared the same academic major, year of graduation and cumulative grade point average but who were not recorded in the URP database. The URP database contained records of individuals who were known to have conducted undergraduate research and to have received some service from the URP, ranging from an initial advisement meeting, to funding, to production of a senior thesis. Alumni surveyed were from the graduating classes of 1982 through 1997.

Content of the Survey

Respondents were asked to reflect upon a large set of questions about their undergraduate experience. There was no indication, either in the survey itself or in the accompanying letter from the University President, that one of the research questions motivating the survey concerned the evaluation of undergraduate research or the URP.

The four-page survey instrument was developed by a team of faculty who were experienced with undergraduate research in a various engineering, science, and humanities disciplines. The survey asked respondents to indicate the number of terms they had participated in a variety of campus and community activities (e.g., intramural sports, employment on and off campus, study abroad, honors classes, undergraduate

research), their perceived benefit from each activity, and their involvement in graduate study and/or employment since graduation. Respondents were also asked to indicate the level to which 32 skills and abilities that are generally valued outcomes of a baccalaureate education had been enhanced by their years of study at this university (responses were indicated on a 5-point Likert scale with 1=not at all; 2=a little; 3=moderately; 4=importantly; 5=extremely importantly). The list of skills and abilities was adapted from a similar list in an unpublished *Albany Alumni Survey* (Office of Institutional Research, 1989). Alpha reliability coefficients for the current survey ranged from .665 to .913 (for questions related to perceived benefits the alpha coefficient was .665; for skills and abilities the coefficient was .913; and for the coefficient for overall impressions of the baccalaureate experience the coefficient was .742).

Respondents

The first copy of the survey was mailed to respondents in March, 1998. Approximately three months later, a second copy of the survey was mailed to all identified alumni who had not returned their survey from the first mailing. Responses were received from 996 individuals, ten of whom did not include identifying information. Ninety-eight surveys were returned because of incorrect addresses. The 986 usable surveys yielded a final response rate of 42%.

Initial analysis of the survey responses revealed a substantial number of alumni who indicated they had participated in research even though they had been included in the comparison group with no research experience. It became clear that the respondents actually fell into three groups: 1) those who had participated in research through the URP and were in that program's database; 2) those who were not in the URP database, and

therefore had not directly received services from the URP, but who identified themselves as having participated in research as undergraduates; and 3) those with no research participation. It was then decided to analyze survey results using a three-way comparison. Initial analysis of the three groups revealed a difference in cumulative grade point average (gpa); therefore, gpa was included as a covariate in all subsequent analyses.

Of the 986 identifiable respondents, 418 were alumni who had participated in research through the Undergraduate Research Program (the "URP" respondents), 213 responded to survey questions about research and were thus self-identified alumni with research experience (the "self-report" respondents), and 355 had had no undergraduate research experience (the "no-research" respondents). Of the total sample, 428 (44%) were men, 558 women (56%). Approximately 95% of the respondents were Caucasian. These demographic figures are consistent with historical averages at this institution for the time period during which most of the respondents had been enrolled.

Seventy-five academic majors were represented; 59% of the respondents had majored in engineering or the sciences, 41% in the arts, humanities or social sciences. For easier interpretation of any effects due to curricular differences, the 75 majors were classified into three groups: science/engineering, social science, and arts/humanities.

Nearly half of the respondents (46%) had enrolled in at least one honors course; but those who participated in research through the URP had enrolled in an average of 5.4 honors courses, significantly more than self-report research (average 3.7 courses) and no-research respondents (average 3.5 courses).

Undergraduate Activities of the Respondents

Table 1 lists the mean number of terms in which alumni had participated as undergraduates in the activities listed on the survey. Respondents who reported participation in these activities said they had spent, on average, one semester in study abroad, two semesters in internships, and three to four semesters participating in intercollegiate and/or intramural sports, clubs/performing arts, and employment. Respondents who had not participated in research had worked significantly more hours off campus than had the alumni with self-reported research involvement ($F=3.20$, $p=.042$). The URP alumni reported having lived on campus longer as well as having participated to a greater extent in student government than the alumni with no research participation. URP alumni reported having spent more terms conducting research than did self-report research respondents.

(Insert Table 1 about here)

Benefit Gained from Activities

Alumni respondents also indicated the level of benefit they received from the activities included on the survey. Involvement in undergraduate research, completion of a senior thesis, study abroad, and internship related to major were rated as most beneficial by the total group of respondents. As shown in Table 2, there were some perceived differences related to participation in undergraduate research. These differences were unaffected by gender, major group, honors participation or year of graduation. Univariate analyses of covariance (with gpa as covariate and Bonferroni test of significance) revealed greater perceived benefits from honors classes for URP alumni than for self-reported and non-research alumni. In addition, benefit received from participation in undergraduate research was significantly higher for URP alumni than for those who self-reported research

participation. Furthermore, perceived benefit from participation in undergraduate research was even stronger for those URP respondents who completed a senior thesis ($F=18.87$, $p<.001$) compared to the URP alumni who did not complete a thesis.

(Insert Table 2 about here)

Skills and Abilities Enhanced During Baccalaureate Studies

Table 3 lists respondents' perceptions of the extent to which skills and abilities were enhanced by their baccalaureate studies. As shown, respondents said that nearly all skills listed on the survey were more than "moderately" enhanced, with highest scores received for becoming intellectually curious, independent, logical thinkers and problem solvers. A multivariate analysis of covariance revealed no significant interactions between research group and gender, major, honors experience, or year of graduation but did reveal main effect differences by research experience.

When comparisons are made between research and non-research respondents for reported level of skills enhanced, significant differences are found for several skills and abilities that are critical components of the baccalaureate curriculum. Not surprisingly, both groups of alumni with research experience reported significantly greater enhancement of their ability to carry out research than did alumni who had done no research beyond that required for courses. Furthermore, alumni whose undergraduate research had been facilitated by the URP reported significantly higher growth in their ability to carry out research than did the alumni with self-reported research experience. URP alumni reported greater increases than non-research alumni for seven additional items (multiancova with Bonferroni, $p<.05$). These include the ability to develop intellectual curiosity, acquire information independently, understand scientific findings,

analyze literature critically, speak effectively, act as a leader, and possess clear career goals.

(Insert Table 3 about here)

A principal components factor analysis of the 32 skill items yielded four factors that account for 48.7 % of the variance in the responses. A multivariate analysis of covariance using the four factors as the dependent variables indicated main effects by research group, gender, and major group, but no significant interactions between research participation and gender, major group, or year of graduation. Among the three research groups, significant differences were found for three of the four factors. These three factors incorporated 19 skills and abilities. The three skills factors are:

(1) Science, math, logic, and problem solving—including the ability to understand scientific findings, understand math concepts, think logically, approach problems creatively, use statistics or math formulas, utilize computing skills, and adapt to changing technology.

(2) Literature, language, and mastery of contexts--including analyze literature critically, know literature of merit in one's field, use foreign language skills, place current issues in historical context, appreciate artistic and creative experiences.

(3) Personal initiative and communication—including the ability to acquire information on one's own, synthesize and use information from diverse sources, solve problems independently, better, understand oneself, write, speak, and listen effectively.

The fourth factor, Personal and Social Skills, showed no significant differences by research group. Table 4 shows the findings for skills factors by research group. No main

or interaction effects for gender or major group indicates that URP alumni of both genders and from all three major groups perceived significantly greater growth in both their science/math/logic/problem-solving skills and their humanities/verbal skills than did comparable alumni with no research experience. The URP alumni also reported significantly greater enhancement of their initiative and communication skills that did either the respondents with no research experience or those with self-reported research experience.

(Insert Table 4 about here.)

Effect of Time Spent in Research

While alumni perceived even one semester's experience in undergraduate research to be very beneficial, responses indicated that in general, the longer one had participated in research, the greater the perceived benefit ($r = .330$, $p < .01$). For example, the mean benefit for those respondents who had been involved for one semester was 3.94; for two semesters it was 4.24; for six semesters it was 4.74, and for eight semesters the mean benefit was 4.90 (1=not at all important; 3= important; 5= extremely important). URP alumni reported having spent about one-third more time in research than self-report research alumni reported (see Table 1), and the URP alumni's undergraduate research experience was more than twice as important in affecting their decisions about graduate school and career than was that of self-report alumni.

Further Education Beyond the Baccalaureate

In addition to inquiring about participation in undergraduate activities, perceived benefits, and skills and abilities enhanced, this survey examined post-baccalaureate education and career endeavors. Of the total respondent sample, 70% reported pursuing

graduate education. Graduate school attendance rates differed by research participation: 80% of the URP alumni, 71% of the alumni with self-reported research experience, and 59% of the alumni with no research experience pursued graduate education. For further examination of the association of research experience with graduate school attendance, a probit analysis was conducted. Since a difference in cumulative gpa had been found among the three groups, the probit analysis was conducted with gpa as an independent variable in addition to research. The probit analysis (with grand mean gpa of 3.496) confirmed that participation in research increased the respondents' likelihood of pursuing a graduate degree. Based on the sample in this survey, the probability that alumni with undergraduate research experience would pursue graduate study was 67%, significantly higher than for alumni with no research experience at 57%.

The extent to which graduate study is associated with undergraduate research experience is even more noticeable when only doctoral degrees are considered. Of those respondents who attended graduate school to earn doctoral degrees (N = 206 excluding M.D. and J.D. degrees unless these were earned in addition to Ph.D.s), 67% were URP alumni, 21% were self-report undergraduate research alumni, and 12% were alumni with no undergraduate research experience. Probit analysis showed that URP alumni were about twice as likely to pursue a doctoral degree as were comparable alumni with no research (43% vs.23%). The likelihood that self-report research alumni would pursue the doctorate was 36%.

Regarding employment, the majority of all respondents said they were employed in a career related to their major; but compared to those who had participated in the URP, about one-third more non-research alums were employed in a career that was not related

to their major. Also, in comparison to URP alumni, more than twice as many respondents who had not participated in research said they were not employed outside the home.

Effect of Research Involvement on Overall Growth and Satisfaction

A final question asked respondents to indicate their overall satisfaction with their baccalaureate experience. Although alumni in all three research groups reported high overall growth and satisfaction, a univariate analysis of covariance found that, compared to alumni with no research experience, URP alumni reported significantly greater overall satisfaction ($F=4.71$, $p=.009$).

Discussion

The primary purpose of this study was to investigate educational outcomes related to the undergraduate research experience, which is a primary method of integrating faculty research into the education of undergraduates. A second goal was to develop a method for using alumni perceptions to assess educational outcomes. To test the assumption that research universities should pursue the integration of research and education (IRE) through undergraduate research programs, the fundamental question being addressed was: Can undergraduate research be shown to add a significant value to the education of its participants?

Instead of asking alumni of the Undergraduate Research Program what they thought they had gained from their undergraduate research experiences, the study surveyed both these alumni and a comparison group, asking the respondents to report time spent in, and benefits received from, a variety of activities, including research. The alumni were asked to report the extent to which their undergraduate education had

enhanced 32 skills and abilities that are important goals of the baccalaureate experience. Respondents were also asked to indicate their overall satisfaction with the undergraduate education they had received and to report any postgraduate education. An initial analysis of the responses indicated two distinct groups of survey participants with research experience. Therefore, findings were compared across three research groups: those who had conducted research through the Undergraduate Research Program, those who had conducted undergraduate research without using services of the URP, and those who had done no undergraduate research. Initial analysis also revealed a difference in final cumulative grade point average among the three groups; thus, all subsequent analyses used gpa as a covariate.

All respondents with undergraduate research experience, whether through the URP or not, gave high ratings to the benefits received from their research experience. Even respondents who reported only one semester of research rated that experience as highly beneficial. Highest ratings were given by those who had devoted the greatest amount of time to research and had completed a senior thesis through the URP.

From responses examined, it appears that involvement in research did not interfere with involvement in other campus activities. On the contrary, respondents who had participated in research also reported involvement in other campus activities (such as sports, clubs, performing arts, and student government) at similar, and in some cases, higher levels than respondents who had not participated in undergraduate research. Likewise, involvement in research did not hinder respondents' ability to enroll in honors courses and maintain high grades. While it is likely that research students have high

academic ability, it is also likely that these students refine their time management skills and learn to apportion time efficiently to a variety of activities.

Alumni of the Undergraduate Research Program reported significantly greater enhancement for eight specific cognitive and personal skills and abilities compared to alumni with no research experience. A factor analysis of these skills and abilities showed that URP respondents believed they had enhanced skills in three of four factors to a greater extent than had non-research alumni. In addition to these areas showing statistical significance, as can be seen in Table 3, there is a consistent trend throughout the survey that shows greater perceived enhancement of skills for those alumni who participated in undergraduate research. While the level of several individual skills items did not reach statistical significance, their presence in the factors, combined with the overall trend in which research alumni report higher enhancement of almost all skills, suggest that these skills may be related to the undergraduate research experience.

Significant differences were also found between the two groups of respondents with research experience. Compared to self-report research alumni, URP alumni reported greater enhancement of their ability to carry out research and a greater enhancement of the skills represented in the Communication and Personal Initiative factor. Because the differences appeared in the areas of independent achievement (acquire information on my own, synthesize and use information from diverse sources, solve problems independently, better understand myself) and communication skills (listen effectively, write effectively, speak effectively), it may be that URP students were given greater individual responsibility and involvement by their faculty in the full range of research activity

leading, for many, to the senior thesis and other projects for which the student became the primary investigator.

The relationship between undergraduate research experience and pursuit of graduate study is notable. The fact that alumni with research experience were significantly more likely to continue their educations beyond the bachelor's degree and were about twice as likely to complete doctoral study as were comparable alumni with no research experience suggests that skills and abilities enhanced by research contributed to their success as doctoral candidates.

The finding that respondents' overall satisfaction with their undergraduate education was significantly higher for alumni of the URP is consistent with responses in other parts of the survey and confirms the perceived educational value added by undergraduate research. One potentially confounding variable, academic ability as measured by cumulative gpa, was used as a covariate in all analyses. In any future studies of alumni at this institution, a second potentially confounding variable could be courses that employ another form of IRE, problem-based learning (PBL). For the time period covered by this survey, however, PBL participation was not a threat to validity because the alumni surveyed had graduated before PBL had become an extensive presence at the institution. A post-hoc analysis by year of graduation showed that results did not vary by year, thus confirming that PBL was not a confounding variable for this sample.

Overall, although the differences perceived cannot be considered cause and effect, it is highly likely that participation in undergraduate research played an important role in

the significant increases in outcomes and satisfaction reported by these alumni when compared to the increases reported by alumni who had not undertaken research.

Implications

Because results of this study indicate important educational gains associated with undergraduate research, faculty concerned with improving undergraduate education should be encouraged to develop undergraduate research opportunities at their universities. However, it should be cautioned that the Undergraduate Research Program model being evaluated in this study defined undergraduate research as direct involvement of undergraduates in on-going faculty research. This model assumes undergraduate research involvement to include increasing independence for the undergraduate researcher over an average period of at least one calendar year. The study's outcomes should be taken to have direct implications only for programs using such a model; these outcomes may or may not be similar to those from programs using other approaches to undergraduate research or other forms of IRE. Results do suggest, however, that as many faculty as possible in all disciplines should become involved in these highly beneficial collaborations and that institutions should commit funds sufficient to allow undergraduates to work with the faculty in research for substantial periods of time.

Faculty researchers collaborate in different ways depending on differing academic disciplines, resources, and individual preferences. Many faculty at present choose not to involve undergraduates in their research. For institutions wishing to follow the Boyer Commission's call to encourage the great majority of their faculty to collaborate with undergraduate researchers, additional studies documenting the range of successful approaches taken by faculty to undergraduate research would be helpful. Such studies

should attempt to document the motivations of faculty for working with undergraduates as well as their perceptions of the costs and benefits to themselves of this form of IRE. Such studies should also determine whether faculty report educational outcomes for their own undergraduate research students that are similar to those reported by research alumni.

In addition to alumni and faculty surveys, other methods for assessment of IRE-program educational outcomes should continue to be developed. To assess the undergraduate research experience, qualitative investigations of undergraduate research students' perceptions of their own learning through research might illuminate the ways in which the research experience works to achieve the results shown. In addition, some assessments should move beyond self-reported data to attempt direct measurement of longitudinal cognitive gains for undergraduate research participants compared to the gains made by subjects in control groups.

The survey used in this study could be readily adapted for the assessment of undergraduate research programs at other institutions. It could also be used to assess other IRE initiatives, especially if only one such initiative was prevalent in the institution whose alumni are being studied during the period when the alumni surveyed were enrolled as undergraduates. The skills and other outcomes included in the instrument are central to all baccalaureate curricula; and they can be adapted to include questions of interest to the investigators. The method for establishing a comparison group matched by predetermined criteria worked in this case even though, post hoc, it was necessary to adjust the comparison groups' membership and to include a covariate in the analyses of data. Since students at the institution in this study are encouraged to arrange their own

undergraduate research placements as well as to use the service of the URP, however, it could have been anticipated that alumni who had done so would be among the respondents in the attempted comparison group.

It is worth noting that this survey had a good response rate (42%). Several respondents added a comment to thank the University President for conducting such a survey and including them in it. Many expressed the belief that studying the alumni experience concerning such central questions as those investigated on the survey showed real educational leadership and would be of benefit to the educational mission of the institution in years to come.

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Table 1

Average Number of Semesters Involved in Campus Activities, Adjusted for GPA

Activity	M # semesters URP Research	M # semesters Self-Report Research	M # semesters No Research
Employed on campus	4.00	3.70	3.88
Employed off campus	3.72	3.39 [b]	4.18 [b]
Studied abroad	1.10	1.15	1.23
Intercollegiate sports	4.23	4.86	5.00
Intramural sports	3.93	4.08	3.81
Clubs, performing arts	5.45	5.14	5.03
Student government	3.78[b]	2.84	2.54 [b]
Internship related to major	1.98	2.16	1.96
Senior thesis	2.37 [b]	1.60 [b]	NA
Honors classes	5.36[a]	3.69	3.50
Undergrad research at university	3.23[b]	2.37 [b]	NA
Lived in campus housing	5.81 [b]	5.60	5.40 [b]
Community Service	3.60	3.59	4.07
Fraternity/Sorority member	5.34	5.34	5.18

[a] indicates group is significantly different from other two groups (Bonferroni procedure, $p<.05$)
[b] indicates these two groups are significantly different (Bonferroni procedure, $p<.05$)

Note. Findings for three items should be interpreted cautiously since only a small number of respondents participated in study abroad (195), intercollegiate sports (74), and student government (77).

Table 2

Benefit By Research Group, Adjusted for GPA

Activity	M Benefit URP Research	M Benefit Self-Report Research	M Benefit No Research
Employed on campus	4.05	3.90	3.89
Employed off campus	3.54	3.69	3.75
Studied abroad [c]	4.49	4.52	4.50
Intercollegiate sports [c]	3.61	3.72	4.22
Intramural sports	3.37	3.58	3.56
Clubs, performing arts	3.97	3.82	3.90
Student government [c]	3.43	2.85	3.11
Internship related to major	4.59	4.55	4.44
Senior thesis	4.65 [b]	3.72 [b]	NA
Honors classes	4.30 [a]	3.96	3.88
Undergrad research at university	4.53 [b]	4.18 [b]	NA
Lived in campus housing	3.82	3.87	3.99
Community Service	3.89	3.80	3.93
Fraternity/Sorority member	3.72	3.90	3.90

5=very strong; 3=moderate; 1=very little benefit

[a] indicates group is significantly different (Bonferroni, $p<.05$)
[b] indicates these two groups are significantly different (Bonferroni, $p<.05$)
[c] Findings for three items should be interpreted cautiously since only a small number of respondents participated in study abroad (195), intercollegiate sports (74), and student government (77).

Table 3

Skills and Abilities Enhanced at Undergraduate Institution by Research Groups, adjusted for GPA

	URP	Self Report	No Research
	M	M	M
Write effectively	4.06	3.91	3.90
Speak effectively	3.69[b]	3.43	3.31[b]
Listen effectively	3.70	3.63	3.69
Better understand myself	3.84	3.86	3.67
Acquire info on my own	4.30[b]	4.16	4.08[b]
Solve problems independently	4.14	3.99	3.98
Act as a leader	3.59[b]	3.41	3.26[b]
Understand ethical implications	3.33	3.28	3.29
Cope with conflict	3.24	3.33	3.24
Understand scientific findings	3.54[b]	3.57	3.30[b]
Utilize computer skills	3.55	3.45	3.33
Carry out research	4.47[a]	3.99[a]	3.44[a]
Use statistics or math formulas	3.19	3.28	3.17
Understand math concepts	3.13	3.31	3.21
Use foreign language skills	2.65	2.46	2.72
Appreciate artistic & creative experiences	3.12	2.98	3.07
Know literature of merit in field	3.49	3.54	3.28
Analyze literature critically	3.67[b]	3.46	3.28[b]
Understand cultural differences	3.13	3.16	3.14
Relate well to people of diff. races/culture	3.25	3.38	3.31
Strengthen interpersonal relationship skills	3.69	3.56	3.72
Maintain openness to new ideas	3.93	3.85	3.90
Possess clear career goals	3.43[b]	3.16	3.08[b]
Place current issues in historical context	3.21	3.07	3.09
Prepare to be good citizen	3.12	3.00	3.17
Work as part of a team	3.55	3.54	3.47
Adapt to changing technology	3.22	3.04	3.11
Think logically about complex material	4.04	4.00	3.93
Approach problems creatively	3.87	3.75	3.71
Synthesize & use info from diverse sources	4.01	3.92	3.83
Develop intellectual curiosity	4.24[b]	4.14	4.02[b]
Tolerate ambiguity	3.20	3.03	3.20

5= extremely; 3= moderately; 1=not at all

Based on estimated marginal means
[a] indicates that all three groups are different (Bonferroni, $p < .05$)
[b] indicates the groups are significantly different (Bonferroni, $p < .05$)

Table 4

Skills and Abilities Factor Scores, Adjusted for GPA

Skill/Ability Factor	URP	Self-Report	No Research
	M	M	M
Science/Math/Logic/Problem-Solving Factor	3.50 [b]	3.48	3.37 [b]
Literature/Language/Mastery of Contexts	3.25 [b]	3.14	3.02 [b]
Communication/Initiative Factor	3.94[a]	3.80	3.78
Personal/Social Factor	3.41	3.36	3.34

5=extremely; 3=moderately; 1=not at all

[a] indicates group is significantly different from other two groups (Bonferroni procedure, $p<.05$)
[b] indicates these two groups are significantly different (Bonferroni procedure, $p<.05$)

Endnote

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