The Disciplinary Effects of Undergraduate Research Experiences with Faculty on Selected Student Self-Reported Gains

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Abstract

Undergraduate research experiences are associated with numerous positive outcomes for students. Yet, less is known about the influence of different aspects of students' experiences in undergraduate research and their effects on students' gains. This study examines the effects of different disciplines on the nature and benefits of research experiences with faculty for 2,670 seniors from 63 institutions. Results show that academic disciplines influence some aspects of students' experiences such as their role, contributions to the research activities, and individual gains. Across all fields, participants report collective gains in intellectual skills, research skills, as well as career and collaboration skills. Being involved in certain research activities and having on-going, substantive faculty contact positively influenced these gains.

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Introduction

Ensuring a high quality undergraduate education has never been more important. The Association of American Colleges and Universities [AAC&U] (2007) strongly recommends that undergraduates engage in "inquiry projects, [because] students should learn how to find and evaluate evidence, how to consider and assess competing interpretations, how to form and test their own analyses and interpretations, how to solve problems, and how to communicate persuasively" (p. 30). The Boyer Commission (1998) similarly advocated providing undergraduate research opportunities to improve desired learning outcomes as these experiences allow students to see first-hand and participate in defining and solving problems as the inquiry process unfolds (Kinkead, 2003). When organized and supervised effectively, undergraduate research experiences are particularly powerful because they require that students devote considerable time and effort, interact with faculty over extended periods of time about substantive matters, receive frequent feedback, and apply what they have learned (Kuh, 2008).

Related Literature

Institutionalized undergraduate research programs are not a new phenomenon. Massachusetts Institute of Technology established the first campus-wide program in 1969 (Hakim, 2000; Merkel, 2001). Taking part in undergraduate research has become more popular during the past decade (Hu, Kuh, & Gayles, 2007) as about one in five seniors in research universities and master's comprehensive institutions do so (Kuh, Chen, Nelson Laird, & Gonyea, 2007; National Survey of Student Engagement [NSSE], 2007a). Seniors at baccalaureate colleges participate at even higher rates (approximately 24%) (NSSE, 2003, 2004, 2005, 2007a; Hu et al.; Hu, Scheuch, Schwartz, Gayles, & Li, 2008).

Involving undergraduates in research is receiving more attention today because it is associated with a range of positive benefits for students. For example, those who do are more likely to earn a baccalaureate degree (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998), take more honors and advanced level courses (Bauer & Bennett, 2003; Jonides, von Hippel, Lerner, & Nagda, 1992), and engage more frequently in educationally purposeful activities (Bauer & Bennett; Hathaway, Nagda, & Gregerman, 2002). They also exhibit greater gains in interpersonal communication and language skills, in scientific, mathematical, and analytical reasoning skills, and in their knowledge of the literature of the topic being investigated (Bauer & Bennett; Lopatto, 2004, 2006; Mabrouk & Peters, 2000; Seymour, Hunter, Laursen, & Deantoni, 2004; Ward, Bennett, & Bauer, 2002). Numerous studies also show that participating in undergraduate research strengthens inquiry skills (Alexander, Foertsch, Daffinrud, & Tapia, 2000; Bauer & Bennett; DeAngelo & Levis-Fitzgerald, 2007; Gafney, 2001; Hathaway et al.; Kardash, 2000; Joyce, 2003; Lopatto, 2004; Mabrouk & Peters; NSSE, 2007a; Seymour et al.; Ward et al.) as well as objective learning in disciplinary knowledge (Ishiyama, 2002; Webster et al., 2006), critical thinking, reflective judgment (Bauer, 2001), and epistemological development (Baxter Magolda, Boes, Hollis, & Jaramillo, 1998; Ryder, Leach, & Driver, 1999). Seymour et al. contends that undergraduate research may help build confidence and self-esteem because students take risks with new responsibilities, behaviors, and relationships, such as formally presenting their research findings and interacting more often with faculty (Alexander et al.; Foertsch, Alexander, & Penberthy, 1997; Jonides et al.; Joyce).

Participating in undergraduate research is also positively linked to career planning and to more interest in and pursuit of advanced education. Students who participate in undergraduate research also have clearer career goals (Bauer & Bennett, 2003; Campbell & Skoog, 2004; Gafney, 2001; Kremer & Bringle, 1990) and express interest in and pursue post-baccalaureate education at significantly higher rates than their peers who do not have such an experience (Alexander et al., 2000; Bauer & Bennett; Foertsch et al., 1997; Hathaway et al., 2002; Ishiyama, 2002; Jonides et al.,1992; Lopatto, 2003a, 2003b, 2004; Mabrouk & Peters, 2000; Schowen, 1998; Seymour et al., 2004; Ward et al., 2002; Werner & Sorum, 2003).

Purpose of the Study

The benefits of undergraduate research are overwhelmingly positive. What is not well understood is whether there are differential effects of disciplines or of different aspects of the research activity on the nature and outcomes of these research experiences. Learning more about these matters will be instructive for program administrators who oversee and desire to improve the scope and impact of these programs as well as for students who are involved in or considering doing an undergraduate research project.

Toward these ends, three research questions guide this study:

1) What effects -- if any -- do disciplines have on the nature of students' involvement in research activities and their contributions to the research activity?
2) What do students gain from participating in undergraduate research?
3) How do various kinds of experiences in undergraduate research affect students' gains?

Methods

The data for this study come from the National Survey of Student Engagement (NSSE), a questionnaire that measures the degree to which first-year and senior students participate in educational practices that prior research shows is linked to valued collegiate outcomes (Chickering & Gamson, 1987; Kuh, 2001, 2003). The NSSE instrument is administered annually to randomly selected first-year and senior students at hundreds of colleges and universities.

Sample

This analysis is based on responses to questions about undergraduate research experiences added to the 2007 Web version of NSSE. These items were completed by 2,670 seniors at 63 institutions (12 doctoral, 23 master's, 24 bachelors, and four other types). Forty-three percent of respondents were from doctoral, 32% from master's, and 22% from bachelors institutions. The institutional sample size ranged from 450 to 4,000 students, and was based upon undergraduate enrollment (NSSE, 2007b). During this particular year the institutional-level response rate was approximately 36% for the Web-based administration modes (NSSE, 2007a). Respondents were from the following major fields: 22% biological and physical sciences, 18% social sciences, 14% arts and humanities, 14% business and professional fields, 10% engineering, and 7% education. Forty-nine percent were male and 90% were enrolled full-time. A majority of the sample was White (79%), and 5% were African American, 4% Asian American or Pacific Islander, 6% Hispanic, and less than 1% Native American. Fifty-three percent lived on campus and 15% percent were adult students over 25 years of age. About 30% of the seniors started college at a different institution.

Measures

To identify behaviors and activities related to undergraduate research experiences worth exploring, staff at the Center for Postsecondary Research reviewed relevant literature to develop a series of questions representing a wide range of activities related to undergraduate research, how such projects might be initiated, and the skills that students could gain through these experiences. After extensive vetting of many items, eight questions were presented to respondents who indicated on the core NSSE questionnaire that they had done undergraduate research (Appendix A contains a list of the undergraduate research items used in this analysis).

Data Analyses

The data were analyzed in four steps. First, we generated descriptive statistics to answer the first research question by summarizing students' experiences in undergraduate research and determining whether differences existed by major field. To answer the second research question and determine what students gained from their research experiences, we computed descriptive statistics for the gains items and compared gains by major field. Then, we completed a factor analysis on these gains items. We used regression analyses to answer the third question about how different aspects of the research experience affected student gains.

Factor analyses. We first ran exploratory factor analyses on the gains items by using principal axis factoring with Promax rotation. Three factors emerged from these factor analyses, which were intellectual skills, career and collaboration skills, and research skills. Table 1 shows the factor loadings and internal consistency estimates (Cronbach's alpha). The Cronbach's alpha scores ranged from .84 to .86.

< Insert Table-1 about here>

We also estimated the robustness of the three factors through confirmatory factor analyses. We created a three factor measurement model and allowed covariance among the error terms of the items where there was usage of similar or the same words (e.g. clearly, efficiently, effectively, etc.) (Byrne, 2001). Using the Maximum Likelihood method for parameter estimation, we used five goodness-of-fit statistics to determine if the model was acceptable: Root Mean Square Error of Approximation (RMSEA), relative chi-square (CMIN/DF), Comparative Fit Index (CFI), Incremental Fit Index (IFI), and Tucker-Lewis index (TLI) (Hoyle & Panter, 1995; Maruyama, 1998). The acceptable cutoff values for CFI, IFI, and TLI were above .90, and for RMSEA it was less than .08. For relative chi-square (CMIN/DF), the acceptable value was less than 5. For better comparability, we used standardized factor loadings.

<Insert Table-2 about here>

The model fit tests indicated the overall measurement model was acceptable. Only the relative chi-square (CMIN/DF) (Table 2) was beyond the recommended range which is acceptable when there is a large data set. The other four model fit statistics are less vulnerable to sample size and are in the acceptable region. The CFI, IFI, and TLI values are above .90 and the RMSEA value is less than .08. The factor loadings (Table 3) were significant at $p<.001$, with the standardized factor loadings ranging from .63 to .89.

<Insert Table-3 about here>

The intellectual skills factor included four items: ‘Thinking critically and analytically,’ ‘Synthesizing, organizing, integrating ideas,’ ‘Writing clearly and effectively,’ and ‘Thinking imaginatively.’ Career and collaboration skills included five items: ‘Solving complex, real-world problems,’ ‘Working effectively with others,’ ‘Speaking clearly and effectively,’ and ‘Acquiring job- or work-related skills.’ Research skills included five items: ‘Understanding how research is conducted,’ ‘Applying theory to practice,’ ‘Making judgments about the quality of information,’ ‘Learning effectively on one’s own,’ and ‘Understanding how knowledge is created.’

Regression Analyses. The three gain factors were used as dependent variables in the three ordinary least squares (OLS) regression models that tested the effects of undergraduate research experiences on these gains. Since the focus of the third question considered different aspects of the research experience (time devoted, who initiated the research project, working with other undergraduates, student contributions, and faculty contact), we entered each of these research experience items as independent variables. The models also controlled for student characteristics (gender, full-time status, academic major). For multivariate multicollinearity we checked the variation inflation factor (VIF) scores. None of the independent variables were problematic as all of VIF scores were less than 3.We used standardized beta coefficients as effect sizes for the OLS models. An effect size of less than .10 was considered substantially trivial and an effect size larger than .10 was thought to have potential practical importance and deserving attention.

Limitations

The institutions that received the additional items about research experiences mirror all US colleges and universities in terms of institutional characteristics such as Carnegie classification and control. However, generalizations are limited because these institutions chose to participate in NSSE. Our results and conclusions most appropriately apply to institutions in this study. In addition, comparisons made between students at different types of institutions are made without controlling for pre-college measures of students' levels of engagement or their predispositions toward college. Consequently, it is possible that differences between students may be due to institutional cultures and other contextual variables or entering student characteristics (Pascarella, 2001).

Another limitation is that the information about learning and personal development outcomes (gains) associated with participating in undergraduate research and questions about the nature of the undergraduate research experience were collected using the same instrument. In such instances, students may tend to rate the outcome items in similar ways as the engagement items, a relationship which Pike (1999) calls constant error of the halo. This phenomenon held in this study. The only way to address this issue is to administer a set of outcome questions separate from the experiences questions, something that should be considered in future research.

Results

Student Experiences and Contributions

Time devoted to undergraduate research. Respondents reported spending varying amounts of time on their research projects, with 31% devoting less than two months, 26% three to four months, 24% five to ten months, and 19% more than 10 months (Table 4). More students in biological and physical sciences as well as engineering spent more than five months on their research projects compared with their counterparts in the arts and humanities, business and professional fields, and education where most were involved fewer than four months. Social science majors were about evenly distributed among these time frames.

<Insert Table-4 about here>

Initiating undergraduate research projects. The most frequent initiator of students' participation in undergraduate research was a faculty member as three of ten respondents said a faculty member invited them to work together (Table 5). Another quarter (26%) said they approached a faculty member and asked to join their research team. A fifth said they developed a research idea and proposed it to a faculty member. Students in biological and physical sciences were more likely to ask a faculty member if they could join a research team (54%), whereas students in the arts and humanities (34%) and social sciences (32%) were more likely to propose a research idea to a faculty member.

<Insert Table-5 about here>

Students working in research groups. More than half (55%) of the students doing research in biological and physical science worked with other undergraduates on their project. Less than a third (30%) of students in the arts and humanities did so (Table 6).

<Insert Table-6 about here>

Data sources. Over half (57%) of the respondents indicated that a substantial amount (very much or quite a bit) of their research data came from existing information obtained from libraries and the internet (Table 7). Most (74%) biological and physical science and engineering (68%) students had a substantial amount of their data come from laboratory work. More than half of the students in social sciences (59%), business and professional fields (53%), and education (52%) also reported that a substantial amount of their data came from fieldwork, interviews, and surveys.

<Insert Table-7 about here>

Students' contributions to research projects. Seven out of ten respondents contributed a substantial amount (very much or quite a bit) to 'Reviewing related literature,' 'Collecting data,' 'Analyzing data,' 'Interpreting findings,' and 'Writing up results' (Table 8). Students majoring in the arts and humanities as well as social sciences most frequently 'Reviewed related literature.' 'Collecting data' was common to almost all disciplines except arts and humanities. More students in the biological and physical sciences and social sciences contributed to 'Analyzing data.' Additionally, more students in the biological and physical sciences contributed to 'Interpreting findings' and 'Formally presenting findings.'

<Insert Table-8 about here>

Nature of contact with faculty member. Three-fifths (60%) of the respondents said they received a substantial (very much, quite a bit) amount of information from faculty as the project started (Table 9). Seven of ten said they got substantial feedback as the project progressed and when it ended. However, 63% reported they had to figure out on their own how to organize their time and conduct the research. Less than half of the students in arts and humanities (49%) and engineering (45%) received a substantial amount (very much, quite a bit) of instruction at the start of the project. Compared with their peers in other areas, seven out of ten students in these two fields had to take substantial responsibility to independently organize their time and figure out on their own how to conduct the research (75% in arts and humanities and 71% in engineering respectively). However, this pattern changed at the project's end with student researchers in the arts and humanities (79%) reporting the most feedback and engineering (63%) students the least.

<Insert Table-9 about here>

Inquiry Experiences Associated with Student Gains

Students' gains compared by academic majors. There were marked differences by academic majors in five out of the fifteen student gains items as related to undergraduate research experiences (Table 10). Close to three-quarters (74%) of education students reported substantial gains (very much or quite a bit) in 'Writing clearly and effectively' as compared to about half (51%) of engineering students. Most (77%) arts and humanities students had substantial gains in 'Thinking imaginatively' as compared to over half of those in engineering (58%) and the biological and physical sciences (55%). More students in education (68%) reported substantial gains in 'Speaking clearly and effectively' as compared to less than half (48%) of those in engineering. While most (73%) engineering students reported substantial gains in 'Solving complex, real-world problems,' about half (51%) of arts and humanities students reported similar gains. Almost all (90%) of biological and physical science students reported substantial gain in ‘Understanding how research is conducted,’ which fewer (70%) arts and humanities students reported.

<Insert Table-10 about here>

Intellectual skills. The independent variables accounted for 47% of the variance in intellectual skills, F (23, 2288) = 89.55, $p < .001$ (Table 11). After controlling for student characteristics and research experiences, students were more likely to develop intellectual skills if they contributed to the research study design (.10), reviewed related literature (.11), and helped to interpret findings (.11). Ongoing contact with faculty research mentors were also significant predictors, such as receiving detailed feedback when beginning the project (.11), as it progressed (.13), and at its end (.24).

Career and collaboration skills. The independent variables accounted for 37% of the variance in career and collaboration skills, F (23, 2267) = 58.52, $p < .001$ (Table 11). Students were more likely to report development in this area when they contributed to the research study design (.13) and formally presented research findings to people other than the research team (.17). Certain faculty interactions were significant predictors, such as providing feedback as the project progressed (.13) and ended (.21). Surprisingly, working with one or more undergraduates was negatively related to gains in this area (-.10), which suggests that working in a research group may not necessarily be linked with the intended outcomes without some additional intervention or guidance from the faculty mentor. This model also showed significant positive gains for students majoring in business and professional fields (.07) and education (.07).

Research skills. The independent variables accounted for 45% of the variance in research skills, F (23, 2250) = 78.70, $p < .001$ (Table 11). Two areas that predicted research skills gains were student contributions to the research effort, such as reviewing related research (.11), collecting data (.10), and interpreting findings (.14), and faculty contact, specifically feedback at the start (.13), as it progressed (.17), and when it ended (.18). The duration of the project (.10) was also significant, as students who were involved in longer periods reported gaining more in terms of research skills.

<Insert Table-11 about here>

Discussion and Conclusions

National reports and scholars are of one mind in recommending engaging students in research experiences to enrich the undergraduate experience (AAC&U, 2007; Boyer Commission, 1998, 2002; Council on Undergraduate Research [CUR] & National Conference for Undergraduate Research, 2005; Hu et al., 2008; Karukstis & Elgren, 2007). As with other aspects of learning and personal development, research activities seem to have conditional effects, in that some have activities have greater or lesser effects (Pascarella & Terenzini, 2005). This study begins to explain some of these conditional effects by examining the nature of activities that contribute to desired outcomes and the disciplinary effects on these aspects of undergraduate research experiences. More specifically, the findings from this study point to three conclusions about undergraduate student research.

First, the nature of students' engagement in research activities affects how and the extent to which they benefitted from these experiences. Significant behaviors that predicted student gains include reviewing related literature, contributing to the research design, collecting data, assisting in interpreting findings, and formally presenting research findings to others outside the research team. Among these activities, students were most likely to review related literature, collect data, and assist in interpreting findings, which are defining characteristics of undergraduate research experiences (Hu et al., 2008; Joyce, 2003; Nadga et al., 1998). As with

Kardash (2000), students were less likely to design research studies, to formally present research findings outside of the research team, and to submit a paper or product for publication.

Others have found that participating in similar activities have significant effects on students' gains in undergraduate research. By reviewing related research, science students discovered that theoretical ideas influence the direction of inquiry (Ryder et al., 1999). Interpreting research findings supported epistemological development in science students (Ryder et al.) and was positively linked with increased higher order thinking and integrative learning experiences among various majors (NSSE, 2007a). Seymour et al. (2004) found that by applying their knowledge, critical thinking, and problem solving in research studies, science students gained insights about generating and framing research problems and developed more understanding of how knowledge is constructed. In part, this is because as Mogk (1983) observed students who conceive and implement research studies must clearly articulate the nature of a problem, evaluate different perspectives from the literature, reconcile their observations with others' results, and interpret their findings in this context, all of which contribute to the skills and competencies needed for independent learning.

Second, the disciplinary area in which a student does undergraduate research with a faculty member significantly influenced the nature of the research experience. Consistent with Lopatto (2006) and others (DeVries, 2001; Joyce, 2003; Malachowshi, 2003; McDorman, 2004; Rogers, 2003), disciplinary differences existed in the amount of time that students' spent, the nature of their contributions, the kind of data that they utilized, whether they worked with other undergraduates on the project, and the kinds of individual gains they experienced. For example, students in the arts and humanities, business and professional fields, and education spent less time on research projects (less than four months) compared with students in the biological and physical sciences and engineering (more than five months). More arts and humanities reviewed literature and fewer collected original data compared with their counterparts in other fields. Most students in biological and physical sciences and engineering used lab-related data, while participants in social sciences, business and professional fields, as well as education used data from fieldwork, interviews, and surveys. Students' participation in research groups was also more common in the biological and physical sciences as compared to the arts and humanities. While these findings are not necessarily surprising, they describe how the nature of undergraduate research activities differs across disciplines.

Finally, the faculty mentor is a significant influence on quality of the undergraduate research experience. Unlike advising graduate students who work relatively independently on research, undergraduate inquiry is a teaching-intensive endeavor that requires faculty interaction, instruction, and guidance (Baenninger & Hakim, 1999). Indeed, the results of this study show that on-going and substantial faculty contact and feedback -- particularly at the onset of project, as it progressed, and when it ended -- were instrumental to facilitating gains in intellectual skills, career and collaboration skills, and research skills. Faculty also helped to facilitate students' engagement by directly inviting their participation or by supervising a team of student researchers.

Implications

This study emphasizes the key role that faculty members can play in supporting and maximizing the impact of undergraduate research experiences. Faculty are instrumental in inviting students to take part in undergraduate research. Administrators who oversee these initiatives could capitalize on this important role by asking faculty to share announcements about institution-wide and departmental undergraduate research programs and by encouraging more faculty to mentor research participants.

As faculty contact and feedback is a major factor in insuring students benefit optimally from their involvement in research projects, program administrators and department chairs must do their part in preparing and reminding faculty about these key aspects of the experience and what makes for effective mentoring. Surprisingly, many students received little direction from faculty at the start of their projects, reporting that they had to figure out on their own how to organize their time and conduct the research. Good mentors in the sciences have been found to be particularly helpful at the onset of research experiences by supporting students in managing initial frustrations with scientific research and communicating to students that investing time and experiencing mistakes were a natural part of being a scientist (Gafney, 2001). While these results support Lopatto's (2006) contention that good mentoring can make or break an undergraduate research experience, our data cannot describe how these faculty interactions contributed to such gains, which future studies could explore.

Working in a research group was negatively associated with gains in career and collaboration skills. This is disappointing as some contend that by participating in research groups students can learn about the value of being part of a larger community of scholars in common cause (Gafney, 2001) and gain insight to the value of teamwork (Ward et al., 2002). In this study, working in a research group was more common among students in the biological and physical sciences, consistent with Lopatto (2006) and Mabrouk and Peters (2000). Perhaps these settings involve less collaborative experiences and more independent contributions to a larger collective research group. Future studies could explore how working in a research group relates to career and collaborative outcomes.

Another noteworthy finding was that disciplines were only significant predictors for career and collaboration skills for students majoring in business and professional fields as well as education. It seems reasonable to assume that mentored inquiry in these fields may involve more collaborative and career-related experiences. Yet, the overall small disciplinary impact on students' gains suggests that undergraduate research can be a meaningful learning experience for students, the major field notwithstanding.

The results of this study also have implications for institutional reward systems. If mentoring students is not valued in promotion and tenure decisions, it will be very difficult to institutionalize undergraduate research (Hakim, 2000; Hu et al., 2008; Kinkead, 2003; Merkel, 2001; Nikolova Eddins & Williams, 1997). Thus, giving weight to research supervision as part of a faculty member's teaching load could encourage and support the involvement of more students in undergraduate research opportunities (Stevens & Reingold, 2000).

Finally, special efforts should be made to facilitate the kinds of research experiences that significantly contribute to students' gains. These include contributing to the research design, reviewing related literature, collecting data, helping to interpret research findings, and presenting research findings to others outside of the research team. Results show that students were less likely to contribute to the research design, which may be unrealistic for undergraduates who join an ongoing research project when the design of which has already been determined. Even so, faculty members can discuss with their student research collaborators how their contributions are helping to achieve various aspects of the project. Also, fewer students presented research findings to others outside the research team or submitted a paper or product for publication, which can be remedied by offering a variety of approaches to undergraduate research forums and institution-specific undergraduate research publications. More information about these initiatives can be found in Hu et al. (2008) and CUR publications that include many institutional examples of opportunities for students to share their research findings.

Conclusion

This study substantiates some of the more meaningful learning experiences associated with working with a faculty member on a research project as an undergraduate, providing more evidence about structural features of mentored inquiry and how students benefit from these enriching educational experiences. Academic disciplines appear to affect some aspects of mentored inquiry experiences, but have a minor influence on students' collective gains. Much of students' combined gains in undergraduate research are related to on-going and substantial faculty contact and the specific nature of the student's contributions to the research project. More in-depth information about what constitutes effective faculty interactions and meaningful student contributions to research projects are welcome and could enrich our understanding about what matters most in terms of the benefits students realize from participating in undergraduate research. Nevertheless, these results offer more evidence about the nature and strength of the kinds of research activities in which students engage when working alongside a faculty member and the benefits they achieve.

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Table 1.Factor Loadings of Undergraduate Research Gains Items

	Intellectual Skills	Career and Collaborative Skills	Research Skills
Cronbach's Alpha	*.86*	*.84*	*.86*
Items			
Thinking critically and analytically	.85		
Synthesizing, organizing, integrating ideas	.83		
Writing clearly and effectively	.75		
Thinking imaginatively	.52		
Solving complex, real-world problems		.74	
Working effectively with others		.69	
Speaking clearly and effectively		.69	
Acquiring job- or work-related skills		.49	
Taking intellectual risks		.49	
Understanding how knowledge is created			.29
Understanding how research is conducted			.82
Applying theory to practice			.57
Making judgments about the quality of information			.54
Learning effectively on my own			.37

Extraction Method: Principal Axis Factoring.
Rotation Method: Promax with Kaiser Normalization.

Table 2. Fit Statistics for Undergraduate Research Gains Measurement Model

Model fit statistics	Values
Number of parameters	40
χ^2	810.53
Degrees of freedom (Df)	65
CMIN/DF (Relative Chi-square)	12.47
RMSEA (Root mean square error of approximation)	.07
CFI (Comparative fit index)	.96
IFI (Incremental fit index)	.96
TLI (Tucker-Lewis coefficient)	.94

Table 3. Unstandardized (sampling error) and Standardized Factor Loadings for Gains Items (Confirmatory Factor Analyses Loadings)

	Unstandardized	Standardized	P
Intellectual skills			
Thinking critically and analytically	1.00	.89	NA
Synthesizing, organizing, integrating ideas	.96(.02)	.88	.001
Writing clearly and effectively	.95(.02)	.74	.001
Thinking imaginatively	.84(.03)	.63	.001
Career and Colloborative Skills			
Solving complex, real-world problems	1.00	.75	NA
Working effectively with others	.84(.03)	.63	.001
Speaking clearly and effectively	.95(.03)	.69	.001
Acquiring job- or work-related skills	.87(.03)	.65	.001
Taking intellectual risks	1.02(.03)	.76	.001
Research Skills			
Understanding how knowledge is created	1.00	.77	NA
Understanding how research is conducted	1.00(.03)	.74	.001
Applying theory to practice	1.14(.03)	.77	.001
Making judgments about the quality of information	.83(.03)	.63	.001
Learning effectively on my own	.94(.03)	.74	.001

Table 4.Time Devoted to Undergraduate Research by Major

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
Less than 2 months	32%	14%	54%	66%	22%	19%	31%
3-4 months	32%	21%	23%	21%	19%	31%	26%
5-10 months	27%	28%	16%	10%	32%	30%	24%
More than 10 months	9%	38%	8%	4%	27%	20%	19%

Table 5. Initiating Undergraduate Research Projects by Major

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
I asked a faculty member if I could join a research team	8%	54%	8%	6%	39%	25%	26%
A faculty member invited me to participate in the project	26%	33%	23%	23%	34%	35%	30%
I developed the research idea and proposed it to the faculty member	34%	17%	14%	8%	8%	32%	20%

Table 6. Students Working Alone or in Groups in Research Projects

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
I worked with one or more other students on the project	30%	55%	37%	37%	58%	44%	45%
I worked with one or more people off campus	22%	23%	23%	21%	26%	21%	23%

Table 7. Data Sources in Research Projects by Major

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
Existing information obtained from libraries, the WWW, etc.	68%	42%	69%	62%	45%	64%	57%
Results obtained in a laboratory or in some other controlled setting	13%	74%	28%	28%	68%	36%	45%
Results obtained outside of a laboratory or controlled setting (fieldwork, interviews, surveys, etc.)	29%	36%	53%	52%	35%	59%	44%
Creative, imaginative, or artistic impulse (e.g., poetry, dance, sculpture, etc.)	50%	8%	25%	37%	16%	11%	21%

*All percentages combine responses of very much and quite a bit

Table 8. Student Contributions in Research Projects by Major

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
Study design	52%	57%	56%	51%	61%	60%	57%
Reviewing related literature	75%	67%	62%	64%	48%	75%	67%
Collecting data	64%	86%	75%	68%	78%	78%	77%
Analyzing data	62%	83%	71%	72%	75%	76%	75%
Interpreting the findings	67%	79%	69%	69%	66%	71%	72%
Writing up the findings	61%	68%	71%	68%	58%	69%	66%
Formally presenting the findings to people other than the research team	45%	57%	55%	55%	49%	52%	53%
Submitting a paper or product based on the research for publication	47%	46%	51%	56%	44%	45%	47%

*All percentages combine responses of very much and quite a bit

Table 9. Nature of Faculty Contact in Research Projects

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
I received detailed instructions at the start of the project about how to proceed.	49%	62%	65%	64%	45%	67%	60%
I had to figure out on my own how to organize my time and how to conduct the research.	75%	61%	57%	56%	71%	59%	63%
I received feedback about my contributions to the project as it progressed.	78%	78%	67%	69%	73%	79%	75%
I received feedback about the quality of my contributions when the project ended.	79%	72%	70%	73%	63%	74%	72%

*All percentages combine responses of very much and quite a bit

Table 10. Student Gains in Undergraduate Research by Major

	Arts & Humanities	Biological & Physical Sciences	Business & Professional	Education	Engineering	Social Science	Overall
Writing clearly and effectively	65%	64%	69%	74%	51%	71%	66%
Thinking critically and analytically	80%	86%	78%	77%	80%	83%	82%
Synthesizing, organizing, integrating ideas	84%	84%	79%	82%	78%	86%	83%
Thinking imaginatively	77%	55%	65%	68%	58%	61%	62%
Speaking clearly and effectively	52%	54%	64%	68%	48%	57%	56%
Solving complex, real-world problems	51%	61%	67%	66%	73%	62%	63%
Working effectively with others	57%	66%	70%	70%	69%	67%	66%
Learning effectively on my own	83%	82%	77%	79%	72%	83%	80%
Understanding how knowledge is created	64%	68%	66%	73%	59%	72%	67%
Taking intellectual risks	65%	60%	65%	67%	57%	70%	64%
Making judgments about the quality of information	78%	81%	76%	76%	75%	82%	79%
Applying theory to practice	69%	80%	72%	75%	74%	80%	76%
Acquiring job- or work-related skills	58%	71%	71%	71%	69%	67%	68%
Understanding how research is conducted	70%	90%	77%	75%	75%	88%	82%

*All percentages combine responses of very much and quite a bit

Table 11. Undergraduate Research Experiences Effects on Intellectual Skills, Career and Collaborative, and Research Skills Gains

	Intellectual Skills			Career and Collaborative			Research Skills		
	B	SE of B	β	B	SE of B	β	B	SE of B	β
(Constant)	-2.75	.16		-2.66	.18		-2.97	.17	
Major									
Biological & Physical Sciences				*Reference group*					
Arts & Humanities	.20	.05	.07***	-.08	.06	-.03	-.03	.05	-.01
Business & Professional	.11	.05	.04*	.20	.06	.07***	.07	.05	.02
Education	.24	.07	.06***	.30	.08	.07***	.19	.07	.05**
Engineering	-.01	.06	.00	.05	.06	.01	-.09	.06	-.03
Social Science	.07	.04	.03	.04	.05	.02	.07	.05	.03
Female	.02	.03	.01	.00	.04	.00	.01	.03	.00
Fulltime	-.16	.06	-.04**	-.03	.06	-.01	-.07	.06	-.02
Months involved in the research project	.02	.01	.04*	.01	.01	.02	.05	.01	.10***
Research initiation									
I developed the research idea and proposed it to the faculty member	-.05	.04	-.02	.16	.05	.06***	.01	.04	.00
I asked a faculty member if I could join a research team	.01	.04	.00	.01	.04	.01	-.09	.04	-.04*
I worked with one or more other students on the project	-.03	.03	-.01	-.19	.04	-.10***	-.02	.03	-.01
Hours per week devoted to working on the research project	.02	.01	.02	.03	.01	.04*	.03	.01	.05**
Research contribution to									
Study design	.09	.02	.10***	.12	.02	.13***	.08	.02	.09***
Reviewing related literature	.10	.02	.11***	.05	.02	.05*	.10	.02	.11***
Collecting data	-.03	.02	-.03	.05	.02	.05*	.10	.02	.10***
Interpreting the findings	.10	.02	.11***	.03	.03	.03	.13	.02	.14***
Writing up the findings	.07	.02	.07**	-.04	.02	-.04	-.05	.02	-.05**
Presenting the findings	.03	.02	.03	.14	.02	.17***	.00	.02	.00

Submitting for publication	.04	.02	.06**	.03	.02	.04	.03	.02	.04
Faculty contact during research project									
Received detailed instructions at the start of the project	.11	.02	.11***	.10	.02	.10***	.13	.02	.13***
I had to figure out on my own how to organize my time and how to conduct the research.	.08	.02	.09***	.06	.02	.06**	.09	.02	.09***
Received feedback about my contributions to the project as it progressed.	.14	.02	.13***	.15	.03	.13***	.19	.02	.17***
Received feedback about the quality of my contributions when the project ended.	.25	.02	.24***	.22	.03	.21***	.18	.02	.18***
Multiple R		0.69			0.61			0.67	
R-squared		0.47			0.37			0.45	
Standard Error		0.73			0.80			0.75	
F		89.55***			58.51***			78.70***	

* p < 0.05, ** p < 0.01, *** p < 0.001

Note: Dependent variable was standardized before regression

Appendix A – Undergraduate Research Survey Items

Variable Label	*Response Values and Labels*
Earlier you indicated you worked with a faculty member on a research project. The following questions are about that experience. If you have worked on more than one project, use what you consider to be the most significant experience as the basis for your answers.	
1. Over what period of time during your undergraduate studies did you work with a faculty member on a research project?	1=Less than one month 2=1-2 months 3=3-4 months 4=5-6 months 5=7-8 months 6=9-10 months 7=More than 10 months
2. Which of the following describes your research experience(s)? (Select all that apply.)	
My participation was a course requirement	
My participation was a graduation requirement	
My participation was through a campus program (e.g., McNair, NSF, UROP)	
The project is directly related to my major field	
I asked a faculty member if I could join a research team	
A faculty member invited me to participate in the project	
I developed the research idea and proposed it to the faculty member	
I was paid for my contributions	
I received academic credit	
I worked with one or more other students on the project	
I worked with one or more people off campus	
I worked with one or more university staff members/graduate students	
3. To what extent was the research project based on:	
Existing information obtained from libraries, the WWW, etc.	1=Very little 2=Some 3=Quite a bit 4=Very much
Results obtained in a laboratory or in some other controlled setting	
Results obtained outside of a laboratory or controlled setting (fieldwork, interviews, surveys, etc.)	
Creative, imaginative, or artistic impulse (e.g. poetry, dance, sculpture, etc.)	
4. To what extent did you contribute to the following aspects of the research project?	
Study design (developing research questions, determining data collection methods, etc.)	
Reviewing related literature	1=Very little 2=Some 3=Quite a bit 4=Very much
Collecting data	
Analyzing data	
Interpreting the findings	
Writing up the findings	

Formally presenting the findings to people other than the research team
Submitting a paper or product based on the research for publication

5. To what extent does each of the following describe the nature of your contacts with the faculty member you worked with on the research project?	
I received detailed instructions at the start of the project about how to proceed.	
I had to figure out on my own how to organize my time and how to conduct the research.	1=Very little 2=Some 3=Quite a bit 4=Very much
I received feedback about my contributions to the project as it progressed.	
I received feedback about the quality of my contributions when the project ended.	

6. To what extent did your research experience(s) with a faculty member contribute to your abilities in the following areas?	
Writing clearly and effectively	
Thinking critically and analytically	
Synthesizing, organizing, integrating ideas	
Thinking imaginatively	
Speaking clearly and effectively	
Solving complex, real-world problems	
Working effectively with others	1=Very little 2=Some 3=Quite a bit 4=Very much
Learning effectively on my own	
Understanding how knowledge is created	
Taking intellectual risks	
Making judgments about the quality of information	
Applying theory to practice	
Acquiring job- or work-related skills	
Understanding how research is conducted	

*Includes those gains items used in the factor analysis