

Assessment of Effectiveness of Undergraduate Research Experience in Student Success

Final Report

by

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Introduction:

The Biology Department underwent a comprehensive Program Review in 2005, which resulted in various recommendations for improvement by the external review panel. In response to this Program Review, as an effort to close the loop of assessment, the Department is implementing a new Action Plan to address specific recommendations and implement relevant improvements in the Biology Undergraduate and Graduate Programs. As part of the new Undergraduate Action Plan, the Department has undertaken a significant streamlining of the curriculum by offering a smaller, more strongly focused set of courses (especially at the upper division level), and a reduction in the number of Majors to simplify the Academic Roadmap for Biology Majors. The Department is now proposing a new Biology Honors program which will provide advanced students an opportunity to enhance their education and preparedness for future careers through increased research participation and a new capstone experience such as an honors thesis.

Along with a strong emphasis on the disciplinary fundamentals, the Biology Student Outcomes Assessment Plan (SOAP revised in 2006 after Program Review; see attached copy) strongly emphasizes (goals 2 & 3) student learning of basic research methodology, critical thinking skills, and intellectual independence. In addition to *Activity* and *Lab* based classes, these goals are often accomplished through faculty-supervised Independent Study projects (Biol 190), as well as volunteer and paid opportunities for students to engage in research in faculty labs. Approximately 15-20% of Biology majors avail themselves of these research opportunities. It is these research experiences that the new Honors program will build upon to improve our undergraduate program. At the same time, the Department is undertaking curricular revision to incorporate new ways to provide equivalent experiences in critical thinking and analytical skill development to students who do not participate in research.

During the 2009-10 academic year, I carried out direct assessment of student learning outcomes using two tools modified to measure the effect of prior research experience. Below I report findings which show a significant improvement in student learning outcomes if they participate in research, especially in the areas of critical thinking and independent thought.

Background:

In 2006, following the Program Review, the Department revised its Student Outcomes Assessment Plan (SOAP) to include the following four Goals (primary learning objectives):

1. Biology majors will gain a broad background in the fundamental concepts of the Biological Sciences.
2. Biology majors will gain knowledge and experiences in the basic methods, instrumentation and quantitative analytical skills used to conduct scientific research in biological science.
3. Biology majors will develop critical thinking and communication skills, both oral and written, for purposes of conveying biological information to both professional scientists and the lay public
4. Biology majors will develop intellectual independence, scientific literacy and an appreciation for the connections between biological science and society.

A recent campus report analyzing the Level of Academic Challenge (LAC) scores on the National Survey of Student Engagement (NSSE) found that Fresno State Seniors are falling significantly behind those from Carnegie Peer institutions. Specific LAC items rated lower by Fresno State Students include:

- *Analyzing basic elements of an idea, experience, or theory in depth*
- *Synthesizing and organizing ideas, information, or experiences into new more complex relationships, and*
- *Applying theories or concepts to practical problems or in new situations*

These areas broadly correspond with components of the *Biology SOAP's Goals 2-4* as enumerated above. In addition to Lecture, Activity, and Lab Class Types already in the Biology curriculum, one significant avenue available to students to develop in these specific areas of learning is to engage in active research projects in faculty labs. The Department continues to encourage students, particularly Juniors and Seniors, to find and take advantage of opportunities to participate in faculty research programs through two basic avenues:

1. Enrolling in Independent Study (Biol 190 at undergrad level or Biol 290/295 at graduate level). The Department has a Spring 2009 enrollment of 55 students under these headings (18, 21, & 16 respectively under Biol 190, 290, & 295). Over the past five years the Department averages a total of 47.5 students enrolled in these courses.
2. Doing research as a volunteer or paid research assistant in an ongoing project. The Department has begun tabulating students doing research on a non-course-credit basis, but data are incomplete at this point.

Goals:

The broad goal of this project was to assess the effectiveness of all the student research activities in meeting Departmental SOAP goals, specifically goals 2-4 which are most relevant to research projects. The primary objective was to test the hypothesis that active participation in a research project outside the classroom context as an undergraduate student enhances student learning in the sciences, particularly in the areas of critical and independent thinking.

Methodology:

Participation in research outside the classroom context requires an active decision from the student doing so. The most research-active students are also likely to be the most motivated students overall. Studying the effectiveness of research participation on learning outcomes becomes challenging due to the self-selection bias if sampling is focused only on students who are (or have in the recent past) actively engaged in research. Therefore, after initially considering assessment of research output (i.e., research reports, posters, and papers) by students, I rejected that approach and chose instead to focus on two assessment tools that measure learning by all students regardless of research experience. The upper division Evolution (Biol 105) course marks the culmination of the required core sequence for Biology Majors. In this class, students are expected to synthesize knowledge from across all areas of biology within the broad evolutionary framework that unifies modern biology. The class provides a sample of students with and without research experience, all engaged in identical learning tasks, providing the perfect opportunity to directly test the hypothesis stated above. I tested the hypothesis using the following direct assessment tools:

1. **Post-Test:** Students taking Biol 105 are subject to the departmental Post-Test (see SOAP) on a regular basis. I modified this test by adding survey questions about research experience, i.e., whether the student had a) participated in undergraduate research, b) enrolled in Biol 190. This modified post-test was applied to students in Biol 105 in the Fall 2009 and Spring 2010 semesters, and scores were compared using a t-test. The post-test was administered anonymously.
2. **Evolution Term Paper:** Biol 105 has a major writing requirement: a Term Paper on an evolutionary topic based on synthesis of at least 8 papers from the primary peer-reviewed literature. Students must draw upon what they have learned in all their previous classes (*SOAP goal #1*), research experience (*SOAP goal #2*), critical thinking and synthesis skills (*SOAP goal #5*). They are also required to pick the topic of the paper on their own from reading the primary literature, and place their work in the broader context of current research in the discipline (*SOAP goal #4*). Therefore, I assessed a number of term papers using a standard rubric measuring *Content, Organization, Integration of Diverse Material, and Critical Analysis*. Each paper was scored for these 4 variables on a 5-point scale: 1 - Beginning; 2 - Developing; 3 - Satisfactory; 4 - Accomplished; and, 5 - Exemplary. The scores were added into a Total Score for each paper for statistical analysis using a t-test. I carried out this analysis using a sample of papers from students with and without research experience, from the Spring 2010 Biol 105 class. A separate survey form (not anonymous) was used to classify students into groups with or without research experience. To minimize bias, term papers were scored with the rubric first, before the students were classified into the two study groups.

Results:

Post-Test:

A total of 50 students took the Post-Test during Fall '09 (N=24) and Spring '10 (N=26) semesters. Preliminary analysis indicated no difference between samples in test scores or distribution of research experience, therefore I pooled the samples for further analysis.

21 of the 50 students surveyed (42%) reported having some undergraduate research experience. Of these, only 28.6% (12% of total) reported having enrolled in Biol 190 for Independent Study credit, while the rest had either volunteered or been supported by a grant. These numbers are similar to estimates based on current enrollment in Biol 190 for the past few years. 7 graduate or non-major students were excluded from further analysis.

Students with any research experience scored significantly higher (mean=15.45±0.73SE) on the Post-Test than students without (mean=13.65±0.68SE) such experience (Fig 1; one-tailed t-test, $p = 0.04$, $N=43$;). The one-tailed t-test is valid in this case because the study hypothesis is directional, i.e., research experience produces higher scores; results confirm this hypothesis.

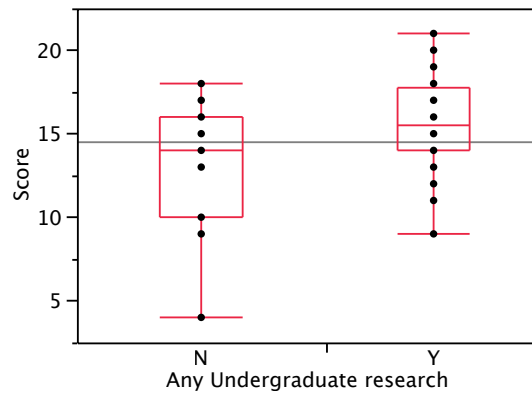


Figure 1: Effect of undergraduate research experience on Biology Post-Test scores. *T-test*, $N=43$, $P=0.08$ (2-tailed), $P=0.04$ (1-tailed).

Evolution Term Paper:

During Spring '10, 21 term papers were chosen randomly and scored according to the rubric before being classified into 2 groups (with and without research experience). Students with research experience scored significantly higher (mean=14.85±0.5SE) on term papers than those without (mean=11.63±0.48SE) such experience (Fig 2, t-test, $p = 0.0002$, $N=21$). This (2-tailed) test also confirms the hypothesis that research experience leads to higher scores.

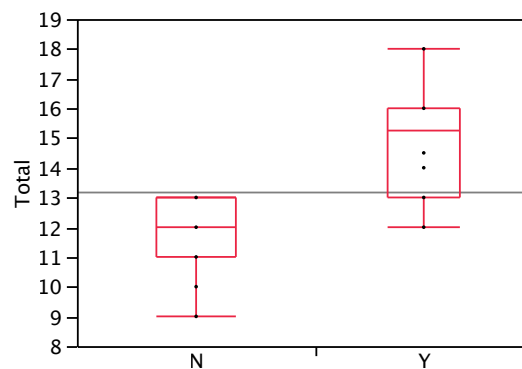


Figure 2: Effect of undergraduate research experience on Evolution Term Paper. *T-test*, $N=21$, $P=0.0002$.

In addition to the above direct measures of student learning outcomes, I also compared the overall grade achieved by all students (30 bio majors) at the end of the Spring '10 semester, and found no significant difference between groups with and without research experience (X² test, $p=0.48$, $N=30$).

Conclusions and recommendations:

The hypothesis that student learning outcomes should improve with undergraduate research experience was supported by both the direct measures used in this study. The effect was much stronger for scores on the Evolution Term Paper than on the Biology Post-Test, which is also to be expected. The Term Paper strongly emphasizes research, critical thinking, and analysis skills, and challenges the students to become intellectually independent (Goals 2-4 in the Biology SOAP). Experience conducting research at the undergraduate level, whether as a volunteer, paid technician, or Biol 190 student, clearly helps improve these skills as evidenced by the term paper written by the students.

The difference between the two groups on the Biology Post-Test scores was smaller (and significant only with a 1-tailed test). This test relies more upon overall content knowledge acquired throughout the Biology Major Core Sequence, and is therefore more general. Research experience had a smaller effect on this test, presumably because it relies more on an understanding of a broad array of biological concepts (Biology SOAP Goal 1) than on critical/analytical skills per se. Interestingly, the two groups of students also showed no difference in overall grade achievement in the Spring 2010 semester. This suggests that students without research experience may be scoring higher in other areas, most likely on exams relying upon content knowledge specific to the class rather than broader synthetic abilities. This also justifies (post-facto) the study design which allowed a direct comparison of students in both groups undertaking the same tasks. Focusing only on students who have research experience (as was initially proposed for at least some measures) would not have picked up this important difference in outcomes.

In the context of the university's goal of increasing undergraduate research experience as a key to enhancing student learning, it is worth noting that currently a vast majority (88%) of students in the Biology major do not appear to enroll for Independent Study credit. Even among those who did participate in research, less than a third (28%) did so for credit. The Biology Department has made note of this finding, and is now recommending that all students participating in research (whether paid or volunteer) be advised to enroll for Independent Study (Biol 190) credit. This will allow us to track student progress more efficiently, and also help the department account for Faculty effort in mentoring undergraduates engaged in research in their labs. Further, as the overall research activity in the Biology program continues to grow, more students should be offered the opportunity to participate in such research for enhancing their own educational outcomes. The results of this study also provide a stronger foundation for the department's proposal to start an Honors program geared towards research-active undergraduate students.

The department (and the university as a whole) should also note that, as this study indicates, research experience outside the classroom context is an important component of undergraduate learning especially for developing critical thinking, analysis, and synthesis skills which are crucial to long-term success of our graduates. At the same time, research

experience is only a part of the overall learning environment, and may have (as seems to be the case here) less of an effect on overall grade achievement. Other areas of the curriculum therefore need to be examined in terms of the relative weight on content knowledge (esp. memorization for test-taking) rather than critical thinking skills. If the university is to produce intellectually independent, critical-thinking, and well-informed citizens, all aspects of these learning outcomes must be addressed - and the critical thinking components enhanced wherever possible. The Biology department will consider these conclusions and recommendations in an upcoming retreat as we continue to close the loop on assessment and carry out our action plan developed after the last program review in 2005.