UCEP WHITE PAPER ON UNDERGRADUATE RESEARCH

Introduction

The University of California is one of the most prestigious university systems in the world. The University's prestige is based, in large part, on the exceptional research being carried out by UC researchers in every discipline. Faculty members are working at the cutting edge of nearly every facet of research being undertaken in the world today. Some of these faculty have or will be awarded Nobel prizes for that research. The caliber of the research conducted at the University of California is the basis for its classification at the top of the Carnegie rankings.

But central to the mission of any great university is the education of students. The University of California boasts an incredibly diverse population of nearly 200,000 undergraduate students. Thousands of UC undergraduates partner with world-renowned faculty and researchers at each of the campuses of the University of California to conduct research. For many of these undergraduate researchers, the experience of working with UC faculty solving some of the world's most pressing challenges and answering questions at the leading edge of knowledge will fundamentally shape their career paths, their ways of thinking, and even their core values.

In a research university like UC there is a synergy between research and teaching. Professors regularly bring their research into the classroom and many bring their students into their research or creative endeavors, be it in a laboratory, a library or a studio. However, this is not a one-way process. Knowledge does not pass only from faculty to student. Professors are keenly aware of the need for lifelong learning and that their students often serve as teacher. Students may contribute through brainstorming, doing data analysis or even by being sounding boards. Teaching and research, though sometimes seen as competitors, in reality often feed off of each other and fertile growth occurs where they coexist. The fruit of the teaching and research at the University of California is a major driver of the economies of State of California and the nation. Graduates of UC contribute significantly to a highly trained workforce. More than 300 research and development- intensive companies have been started in California by UC graduates and over 1000 California R&D intensive companies actively engage in research projects with UC faculty and students.

The Exposure of Undergraduates to the Research Mission of the University

What is the relationship between the extensive research endeavors of the University of California and the education of its students? Certainly all UC undergraduates are exposed to the primary fruits of research: the most up-to-date knowledge, the open questions in the field of study, and the principal procedures and methods of inquiry in any given discipline. Students are exposed to these fruits of the research endeavor in several ways.

- Attending classes and seminars that present research
- Hearing course instructors present their own research in the classroom
- Writing term papers on topics both inside and outside the scope of course content
- Taking methodology courses

Beyond these common and more introductory activities, UC students also have the opportunity for participation in activities providing a more in-depth research experience:

- Assisting in the gathering of information for a scholarly publication.
  Many faculty give course credit or fund students to aid in their research by library searches, interviews, data analysis, synthesis and assimilation of results. UC students use a system of campus libraries linked together to provide access to a range of materials that is second to no other university in the world.

- Writing a paper for publication in a scholarly journal.
  As a result of undergraduate student participation in library searches, interviews, data analysis, synthesis and assimilation of results, and the writing process, a faculty member often includes the student's name in the author list. Some undergraduate students will be the first author of a paper published in a scholarly journal.

- Critiquing publications in a seminar environment.
  Students read papers in a certain field and present a synopsis to their peers. It is not uncommon at UC for some of these papers to have been written by the instructor of the seminar course, thus providing the undergraduate student with a unique opportunity to come to a more complete understanding than would be possible otherwise.

- Attending or even presenting research at a scholarly conference.
  Often the undergraduate student has the opportunity to conduct research in a new field or to find unique aspects of a more established area where no one has yet explored, thus yielding unique information that is 'owned' by the student and thus can be presented at an appropriate workshop or conference.

- Serving as a lab assistant.
  In the sciences and engineering, undergraduates frequently work in a laboratory setting. Such work may begin with mundane tasks such as cleaning, sorting, counting, and labeling, but often this leads to more substantial tasks such as setting up experimental protocols, data analysis, making and recording measurements, running computer software, writing computer software, preparing graphics, etc. These experiences yield insight into how experiments are designed and carried out and often an appreciation for the difficulties, challenges and pitfalls that go hand in hand with meaningful research.

- Conducting experiments.
  It is not uncommon for undergraduates to conduct experiments independently. They set up the experiment, collect data (this may entail writing computer software), analyze data, synthesize and present the results.

- Creating unique artistic works.
  Creating art, be it paintings, poems, sculptures, performances, electronic music, photographs, plays, musicals, costumes, choreography, novels, screenplays, is always enriched by studying with established artists. UC attracts world-renowned artists to their faculty who provide an environment for their students to learn new techniques, encourage their students explore their own talents and passions and open up opportunities for them to exhibit their creations in a variety of enriching venues.

- Participating in a capstone experience.
  In many fields students are given open-ended problems to solve that require them to combine the many tools they have gained over the course of their university coursework. This usually is approached as part of a team and often national and international competitions are involved. Local industries, many of which already employ UC graduates often suggest a problem to address and supply resources to attack it . Post-graduation employment is commonly a possibility.

- Writing real or mock grants.
  Most of the research done at UC requires writing grants to federal or state agencies or private foundations. For those students who want to make research their career, mock 'requests for proposals' provide an opportunity for students to study under faculty who have themselves been successful in attracting funding from outside the university. In some cases undergraduates play a role in writing grants for real funding opportunities from agencies inside the university or even from outside agencies.

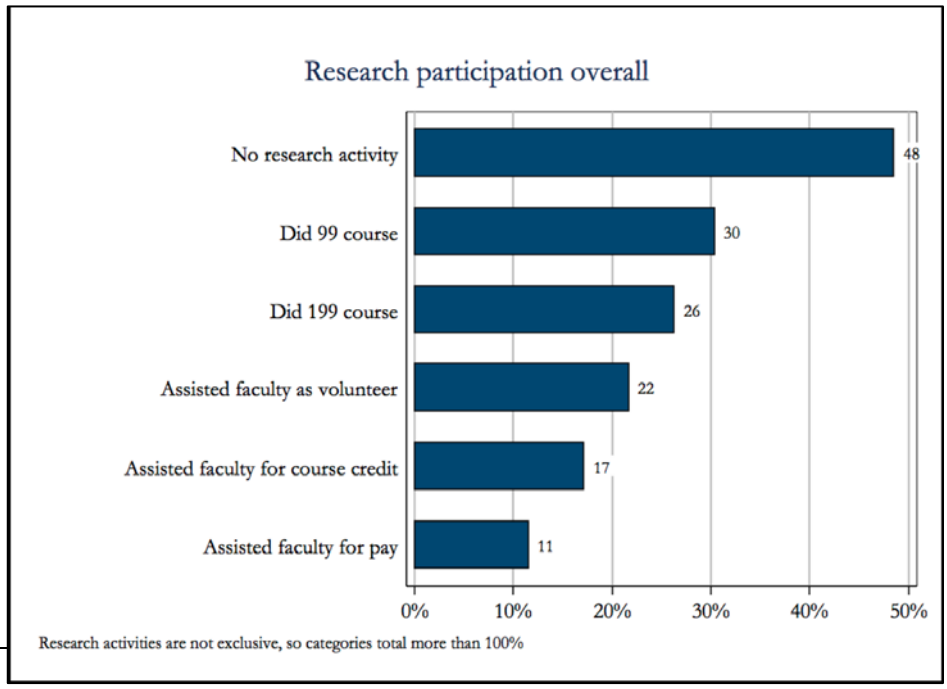
- Working as an intern.
  Many college students seek part-time jobs in a variety of settings: in industry, in government, in health-care. UC students have the opportunity to work in cutting-edge industries perhaps founded by UC graduates. They work at all levels of government: local, state and federal. Our students work in medical centers that are leading the way in finding cures for a spectrum of diseases.

- Intercampus exchange.
  Each UC campus is unique. Many majors can be found at each location but every campus has programs, expertise and/or facilities that are available only in that location. If a UC student becomes interested in a topic of study that is more highly emphasized on another campus, they are free to take regular courses or independent study courses for credit at the other campus and work with a faculty member whose research better matches the student's interests than those of anyone local. Thus students could be taking courses simultaneously at two campuses or even take up temporary residence at the other campus.

There are a variety of ways undergraduates can become involved in faculty-supported research. Although the mechanism for involvement in undergraduate research differs across campuses, majors, and departments, in general there are two major avenues for student participation in research: competitive selection to a recognized program or student-initiated participation in a research internship. Most campuses mentor undergraduates interested in conducting research through a centralized university office dedicated to undergraduate research and creative projects. These university centers of undergraduate research go by different names and are operated under the auspices of different university offices at each campus. For example, students at UCSB interested in undergraduate research are directed to The College of Letters and Science Undergraduate Research and Creative Activities (URCA) Office. The major program at Berkeley that connects faculty with undergraduate researchers is called the Undergraduate Research Apprentice Program (URAP). At UCSD students are directed to the Undergraduate Research Center, a primarily online resource. At UCSC, there is a less centralized approach and students are directed towards student-faculty research partnerships through their major departments and Crown College.

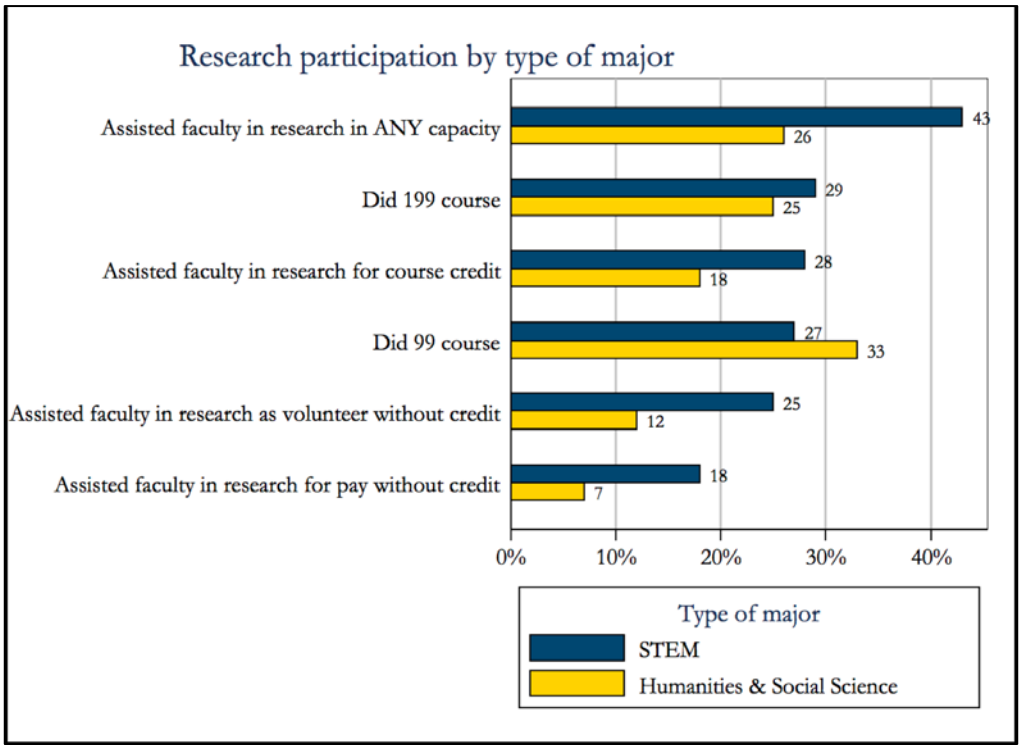
A second avenue for student participation in research is through a student-initiated process. Virtually every undergraduate major at every UC campus offers the opportunity for students to do independent study and conduct research and generally these entail writing a thesis or research paper. Student-initiated opportunities are student-faculty research partnerships that are primarily focused around the interests of the student as opposed to a student joining an ongoing research activity initiated by the faculty member. These research arrangements can be informally arranged but students may receive pay, credit or volunteer their time on these research activities.

The most up-to-date data regarding the extent of undergraduate research at the University of California comes from an analysis of the 2008 UC Undergraduate Experience Survey (UCUES)[1]. Those data show that approximately 10,350 upper-division undergraduate students have participated in research under the direction of a faculty member outside of class. This represents a participation rate of approximately 33% of upper-division respondents to the survey. A recent white paper published by the Teagle Foundation using the National Survey of Student Engagement (NSSE) data from over 200 four-year colleges and universities found that only one in five (19%) of senior students nationally had worked on research with a faculty member outside of class (The Teagle Working Group on the Teacher Scholar, 2007). By comparison with this national data, undergraduates at the University of California are conducting research with faculty at a significantly higher rate. Figure 1 shows research participation as a function of the total number of upper-division respondents to the survey by type of involvement (credit, pay, and volunteer). Special studies courses, such as research internships with faculty, have been given special course numbers by the university. Course number 99 is reserved for Supervised Independent Study by academically superior lower-division students, who are to be defined by each department or program. This definition includes, as a necessary part, a grade-point average of at least 3.3. Course number 199 is reserved for upper division students.



[1] UCUES is a web-based census survey administered at all undergraduate campuses of the UC system every two years. It is a product of a collaboration between the UC Office of the President, the Office of Student Research and Surveys at UC Berkeley, and the Student Experience in the Research University Project based at the Center for Studies in Higher Education at UC Berkeley.

National evaluations show that between 25% - 39% of biological or physical science students participate in research activities by the time they are seniors (The Teagle Working Group on the Teacher-Scholar, 2007). Analysis of the 2008 UCUES data shows that a higher percent of STEM majors (43%) than Humanities or Social Science majors (26%) engage in research opportunities. Figure 2 shows that STEM majors participate in research as volunteers, for pay and for independent study credit (course 199 on most UC campuses) at substantially higher rates than humanities and social science majors. However, humanities and social science majors report engaging in research for student research credit (course 99 on most UC campuses) at a higher rate than STEM majors.



Gains Related to Undergraduate Research Experiences

Undergraduate research activities exist at the nexus of two of the primary missions of the University: research and education. In a very practical way, undergraduate research also exemplifies the best aspects of each of these missions. Much productive research involves teams of researchers, each of whom brings in fresh perspectives Education scholars since John Dewey have proven again and again that students involved in inquiry are more confident in their learning, demonstrate greater learning gains, and retain knowledge longer than students in lecture-based courses built around the memorization of facts (e.g., Dewey, 1910; Lehrer, Carpenter, Schauble, and Putz, 2000; NRC 2003; White & Frederiksen, 1998; Von Secker & Lissitz, 1999).

In 1995 the Carnegie Foundation for the Advancement of Teaching initiated the National Commission on Educating Undergraduates in the Research University, which was later renamed the Boyer Commission. In the final report the Boyer Commission recommended ten ways to change undergraduate education at research universities. The very first recommendation the commission gave was to make research-based learning the standard for undergraduates in research universities. The authors argued that learning is inherently a discovery process aided by mentors and not simply a transmission of information. The Boyer Commission argued that lecturing should not be the primary mode of instruction at a research university. Instead, the undergraduate academic experience at all levels should focus on learning through discovery-based methods that progress towards independent inquiry activities similar to those of the first-year graduate student. The Boyer Commission report (1998) stated:

> The basic idea of learning as inquiry is the same as the idea of research; even though advanced research occurs at advanced levels, undergraduates beginning in the freshman year can learn through research. In the sciences and social sciences, undergraduates can become junior members of the research teams that now engage professors and graduate students (17).

Inquiry activities that are not part of a recognized lecture course and are faculty-driven have come to be called undergraduate research experiences and are increasingly supported at the institutional level by university offices of undergraduate research, deans, vice provosts, or vice presidents of undergraduate education, or other senior university administrators (The Reinvention Center, 2002), probably partially as a result of the Boyer Commission report.

Several researchers have described the benefits of participation in undergraduate research. Their investigations have appeared in peer-reviewed journals and program reviews across the country. These benefits include insight into how researchers in particular fields think and reason, clarification of career plans, enhanced preparation for various careers and entry into graduate programs, the development of positive attitudes regarding field-specific learning and conducting research in the field in question, and an increased understanding the theories, methods and modes of inquiry of a discipline (Barlow & Villarejo, 2004; Berkes, 2007; Lopatto, 2003 and 2004; Nagda et al., 1998; Seymour et al., 2004).

This year, a large-scale quantitative assessment of student-reported learning gains related to faculty-supported undergraduate research and creative project participation was conducted at the Center for Studies in Higher Education (Berkes, 2009). That investigation demonstrated that undergraduate research and engagement with faculty in creative projects produced significant and notable student-reported learning gains in the following 15 areas:

Analytical and critical thinking skills
Ability to be clear and effective when writing
Ability to read and comprehend academic material
Ability to understand a specific field of study
Quantitative (mathematical and statistical) skills
Computer skills
Internet skills
Library research skills
Other research skills
Ability to prepare and make a presentation
Interpersonal (social) skills
Ability to appreciate the fine arts
Ability to appreciate, tolerate and understand racial and ethnic diversity
Ability to appreciate cultural and global diversity
Self-awareness and understanding

Berkes (2009) demonstrated that undergraduate researchers and creative project participants report learning more than their non-participating peers, no matter what their major is. But isn't it possible that undergraduate researchers appear to be more likely to do well and persist in college and go on to graduate study and careers because they are better students in the first place, or have certain inherent advantages (e.g., particular race/ethnicity or gender), or have advantages afforded by highly educated parents? Isn't it possible that disadvantaged students are less likely to participate in these extracurricular activities? Berkes (2009) also addressed this most important critique of past studies to understand the benefits of undergraduate research experiences by taking into account seven potentially confounding variables: major, gender, race/ethnicity, immigrant generation, parental education, SAT/ACT score, and high school GPA. Even controlling for all these factors, Berkes found that participation in research and creative projects boosted student-reported learning each of the 15 areas studied.

Bibliography and References

Anaya, G., (1999). College Impact On Student Learning: Comparing The Use Of Self-Reported Gains, Standardized Test Scores, And College Grades. *Research in Higher Education. 40*(5), 499-526.

Barlow, A., & Villarejo, M. (2004). Making a difference for minorities: Evaluation of an educational enrichment program. *Journal of Research in Science Teaching, 41*(9), 861–881.

Bauer, K. W., & Bennett, J. S. (2003). Alumni perceptions used to assess undergraduate research experience. *Journal of Higher Education, 74*.

Berkes, E., & Radwin, D. (2009). Research Participation at the University of California. *Student Experience in the Research University (SERU) Annual Report*.

Berkes, E., (2008). Research Participation at the University of California, Berkeley. *Center for Studies in Higher Education Research and Occasional Papers Series*.

Berkes, E. (2009). Undergraduate Research Participation and Learning at the University of California, Berkeley. *Paper presented at the American Educational Research Association Annual Conference.* San Diego, CA.

Boyer, E. L. (1998). *The Boyer Commission on Educating Undergraduates in the Research University, Reinventing undergraduate education: A blueprint for America's research universities*. Stony Brook, NY.

Campbell, A. M. (2002). *The influences and factors of an undergraduate research program in preparing women for science careers.* Unpublished Dissertation, Texas Tech University.

Campbell, A. & Skoog, G. (2004). Preparing women for science careers. *The Journal of College Science Teaching, 35*(7), 16-21.

Dewey, J. (1910). *How we think.* Boston: Heath.

Fordham, S. & Ogbu, J.U. (1986). Black students' school success: Coping with the "burden of 'acting white.'" *The Urban Review, 18,* 176-206.

Hathaway, R. S., Nagda, B. A., & Gregerman, S. R. (2002). The relationship of undergraduate research participation to graduate and professional education pursuit: an empirical study. . *J. Coll. Stud. Dev., 43*, 614 -631.

Kamen, M., Roth, W., Flick, L.B., Shapiro, B., Barden, L., Kean, E., Marble, S., & Lemke, J. (1997). A multiple

perspective analysis of the role of language in inquiry science learning: To build a tower. *Electronic Journal of Science Education, 2*(1).

Lehrer, R., Carpenter, S. Schauble, L. & Putz, A. (2000). Designing classrooms that support inquiry. In J. Minstrell & E. H. van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 80-99). Washington, DC: AAAS.

Lopatto, D. (2003). The essential features of undergraduate research. *Council on Undergraduate Research Quarterly*.

Lopatto, D. (2004). Survey of Undergraduate Research Experiences (SURE): First findings. *3*(4), 270-277.

Martinez, G. A. (2000). *Making a difference: The effects of an undergraduate research mentorship program on the production of minority scholars.* Unpublished Dissertation, University of California at Davis.

Marx, R. W., Blumenfeld P. C., Krajcik, J. S., Fishman, B., Soloway, E., Geier, R., & Tali Tal, R. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching, 41*(10), 1063-1080.

Nagda, B. A., Gregerman, S. R., Jonides, J., von Hippel, W., & Lerner, J. S. (1998). Undergraduate student-faculty research partnerships affect student retention. *The Review of Higher Education, 22*(1), 55-72.

National Research Council. (2003). *BIO2010: Transforming undergraduate education for future research biologists*. Washington, D.C.: National Academies Press.

Pearce, R.R. (2006). Effects of Cultural and Social Structural Factors on the Achievement of White and Chinese American Students at School Transition Points. *American Educational Research Journal, 43*(1), 75-101.

Reinvention Center. (2002). *Reinventing undergraduate education: Three years after the Boyer report.* Stony Brook, NY: SUNY Stony Brook.

Schunk, D. H. (1984). Self-efficacy perspective on achievement behavior. *Educational Psychologist, 19*, 48-58.

Seymour, E., Hunter, A. B., Laursen, S. L., & Deantoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education, 88*(4), 493-534.

The Teagle Working Group on the Teacher-Scholar, (2007). *Student Learning and Faculty Research: Connecting Teaching and Scholarship.* The Teagle Foundation, American Council of Learned Societies.

Von Secker, C. E., and Lissitz, R.W. (1999). Estimating the impact of instructional practices on student achievement in science. *Journal of Research in Science Teaching, 36*(10), 1110-1126.

Ward, C., Bennett, J., & Bauer, K. (2002). Content analysis of undergraduate research

student evaluations. [Electronic Version] from http://www.udel.edu/RAIRE/Content.pdf.

White, B., & Frederiksen, J.R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition & Instruction, 16*, 3-118.

Zimmerman, B. J. (1999). Self-efficacy and educational development. In A. Bandura (Ed.), *Self-efficacy in changing societies*. Cambridge: Cambridge University Press.

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