

Primary Literature-Based Learning Complements and Enhances Research Experience: The Howard Hughes Undergraduate Research Program (HHURP) at UCLA

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One of the challenges in biomedical education is transitioning undergraduates from a didactic, textbook-based instructional paradigm to one based on seminars and understanding of the primary literature. Our experience with the difficulties encountered by first year graduate students in literature-based learning inspired us to create the Howard Hughes Undergraduate Research Program (HHURP) at UCLA. The HHURP trains highly motivated undergraduates who have expressed a desire to continue research at the graduate level. HHURP is a collaborative venture between the School of Medicine and the College of Letters and Science. Although the undergraduate participants work in faculty research laboratories in both the College and School, the program is managed and directed on a volunteer basis by Medical School faculty. This has proven to be a highly effective collaboration.

The foundation concept for HHURP is direct participation in mentored research enhanced by a rigorous seminar course. The course is centered on the presentation and critical analysis of scientific journal articles as well as the students' own research. This focus on effective scientific communication emphasizes the development of experimental design skills, promotes critical thinking and prepares students for a graduate curriculum in biomedical sciences.

The program is administered by the Undergraduate Research Center (URC) and is advertised on the URC, HHURP and undergraduate course websites in September and October. Applicants must be performing research in a UCLA lab and possess a minimum 3.4 GPA. The HHURP faculty members select students using written applications that contain a statement of career goals, a brief research plan and a letter of support from the research mentor. Selections are made from a group of finalists following

personal interviews with all three HHURP faculty members. Students enter at the beginning of their junior year for a two-year program that includes support for research during the intervening summer quarter. The support is provided by a grant from the HHMI to Dr. Fred Eiserling, former Dean of the College of Letters and Sciences, and Dr. Judith Smith, Dean of Honors and Undergraduate Programs and Vice Provost for Undergraduate Education. Throughout the academic year, students meet once per week for 2 to 2.5 hours to present and discuss journal articles and research findings. The class, which is the focus of this article, serves as a platform for a multi-component curriculum that fosters an understanding of the scientific process, promotes self-confidence and hones the presentation skills of students.

To determine the effectiveness of program components, annual course evaluations have been conducted and the results used to identify problem areas and design improvements. We will discuss results from these evaluations, and how they have been used to adapt the program to the students' needs.

Objectives

The specific objectives of the UCLA HHURP are to develop the students' abilities in the following areas:

1. Defining appropriate and relevant research questions.
2. Critically analyzing experimental design.
3. Interpreting experimental results.
4. Formulating and testing hypotheses and working models.
5. Practicing effective scientific communication: preparation and delivery of basic research seminars and journal club presentations.

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A typical journal club class is shown with the speaker (left, standing) giving a PowerPoint presentation to classmates and faculty seated around a large conference table. Students answering questions posed by the speaker will sometimes answer from the front of the room (right, standing) in order to make use of the white board. Classes, which meet Fridays at 4:30 and last for 2 – 2.5 hours, are provided with food and drinks.

6. Becoming familiar with the peer review and publication process.
7. Interacting productively with other scientists at all levels.
8. Expanding their science knowledge base by examining papers on topics of contemporary importance.

The use of a peer group setting provides a network of support for students as they work towards achieving these goals.

Program Components

Each of the key program components is discussed below. Where applicable, we have included results from course evaluations to indicate the value to the students. The evaluations were completed anonymously and included 15 questions about course and faculty, as well as space for general comments. The scale used for assessment was: 9 = strongly agree; 5 = neither agree nor disagree; 1 = disagree strongly. We have compiled scores from 1998 through 2004. The scores have not changed significantly among classes and the 2004 values (n=11) are shown unless otherwise noted.

Experimental Research

The foundation of the HHURP is direct involvement in basic research. At the time of application to the program (Fall of junior year), students have usually been engaged in research with a UCLA faculty mentor for 3 to 12 months. Fundamental to the program is that the students continue their research work, typically on NIH R01-funded projects with a group of postdoctoral fellow and graduate students. A disadvantage to this arrangement, however, is that these undergraduate students working as part of a research team may not receive as much direct faculty mentoring as they would at a primarily undergraduate institution. HHURP students are therefore expected to develop a significant degree of independence, while participating fully in lab group activities (e.g. lab meetings) to the degree permitted by their class schedules.

Journal Club

A central component of the HHURP at UCLA is participation in “Topics in Contemporary Biology.” This class is run as a modified journal club. Students select a paper, typically with faculty guidance, in any of a wide range of subjects from biophysics to behavioral neurobiology. The paper is then made available as a PDF file on the class web site (www.biolchem.ucla.edu/hh_jclub/index.htm). Several days before class, the student presenter meets with one of the course faculty for one to two hours to discuss the paper and their PowerPoint presentation. This is an opportunity to address questions the student has about the paper, and to provide guidance on content and effective slide layout. Students cite this meeting as one of the most helpful components of the class (rated 8.4). Following each presentation, students are given immediate critical evaluation to point out areas for improvement and to reinforce effective techniques.

A UCLA faculty colleague with expertise in the subject area of the journal article is selected about a week prior to class. These faculty members attend class and are also available to assist the student in preparing the presentation. The “guest faculty”, who are often leaders in their fields, help students to probe more deeply into the material and often provide valuable insights based on information that is not yet published. The statement “The inclusion of outside faculty commentators was helpful” was rated 8.8 by the students and has been consistently at that level for six years. We feel this exercise also enhances the ability of the students to communicate with scientists outside of their research area.

In addition to preparing their presentation, students are required to create a list of questions for their classmates. These questions are designed to focus attention on key techniques (e.g. “How does fluorescence activated cell sorting work?”) and critical aspects of experimental design or interpretation (e.g. “In Figure 3, what control was used to rule out non-specific interactions?”). The questions are modified and assigned to specific students by the course faculty and then distributed by email several days before class. Students are encouraged to use multiple sources while

preparing their answers and to seek help from each other as well as graduate students or postdoctoral fellows. The questions are integrated into the presentation, providing a mechanism to ensure class participation. This is also an opportunity for each student to become an “expert” in some aspect of the discussion, building self-confidence and promoting further student engagement. The peer-peer interactions stimulated by the questions also allow the students to explore ideas that they otherwise might be reluctant to propose to senior lab members. Although the questions generate extra work for the students they value the exercise as indicated in the course evaluations: “The weekly questions in journal club were useful and helped me understand the paper” was rated 8.8. Based on course evaluation comments over the years we have given students the primary role in crafting the questions for their classmates. Course faculty members edit and revise questions as needed.

A “round table” discussion is held following the presentation, providing a forum for each student to share thoughts and criticisms about the journal article. Recent student evaluations included a suggestion that “focus points” be provided to help guide these end-of-class discussions. We have implemented this change and include round table discussion topics with the questions distributed by email before class. The roundtable topics require students to evaluate the strength of the authors’ conclusions, suggest experiments to challenge a proposed model, assess the ethical implications of novel clinical applications, or examine the publication and review process. The round table is another forum for the students to gain confidence while providing an environment for creative thinking in a peer setting.

■ Research Presentations

Student research presentations, organized by our colleague Dr. Lily Wu in the Department of Urology, are interspersed throughout the year with the journal club. Relevant background research and/or review articles are provided to all students prior to class. As with journal presentations, research talks are presented in PowerPoint format and students meet with an instructor prior to class for a discussion of how to most effectively describe their experimental system and results. Research mentors are strongly encouraged to attend the presentations of their trainees and other lab personnel are welcome. Following each research presentation, the presenting student meets with course faculty, as well as their mentor, for evaluative critiquing.

Two additional opportunities are provided for students to present their research to an audience. First, each student is required to give a poster presentation as part of the undergraduate college’s Science Poster Day. Students are encouraged to obtain guidance from mentors, lab mates and HHURP faculty in preparing effective posters. The posters are open to review by the entire university community and students are assigned periods during which they are

available to answer questions. Second, senior students make a short research presentation during the Spring HHURP banquet attended by students, mentors and guests. Each year one student is selected by HHURP faculty to receive the Eiserling Prize (in honor of Dr. Fred Eiserling). Students are also encouraged to attend a national scientific conference in their field of research. Program funds are often used to cover meeting expenses, but only when the student submits an abstract for a poster presentation.

As part of the HHURP, students are required to submit an Honors Thesis by the end of their senior year or write a paper detailing their findings. The Honors Thesis is a scholarly report of research activities, the precise format of which is determined by the students’ major departments. Finally, students are encouraged to participate in, and contribute to, *The UCLA Undergraduate Science Journal*.

■ Seminar Speakers

To further enhance the students’ access to highly accomplished research scientists, the scholars host a HHURP Speakers Series. This is another improvement derived from student comments on class evaluations. Scholars select and invite the speakers, and they organize the campus visits. The scholars also have lunch with each speaker. At these lunches, the discussions range from the scholars’ research projects to assessment of experimental systems, viewpoints on scientific education and career choices. Last year Professor Stanley Fields from the Department of Genome Science and Medicine at the University of Washington gave a talk on *Protein Interactions* and Professor Helen Blau from the Department of Molecular Pharmacology at Stanford University gave a talk on *Regenerative Medicine for Brain and Brawn*. Dr. Andrew Fire presented his groundbreaking work on the mechanisms of RNA interference at this year’s seminar. We have incorporated research articles from invited speakers into the class presentation schedule to promote greater engagement of the scholars with the guest.

One of the seniors introduces the guest at the start of the seminar and other students escort the speaker around campus during their visit. This exercise, which has become very popular with the students (rated 8.7), has helped to foster self-confidence in interacting with other scientists.

■ Career guidance

During the academic year each student meets individually with one of the course faculty to discuss their performance in the program as well as their career objectives. This is an opportunity to discuss their level of participation in class discussions and offer encouragement. The emphasis is on developing effective skills for working in a group setting.

Students are asked about their career goals during these one-on-one discussions. Typically HHURP students are interested in pursuing MD, PhD or MD/PhD degrees. One

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advantage of these discussions is that among the three HHURP faculty members, two are on the MSTP admissions committee, one is a former MD/PhD and practicing physician, and two are Graduate Program advisors for various departments. Thus, we are able to provide insightful guidance on career options. Discussions of career satisfaction and lifestyle choices are often helpful. Students are also encouraged to speak with researchers representing a variety of career paths. Program faculty keep track of students through the graduate program application and interview process and are available to discuss issues as they arise. The class also provides a valuable opportunity for students to share interview experiences with their peers.

Outcome Assessment

Several quantitative and qualitative “measurables” are used to assess the effectiveness of meeting course objectives and to identify areas for improvement. These include course evaluations, student awards and matriculation to MD and PhD programs.

Evaluations

Course evaluations over the past 6 years have focused on measuring our progress towards the programmatic objectives. We commented on several objectives in the sections above. Three issues are of primary concern. Two address the development of presentation skills: “I am now more comfortable reading/presenting the scientific literature” was rated 8 in year 1 and 8.9 in year 6. “I am now more comfortable presenting my research” was rated 8.8. One issue addressed the value added to their own research by taking the course.

“The course complemented and enhanced my research lab experience” was rated 8 in year 1 and 8.6 in year 6. We are in the process of compiling a detailed alumni survey to determine how effectively the course influenced the students’ abilities in graduate and medical school. One of the future challenges will be quantitatively evaluating the effectiveness of the literature-based paradigm in teaching by comparing the HHURP scholars to a control group with similar aspirations and intellectual skills.

Poster awards

A second method to assess achievement is the ability of HHURP scholars to compete for awards. Each year the College sponsors a Science Poster Day for undergraduates performing research in the biological sciences. This year over 100 undergraduates presented their work. The HHURP students have won 7 of the 20 Dean’s prizes for best poster presentation over the past three years. Six of those awards went to seniors in the program, which is not surprising given the remarkable sophistication that the students develop by the end of their senior year.

Postgraduate research

The final method of evaluation is the matriculation of students from undergraduate to graduate studies. We have tracked the progress of HHURP Scholars from 1998-2004 to assess our methods for selecting students that will pursue professional studies and follow a career path in biomedical science. Over the past six years, 41 scholars have graduated from the program. Of those, 22 are currently pursuing research in PhD or MD/PHD programs, while 14 are attending medical school. Five others are still in the early stages of their careers but continue to work in biomedical research.

It might be argued that a rigorous literature-based course is not necessary for students whose career goal is solely an MD. However, many of the students who attended medical school have indicated through email interviews that they are continuing research during summers or in programs between their second and third years. Additionally, a student from our first class received his MD and then continued on to begin a PhD in a combined residency program.

Conclusions

Our experience has convinced us that, together with direct involvement in research, familiarity with primary literature is the touchstone of a successful scientific training program for undergraduate students interested in pursuing postgraduate study. What we have described is a rigorous program that provides faculty guidance in presentation skills, critical analysis of primary literature, and career guidance. At the same time, the program requires each student to participate regularly and at multiple levels including oral and poster presentations, and weekly discussions of scientific literature. We have also found that the creation of peer cohorts and the promotion of peer interactions have a profound and lasting impact on the development of student independence and self-confidence. Many of the program components presented here have resulted from attempts to address concerns raised in annual student evaluations. We strongly believe that such evaluations are an essential component of any such program.

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