# “Hands-On” Undergraduate Research Opportunities in the Life Sciences: Preparing the Next Generation of Biological Researchers

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## Introduction

Over the past decade, a number of scholars have publicly criticized large research universities for failing to provide undergraduate students with the skills and abilities needed to succeed both in life and in the workforce. At the heart of this criticism is the concern that research institutions have de-emphasized teaching by increasing the size of undergraduate classes, expanding the role of teaching assistants, and structuring the faculty promotion process so that it provides greater rewards to those who conduct exceptional research at the expense of student learning (Boyer, 1990; Boyer Commission, 1998). Concerned, a number of institutions have examined their curriculum, looking for ways to improve the quality of the undergraduate experience. One strategy, taken at UCLA, is to use our strength as a research institution as the foundation of curricular reform; for example, by bringing research experience into science general education (Kerfeld, Levis, & Perry, 2001). We have developed a program (www.lsic.ucla.edu/ugri) in which large numbers of students (nearly 2,000 annually) participate in a research project in the context of their undergraduate coursework. The Undergraduate Genomics Research Initiative (UGRI), uses a common research goal, the sequencing of a microbial genome, to link several upper and lower division life sciences courses and science general education courses. In order to facilitate this multi-course collaboration, it was necessary to invent a new course based entirely on undergraduate research to serve as the hub of the UGRI. This paper presents findings from the first year assessment of this novel course, Life Sciences 187, *Principles and Practices of Genomic Research*.

## Conceptual Framework

Institutions across the country are examining the undergraduate curriculum with an emphasis on academic and personal development. A number of professional associations and blue ribbon panels have advocated fundamental change in the design and delivery of undergraduate education, particularly in large universities (e.g., Boyer Commission on Educating Undergraduates in the Research University, 1998; National Research Council, 2003).

Most agree that the undergraduate curriculum is in special need of attention. A complete review of the recommendations is beyond the scope of this paper, but most reports agree on at least the following: (a) pedagogical methods that foster active learning, including opportunities for students to participate in inquiry-based education and research, offer numerous benefits; (b) barriers to interdisciplinary education should be removed; (c) courses and curricula should be designed to help students make connections among concepts, ideas and meanings; (d) institutions should strive to build community and instill in students a sense of belonging to the academic enterprise; (e) students need a stronger foundation in writing and other communication skills, including the use of new technologies; and (f) given the increasing significance of the life sciences, science education should be strengthened.

The Boyer Commission on Educating Undergraduates in the Research University (1998) and the National Research Council's Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21$^{st}$ Century (2003) have identified developing the undergraduate research experience as a top priority in undergraduate education reform. Both panels suggested making research-based learning the standard.

Although undergraduate research is not a universal remedy for all problems, it is one way in which students can feel more connected to their educational experience (National Institute of Education, 1984).

At a broad level, such connected learning programs have been associated with higher levels of satisfaction by both students *and* faculty (Hakim, 1998; Mabrouk & Peters, 2000; Manduca, 1997), as well as increased retention rates (Nagda, Gregerman, Jonides, von Hippel, & Lerner (1998). At a more specific level, research experience – especially laboratory experience – stimulates student interest and participation, cultivates the ability of students to think independently, and teaches students how to work cooperatively in groups (NRC, 2003). Project-based laboratories are also ideal settings for students to develop their scientific writing, speaking, and presentations skills (NRC, 2003), all of which contribute to their intellectual and social development.

Accordingly, UCLA, a large public research university enrolling about 24,000 undergraduates and 7,000 graduate students is in the process of transforming its undergraduate science education curriculum. As part of this process, we have developed the UGRI to bring research experience into the curriculum in the context of undergraduate classes. To realize such a collaborative program, it was necessary to create a hub course, Life Sciences 187. This unique course offers experience in inquiry, analysis, collaboration and communication through an innovative discovery-oriented experience based on the burgeoning field of genomics.

Research Question:

How does conducting “hands-on” laboratory research affect students’ science learning, skill development, and future plans for research?

**Program Description**

UCLA’s innovative undergraduate curriculum is the ideal setting in which to emulate the collaboration among scientists, industry and society that is essential to today’s science. Our goal is to unite the community of this university’s undergraduates by making them part of a research team working together to share the goal of sequencing a microbial genome. The design of the UGRI is based on the belief that actual research experience is the best way to achieve all levels of practical and theoretical scientific literacy.

A microbial genome sequencing project involves several experimental steps. We have situated each among a variety of courses. They are:

1. Prepare a genomic library
2. Isolate DNA from the library
3. Prepare the DNA for sequencing
4. Sequence the DNA
5. Perform bioinformatic analysis of the DNA sequence
6. Build and curate the genome sequence database

The core course of the UGRI is LS 187, *Principles and Practices of Genomic Research,* where approximately 20 students are enrolled each quarter. This course is designed for students just entering upper division life sciences coursework. The student experience in this course is modeled on the modern research laboratory. The students use a state-of-the art DNA sequencer and perform bioinformatic analyses of the data they obtain. Teamwork is essential-- for each student does one part of each day’s experiment; some students are involved in expanding and maintaining the library (step 1), others prepare the instrumentation or work with the DNA samples (steps 3 and 4) or develop and manage the database (step 6). In this way they learn vital skills such as communication and collaboration--necessary to each day's successful experiment in sequencing.

Students also have the opportunity to develop mentorship skills. Students may elect to enroll in LS 187B and, subsequently, LS 187C. In each successive course the student takes on greater responsibility in terms of leadership and database curation. All students participate in a weekly lab meeting, in which their understanding of the theory behind the science they practice is deepened. We discuss lab issues--troubleshooting the problems and conflicts that, as in any modern research laboratory, inevitably arise. We also review our progress and explore the implications of our genomic research.

Not only is the UGRI a model of the collaborative nature of modern genomic biology, but it also reflects the growing synergy between industry and academic research. UCLA has partnered with the LI-COR corporation, a leader in DNA sequencing technology, to examine the feasibility of bringing real research in genomics into the undergraduate curriculum.

The UGRI is unique for its emphasis on collaboration, teamwork and a dedicated goal of conducting actual research. It is unique as its central focus is not a "canned" exercise with a preordained outcome. Instead, students experience the excitement of real research while developing a sense of pride and accomplishment as they build toward a research goal, the sequencing of a microbial genome.

## Methodology

The main strength of the UGRI assessment was the use of multiple methods, both qualitative and quantitative; the data were collected from multiple perspectives (i.e., from students and faculty). The primary methods in the assessment included student surveys, student focus groups, and faculty interviews conducted at the end of the 2003-2004 academic year. High participation rates contributed to the strength of the assessment.

The surveys administered to students in the LS 187 A, B, and C courses included questions about students' (1) demographic or background characteristics (e.g., gender, ethnicity), (2) major, (3) motivation, (4) aspects of the course that helped them learn, (5) collaboration, (6) presentation and teaching skills, (7) research and analytical skills, (8) science competence, (9) science confidence, (10) future plans for research, and (11) suggestions for improvement (see Appendix A for a copy of the student paper survey).

In order to gain a deeper understanding of the student experience in UGRI, focus groups were also conducted with all the students who completed the LS 187 courses (see Appendix B for a copy of the student focus group protocol). Other students who did not continue in the LS 187 course for the spring 2004 quarter were contacted either by email or phone requesting completion of the student survey (see Appendix A for a copy of the student email/phone survey).

In order to understand faculty members' experiences and observations of student experiences, individual interviews were conducted with those faculty members who taught the LS 187 courses during the 2003-2004 academic year. For all interviews, researchers used the semi-structured interview as it allowed them a certain level of flexibility and provided them with the ability to probe when necessary (see

Appendix C for a copy of the faculty interview protocol). All interviews were audiotaped and transcribed. Following transcription, the analysis process consisted of reading and re-reading interview transcripts to develop a codebook containing analytic categories relevant to the issues at hand. Using the data analysis software program ATLAS.ti, the research team used these categories to code all of the interviews. A subset of interviews was coded by multiple researchers to ensure reliability across researchers.

**Assessment Framework**

The assessment framework was designed to guide the construction of the student survey, student focus group protocol, and faculty interview protocol (see Table 1). Students were asked about their background characteristics and motivation for enrolling in the course. The primary focus of the assessment, however, was to query the students as to how the LS 187 course had affected their learning, skill development, and future plans for research. Students were also asked for suggestions for improvement of the course. Additionally, faculty was also interviewed about their observations of the student experience in the LS 187 course.

**Table 1. Assessment Framework**

| **Theme Heading** | **Student Questions** | **Faculty Questions** |
|---|---|---|
| Student Profile | Gender<br>Ethnicity<br>Major | |
| Motivation | Why did you choose to take this course?<br><br>When you began the course, what did you hope to get out of it? | |
| Student Learning | | |
| • Lab activities | How much did the lab activities (class presentations, collaboration with other students, and understanding each part of the experiment) help you learn? | (The following 2 questions apply to all 3 student learning themes)<br><br>How do you think the research experience has affected the students' understanding of science? |
| • Resources | How much did the students and instructors help you learn? | |
| • Support as a learner | How much did the quality of contact with the teachers and the other students help you learn?<br><br>How much did the way that this course was taught overall help you learn? | Did participating in the research project help to foster a sense of collaboration or community among your students? |
| Student Skill Development | | |
| • Collaboration | How much has the course improved your collaboration skills?<br><br>How do you think the course has improved your view of the collaborative nature of science? | Did participating in the research project help to foster a sense of collaboration or community among your students? |
| • Presentation & teaching skills | As in most research labs, a significant part of the experience is studying the scientific literature and presenting findings to one's colleagues. Has this course given you a new skill in this area of expertise? | |

| | | |
|---|---|---|
| • Research & analytical skills<br><br>• Science competence<br><br><br><br><br><br><br><br><br><br><br>• Science confidence | How much has the course improved your problem-solving skills, analytical skills, presentation skills, mentorship/leadership skills, and troubleshooting skills?<br><br>How much has the course raised your understanding of the relationships between theory and practice, the fundamentals of genomic biology, and the process of science?<br><br>How much has the course raised your feeling comfortable with science/research?<br><br>How much has the course raised your ability to be conversant about genomics?<br><br>How has this course influenced your perception of scientific research and how scientific progress is made?<br><br>How much has the course affected your confidence in conducting research? | How do you think the experience has affected the students' analytic and research skills?<br><br>How do you think the research experience has affected the students' understanding of science?<br><br><br><br><br><br><br><br><br><br><br>How do you think the course has affected the students' self-confidence (before and after the course) about science and biology? |
| Future plans | How has thinking about your own field of study been influenced by this course? | How do you think the course has affected the students' research aspirations/attitude toward research? |
| Suggestions for Improvement | What do you see as the challenges/problems of the course?<br><br>What might you add or change about the course if it was to be taught again in the future? | What were the challenges? |

**Sample**

A total of 24 students completed the survey (see Table 2). All of the students who completed the LS 187 course in the spring 2004 quarter and five students from previous quarters participated in the assessment. The findings are broken down by section: LS 187 A (n=15), B (n=3), and C (n=5). One student did not report the LS 187 course in which s/he was enrolled. The students were approximately half female and half male; however, the majority of the students were Asian American/Pacific Islander. Also, the vast majority of the students reported majoring in the life sciences.

**Table 2. Student Characteristics for Survey Respondents**

| Student Characteristics | LS 187A (n=15) | LS 187B (n=3) | LS 187C (n=5) | All respondents (n=24) |
|---|---|---|---|---|
| **Gender** | | | | |
| Female | 8 | 1 | 3 | 13 |
| Male | 7 | 2 | 2 | 11 |
| **Ethnicity** | | | | |
| Caucasian/White | 3 | | 1 | 4 |
| Asian American/Pacific Islander | 10 | 3 | 4 | 17 |
| African American | | | | |
| Chicano/Latino/a | | | | |
| Multiracial | 1 | | | 1 |
| Other or Unknown | | | | 1 |
| Did not respond | 1 | | | 1 |
| **Major** | | | | |
| Asian American Studies | 1 | | | 1 |
| Bio/Biochemistry | | | 1 | 1 |
| Biology | 1 | | | 1 |
| Biology/Marine | 1 | | | 1 |
| MCDB* | 11 | 2 | | 14 |
| MIMG± & Biochemistry | | | 1 | 1 |
| MIMG± | | | 1 | 1 |
| Molecular Biology | | | 1 | 1 |
| Psychobiology | 1 | | | 1 |
| Psychology | | 1 | | 1 |
| Women studies | | | 1 | 1 |

*Molecular, Cell and Developmental Biology
±Microbiology, Immunology and Molecular Genetics

A total of three faculty members were involved in the teaching of the LS 187 course. Two of the three faculty members were interviewed for the evaluation. One instructor was not interviewed because s/he had left the university at the time of the interviews.

## Results

### *Motivation for taking course*

Students enrolled in this lab course because they wanted to obtain develop research skills, learn more about the subject material, satisfy a research requirement, and fulfill requirements for the major. For example, one student noted:

> I chose to take this course because I actually got some information from my counselor. I'm an MCDB major, Molecular Cellular Development Bio. And I-- at the time had to fulfill [an] upper laboratory requirement, so I saw this as a good opportunity also. One of the professors I was actually taking a class with at the time, Professor Perry, she was one of the co-coordinators, I guess. And she was telling me about it. And I was really interested in sequencing in general…

Students often commented how this lab course was appealing to them because it was a hands-on lab experience and complemented other courses in the life sciences that were more conceptual and theoretical. One student described his experience through the progression of the three quarter course:

> So I wanted to get to know more about this type [of] research. And going through the basic courses like LS1, 3, and 4, etc., you learn all these different tools. But in order to apply these and to have a better understanding you actually physically have to do a research project. So at first I was kind of apprehensive to even do it because I thought I won't be successful, but as I went through the program it was really interesting seeing, using all the tools, everything you had learned, all the theoretical, and putting it to actual practice. And it was really interesting.

Another student said:

> I wanted research experience in molecular biology, and that's what I was expecting. And it included involvement in genetics research and gene sequencing. And I knew nothing of that except what it was used for, and to be able to actually carry out those procedures was helpful in terms of understanding exactly why it was useful. So, I continued to do it because each quarter offered new experiences… after [taking the first course, LS 187A] I would deal more with the collection of data and the interpretation of data, and not just carrying out the experiment to get the data.

### *Student Learning*

Students were asked to comment on how various aspects of the lab helped them learn. Three aspects of the lab are explored in this section: lab activities (presentations, collaboration, and conducting an experiment), lab resources (how the students and instructors helped them learn), and lab support (the quality of contact with teachers and students and overall class instruction).

#### Lab Activities

Students indicated that the lab activities helped them learn (see Table 3). Many students found the class presentations helpful and that collaboration with other students and the lab experiments also helped them learn. Students who had taken two or three of the lab courses found the lab activities more helpful than those that had only taken one lab course.

**Table 3. Summary of Quantitative Results for Lab Activities**

| Lab Activities | Was of no help/ Helped a little | Helped | Helped a good/ great deal |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| Class presentations | 3 | 2 | 10 |
| Collaboration with other students | 1 | 3 | 11 |
| Understanding each part of the experiment | 0 | 2 | 13 |
| **LS 187B (n=3)** | | | |
| Class presentations | 1 | 0 | 2 |
| Collaboration with other students | 0 | 1 | 2 |
| Understanding each part of the experiment | 0 | 0 | 3 |
| **LS 187C (n=5)** | | | |
| Class presentations | 0 | 2 | 3 |
| Collaboration with other students | 0 | 2 | 3 |
| Understanding each part of the experiment | 0 | 0 | 5 |
| **ALL STUDENTS (n=24)** | | | |
| Class presentations | 5 | 4 | 15 |
| Collaboration with other students | 1 | 6 | 17 |
| Understanding each part of the experiment | 0 | 2 | 22 |

Students also frequently noted how they learned from each other. As one student said, "you've worked as a team in this course, and the results were dependent on working together by dividing up the sequencing experiment in stages, with the success of each stage dependent on the other." Students who had completed the three quarter lab sequence also noted how working in a team requires each member to contribute. One student noted:

> I think it's because it's not like any normal laboratory class where they have the lab set up for you and you're supposed to do like a certain experiment and get a certain result. Like the progress in this lab, it's your responsibility. So you want the lab to go well. So you need to understand what you're doing, and you want to make progress too during the quarters. So that gives you some incentive to do well.

Another student added:

> Well, we have other students looking out for each other because if one person makes a mistake, then it affects an entire experiment. And so there's this natural tendency to want to collaborate and then it becomes mutually beneficial, and it becomes a fun environment as well.

Faculty also observed the collaborative spirit in the lab. Over time, the lab became more organized and students became more efficient, "like a conveyor belt almost, like a factory." However, because of this structure, if one student was missing, then the whole process stopped. One of the challenges to accomplishing each day's research was to make sure that there were enough students to fill in every experimental slot. However, by creating specialization of tasks, students felt that they sometimes lost sight of the big picture and how each step relates to one another. Students also commented, though, that because they became a specialist in one area, they would be the one to explain to others what they did. As one student noted, "So you became an expert in a piece of it. So then you become kind of dependent on each other. I mean, if you're the expert."

Resources

In the lab, more advanced students were expected to mentor the newer students. The majority of the students found each other to be a useful resource and noted the importance of having the instructor explain what was happening if the other students could not. Table 4 summarizes the quantitative findings for resources from the student survey.

**Table 4. Summary of Quantitative Results for Resources**

| Resources | Was of no help/ Helped a little | Helped | Helped a good/ great deal |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| Students in other levels of the course | 0 | 1 | 11 |
| The instructors | 2 | 1 | 11 |
| **LS 187B (n=3)** | | | |
| Students in other levels of the course | 0 | 2 | 1 |
| The instructors | 0 | 1 | 2 |
| **LS 187C (n=5)** | | | |
| Students in other levels of the course | 1 | 0 | 2 |
| The instructors | 0 | 0 | 5 |
| **ALL STUDENTS (n=24)** | | | |
| Students in other levels of the course | 1 | 4 | 14 |
| The instructors | 2 | 2 | 19 |

The students also commented on the helpfulness of their peers during the focus groups. For example, one student noted:

> I think that a really good facet of this process is that you don't answer to professors. You answer to each other basically. For example, like the BLAST data that we have. We're each given BLAST data, and then there's one person, [student], who compiles all of it. So everything goes to him, and it's like a hierarchy of students. Rather than just giving something to the professor and saying, here's my work. And I think it helps a lot more when you're interacting with other people that you can relate with more, and relate to. So, I think that's really good.

Another student added, "Whenever I had a question, instead of bugging the TA or the instructor, I'll reach out and ask one of the C students. And so they really were helpful." Students also noted that they learned a lot by teaching. As one student indicated:

> You actually learn a lot more when you're the mentor. Because when I was an A student, one of the B students showed me a lot. But it wasn't until I became a B student that I actually put all that into practice.

Another student added:

> You also have other students asking you questions, and if you don't know it really well, then you realize that you need to go and ask the teacher. And so you learn as well. It tests you to make sure that you know everything.

Students became more comfortable in the lab over time and learned what was expected and the role they would play in an experiment by working with each other. One student reflected:

> By the end of the first week, you're familiar with what you're supposed to do. You just have to get acquainted with how to do it, and then the B and C people will feel more relaxed at that point to tell you exactly the process or how to carry out the protocol. So it becomes collaborative, and it becomes more relaxed because now the A people have B and C people to rely on, and the B and C people can kind of rely on the A people to carry out what [they would] normally be doing if it was a quarter ago.

Again, collaboration helped students gain a deeper understanding and appreciation of collaborative practices. As another student so aptly stated:

> Every part of the process we had to be involved with other students, and in order for it to work and for you to understand what you're doing you have to be collaborative with your peers. So I think before this I probably had a lesser understanding of how research projects are actually done and how people work in groups as opposed to two. Afterwards, where you see the beginner students doing the stuff that you eventually are going to be analyzing, you see the whole process and how every person plays a part.

Students also appreciated having the instructors as "resources." One student said,

> Right now we're LS 187C, so we help the Bs and the As. But Chou is like 187D because she knows everything and she would be there from day one just teaching us. But she's an instructor. It's very relaxed. She shows how you do it. She's such a resource, and I think without her we probably wouldn't have known half the things we do now.

Another student commented that it was "like [having] your own personal tutor by your side." The LS 187C students were also required to meet with the instructors once a week in a troubleshooting/course planning and development type meeting. One student said, "It was interesting, like it sort of gives you like a behind the scenes look at what the teachers have to do and stuff. I mean it just gave us sort of insider help." The instructors commented that they were very honest with the LS 187C students during these meetings, and valued and welcomed their input, comments, and any suggestions that they might have on how to better the lab.

The instructors in the course indicated that student participation in the research helped to foster a sense of collaboration among the students. One instructor noted that the students paired up, and worked in teams. He noticed how the less advanced students learned from the more advanced students, and that there's a "learning and talking between them…there's camaraderie."

<u>Support as a Learner</u>

Students were asked to comment on the quality of contact with the teachers, students, and overall instruction and how it impacted their learning. Most students valued the contact with the instructors and students and were generally satisfied with the way the class was taught (see Table 5).

**Table 5. Summary of Quantitative Results for Support as a Learner**

| Support as a learner | Was of no help/ Helped a little | Helped | Helped a good/ great deal |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| The quality of contact with the teachers | 1 | 2 | 11 |
| The quality of contact with other students | 0 | 3 | 12 |

| | | | |
|---|---|---|---|
| The way that this class was taught overall | 1 | 1 | 13 |
| **LS 187B (n=3)** | | | |
| The quality of contact with the teachers | 1 | 0 | 2 |
| The quality of contact with other students | 0 | 0 | 3 |
| The way that this class was taught overall | 1 | 0 | 2 |
| **LS 187C (n=5)** | | | |
| The quality of contact with the teachers | 0 | 0 | 5 |
| The quality of contact with other students | 0 | 0 | 4 |
| The way that this class was taught overall | 0 | 1 | 4 |
| **ALL STUDENTS (n=24)** | | | |
| The quality of contact with the teachers | 2 | 3 | 18 |
| The quality of contact with other students | 0 | 4 | 19 |
| The way that this class was taught overall | 2 | 2 | 20 |

Furthermore, students felt support for learning and felt that it was "ok" to make mistakes because learning occurs when one makes a mistake. As one student revealed, "They never got mad at us if we messed up, so that was good. We could be wrong but they did not make us feel bad about it." Another student added:

> Cheryl made it clear that if we made a mistake that we should write it down. And once we have that mistake written down, she said even though we might have to load it twice it was okay. It was okay to make mistakes; this was an ongoing process.

Students commented on the value and efficiency of the peer learning model. For example, another student said, "It's impossible for the professor to work with us each individually, one on one, and so it's like she'll teach one of us something, and then one of us something else, and we'll learn from each other." And another student added, "It's like working together to teach one another rather than coming only from one source."

One challenge with the peer learning model, however, is miscommunication. As one student described:

> I think the only thing was when there was miscommunication. Since you're not getting information straight from the professor, it's possible that the information you get is wrong from your peers. Like when we would do BLASTing and no one knew how to do it, and we had all these different methods of doing it, and so we didn't really know the correct way, and so Cheryl, the professor, she had to actually address [this] in class.

Students noted that a few more lectures would help avoid undetected miscommunication. However, other students commented that faculty were always available as resources. As one LS 187C student expressed:

> Well having Chou and Gaston in the lab all the time, they're basically guiding us to a point where we're starting to guide ourselves, and then guide the B and A students. So, the quality of interaction between [the students and] Chou and Gaston was really good. And then the few times that I actually visited Professor Kerfeld in her office she was very receptive and very willing to just go off on a tangent or discuss things directly related to the course. So, it was good overall.

The loose structure of the lab encouraged students to figure out the answer on their own and build confidence over time. Another LS 187C student noted:

> It seems that we figured out more than they taught. In the beginning we didn't have somebody saying, this is what you're supposed to do, and it's how it's done. We just heard them say, Oh this is how it's normally done, but you're free to change things however you want, in terms of the PCR and what works best. So by not having that rigid structure, I think that we were able to play around with things, see how we liked it better. And in the end, I think we had a good understanding of what we were doing.

Students also commented that they valued the hands-on aspect of the lab and this was most effective for students who took the lab for three quarters. As one young woman aptly described:

> I think that this course over the three quarters has taught me a lot, but not only that, I've retained most of it because we've been doing it. So it is cemented in your brain, why you're doing it, and what the principles are behind it as opposed to a one-quarter course where everything is just going by so fast and you're just taking notes. So I think the actual practical aspect of it really drives the whole experience.

***Student Skill Development***

This section presents how students' skills have changed as a result of participating in this lab course. Variables of interest include collaboration skills, presentation and teaching skills, research and analytical skills, science competence, and science confidence.

<u>Collaboration Skills</u>

As mentioned earlier, the lab required students to work together. As a consequence, most students noted that they learned a great deal by working with other students, and that over time their collaboration skills grew and they got better at working with each other. Table 6 summarizes the quantitative findings for collaboration from the student survey.

**Table 6. Summary of Quantitative Results for Collaboration**

| **Collaboration** | **Nothing/ Just a little** | **Somewhat** | **A lot/ A great deal** |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| Skills in collaboration | 1 | 2 | 12 |
| **LS 187B (n=3)** | | | |
| Skills in collaboration | 1 | 0 | 2 |
| **LS 187C (n=5)** | | | |
| Skills in collaboration | 0 | 2 | 3 |
| **ALL STUDENTS (n=24)** | | | |
| Skills in collaboration | 3 | 4 | 17 |

The students learned quickly that the collaborative nature of this lab was an efficient way to coordinate the lab activities. A few of the students, however, indicated that they preferred working alone and found working with others very challenging. One student said:

> I think for me it was difficult because I work in another lab where I do my own thing, and so to depend on other people to be able to do their thing and for me … I'm a control freak and I have to do things by myself.

For the most part, however, students also learned about the collaborative nature of science and making sure you "contribute your part." One student commented, "I think you become more responsible for your own actions, since everyone depends on your work. You become more responsible, then in some way your data will become more reliable. It's about trusting, too, from your colleagues." Another student described sharing responsibility, "I think this class is just a lot about personal responsibility. You have to kind of own up to your own faults, if you happen to mess up on a certain experiment."

Students continued to comment on how collaboration requires each person to contribute to the lab work. The more senior students enjoyed teaching the newer students and realized they really needed to understand the material to teach it. They noted that they gained a deeper understanding or appreciation of collaborative practices because of this course. One instructor summarized how important it is to be able to work with others:

> Teamwork, they say, is now an essential component of the life sciences and I agree. In my research, I'm in more and more collaborations than I was five years ago. I see this type of course as what we need in order to be able to communicate, we need that professionalism, accountability, this kind of thing, and just the ability to work with one another. I think we really tried to cultivate that in LS187 as well.

Faculty who taught in the lab noted how their students were collaborating and valued being part of a community. Another instructor felt that participating in this research helped students to foster a sense of collaboration among their peers and to work as a team. He added that students became dependent on each other as they each developed an expertise critical to the experiment.

<u>Presentation and Teaching Skills</u>

The collaborative nature of the lab provided many opportunities for students to present findings and teach each other. The lab required students to present and the more senior students frequently served as instructors to the newer students. As a result, students noted that they developed their presentation skills in this class. As one student described:

> We have to present each week, each of us would take turns presenting a part of a chapter, or finding an article and presenting all that information. And you have to kind of understand the material first before you can teach the rest of the class.

Students commented that their teaching skills grew as result of participating in the lab. Another student said, "You learn patience, because we have to teach other. Patience for others and patience for yourself." While the LS 187C students probably had the most opportunities to teach their peers, the students who had taken LS 187A and B also felt that there were several opportunities for them to teach other students and used a variety of strategies to help students learn. For example, one student described:

> I think that you basically break it down to the basics, use colloquial terms, simple terms. You explain it how you would like it explained, very simply. You don't want to use all these verbose and bombastic words to explain all these. I know there are scientific terms to explain certain phenomena etc., but I just explained it so that it was really easy and to the point…You can only teach something if you're confident in the techniques or the process.

Another student described her teaching experience and the importance of practice:

> I think for me there are different experiences I had in terms of teaching. One is the actual cause. What I do is analyze gel. So when they ask me to teach somebody how to analyze gel I would sit down and go through…this is what I look at, this is what I look for. And then they're like; oh you're going too fast. Then I have to start over again. And then you basically do what you're doing, but just slow it down and tell them what you're doing as you're doing it. And that's kind of my approach. And the other thing that taught somebody was…So I sat them down and I explained it, the way that we were explained, and I brought out books and stuff we used. I'm sure it made sense, but it didn't click until they were actually doing it themselves. So I think that in practice you learn way more than if somebody is just telling you.

Faculty also noted the value of the presentations and how they helped students learn to present material. They also described how powerful the hands-on aspect of the lab was for students. For example, one professor said:

> The gray, it's not perfect data, depending on the gel, the quality is good or bad or very good or very bad. And you have to make some adjustments at some point. It helps to evaluate. That's a real experiment. And I think it's very good.

Faculty also commented that students were more comfortable in the lab in the second and third quarter and that the more senior students began to understand the complexity of science.

<u>Research and Analytical Skills</u>

Many students reported that the lab helped them develop their research skills, especially understanding data. Students also noted that the lab impacted how they solved problems. The data also suggests that students who continued in the lab sequence for more than one quarter were more likely to experience greater change in these skills. In the focus groups, students commented on how the lab helped them develop their troubleshooting skills. Table 7 presents the findings for research and analytical skills for the student survey.

**Table 7. Summary of Quantitative Results for Research and Analytical Skills**

| **Research and Analytical Skills** | **Nothing/ Just a little** | **Somewhat** | **A lot/ A great deal** |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| Solving problems | 4 | 8 | 3 |
| Research skills both in the laboratory and on the computer | 1 | 3 | 11 |
| Understanding data | 1 | 4 | 10 |
| Ability to think through a problem or argument | 2 | 7 | 6 |
| Ability to think in different ways | 2 | 5 | 8 |
| **LS 187B (n=3)** | | | |
| Solving problems | 0 | 3 | 0 |
| Research skills both in the laboratory and on the computer | 0 | 0 | 3 |
| Understanding data | 0 | 0 | 3 |
| Ability to think through a problem or argument | 0 | 2 | 1 |
| Ability to think in different ways | 0 | 2 | 0 |
| **LS 187C (n=5)** | | | |
| Solving problems | 0 | 2 | 3 |
| Research skills both in the laboratory and on the computer | 0 | 0 | 5 |

| | | | |
|---|---|---|---|
| Understanding data | 0 | 0 | 5 |
| Ability to think through a problem or argument | 1 | 0 | 4 |
| Ability to think in different ways | 1 | 1 | 3 |
| **ALL STUDENTS (n=24)** | | | |
| Solving problems | 5 | 13 | 6 |
| Research skills both in the laboratory and on the computer | 1 | 3 | 20 |
| Understanding data | 1 | 5 | 18 |
| Ability to think through a problem or argument | 3 | 9 | 11 |
| Ability to think in different ways | 3 | 8 | 11 |

As the students became more involved in the research, some remarked on how the research process is repetitive, takes a long time to unfold, is tedious, and requires precision. However, many of the students also realized the appealing aspects of research as well. As one student said, "This repetition piece is particularly helpful because it reinforces it and you have many chances to do that." Another student noted, "I think the main thing that I got out of this class is that it's a lot of toil. It's a lot of repetitiveness." And yet a third student said, "You're not extremely riveted while you're doing the project, but, after it's done, you look back and it's probably really rewarding to know what you've done. And what all you've accomplished through all your hard work."

When asked how this course impacted their research and analytical skills, students expressed modest growth. Most students noted that the course helped them develop troubleshooting skills. Students also felt that they valued being part of an ongoing research project that "would some day get published." One student commented that this course made her more confident about her research skills because "you do it over and over." The faculty were also invested in developing students' research and analytical skills. One professor noted:

> Students really have to stop and look and I think even in 187C one of the assignments for one of those students was to find the systematic errors, 'Okay, so your job is when this gel doesn't work, then you figure out why. Okay, look at the evidence and figure out why.' And then, 'Did that happen last week? Did that happen before? Did we see this again? Could it possibly be that we need to be adding a little bit more this?' You know, this kind of thing and so I think those sorts of experiences you can't find them very often in the regular curriculum and those are the ones where you really grow. And it's those sorts of things and even just making them, because they did have to leave notes from one another, when they set up the PCR and then the next people and so on. You had to always have that level of professionalism and really knowing what you've done and this kind of thing - the idea was if there was something that they goofed up, they had to leave the note there so that the people could understand. This kind of thing is a form of an analytical skill. It's realizing that what you do counts.

Science Competence

Most students indicated that their knowledge of science was positively impacted by participating in this lab (see Table 8). This learning became more pronounced for students who enrolled in the lab for more than one quarter. Not only did students indicate that they made gains understanding the main concepts and the relationships between theory and practice, they also indicated feeling more comfortable with science research.

**Table 8. Summary of Quantitative Results for Science Competence**

| Science Competence | Nothing/ Just a little | Somewhat | A lot/ A great deal |
|---|---|---|---|
| **LS 187A (n=15)** | | | |
| Understanding the main concepts | 0 | 2 | 13 |
| Understanding the relationships between theory & practice | 0 | 3 | 12 |
| Understanding the fundamentals of genomic biology | 0 | 4 | 11 |
| Confidence in your ability to use computer-based tools for biology | 1 | 2 | 12 |
| Feeling comfortable with science/research | 0 | 2 | 13 |
| Understanding the process of science | 0 | 2 | 13 |
| Ability to be conversant about genomics | 1 | 2 | 12 |
| **LS 187B (n=3)** | | | |
| Understanding the main concepts | 0 | 0 | 3 |
| Understanding the relationships between theory & practice | 0 | 1 | 2 |
| Understanding the fundamentals of genomic biology | 0 | 0 | 3 |
| Confidence in your ability to use computer-based tools for biology | 0 | 1 | 2 |
| Feeling comfortable with science/research | 0 | 0 | 3 |
| Understanding the process of science | 0 | 0 | 3 |
| Ability to be conversant about genomics | 0 | 1 | 2 |
| **LS 187C (n=5)** | | | |
| Understanding the main concepts | 0 | 0 | 5 |
| Understanding the relationships between theory & practice | 0 | 0 | 5 |
| Understanding the fundamentals of genomic biology | 0 | 1 | 4 |
| Confidence in your ability to use computer-based tools for biology | 0 | 0 | 5 |
| Feeling comfortable with science/research | 0 | 0 | 5 |
| Understanding the process of science | 0 | 1 | 4 |
| Ability to be conversant about genomics | 0 | 0 | 5 |
| **ALL STUDENTS (n=24)** | | | |
| Understanding the main concepts | 1 | 2 | 21 |
| Understanding the relationships between theory & practice | 1 | 4 | 19 |
| Understanding the fundamentals of genomic biology | 0 | 6 | 18 |
| Confidence in your ability to use computer-based tools for biology | 2 | 3 | 19 |
| Feeling comfortable with science/research | 1 | 2 | 21 |

| | | | |
|---|---|---|---|
| Understanding the process of science | 1 | 3 | 20 |
| Ability to be conversant about genomics | 2 | 3 | 19 |

Many students talked about how the lab helped them raise their level of awareness of genomic biology and deepened their theoretical understanding of what they gained from other courses. For example, one student said, “It's like we learned PCR in LS3, and now, without anyone preparing the gel or anything for you, you do it on your own.” Students also revealed that the lab helped them appreciate more “those that discover.” Another student aptly stated:

> In terms of the steps and the procedures, we’re able to realize if we mistakenly leave out a step the consequences it’ll have. And in terms of carrying out the procedure, after having committed so many mistakes you realize what is really detrimental, what you can get away with, why it is you have to add this, and what happens if you don’t, how the data is going to look if you do this.

When students were asked how much they had learned in this course compared to other courses they had taken in terms of subject content, the responses were mixed. Some students indicated that compared to other courses, they found the course repetitive and boring. Other students noted that the lab was focused on one thing and they learned that one thing very well. For example, one student commented:

> I don’t think I’ve learned a whole lot more, but I think I’ve gained a better understanding of a small base of knowledge that was kind of thrown at me, and some of the courses I’ve taken. I think just in terms of genomics in general, the scope of the class isn’t like that big, but it’s really focused, I think.

Science Confidence

Most students also developed science confidence in this lab; again, this was most notable for students who spent more than one quarter in the lab. Students often described that this confidence grew as they learned more and mentored the newer students. Students also observed how their comfort with the lab changed. For example, one student said:

> Before I came into this class I was actually really…whenever I’d do something in a lab, I’d ask, “Am I doing this right?” I’m always kind of shaky, and I’m not sure what I’m doing. But I’m taking a lab right now. After the second quarter of taking this, I don’t really second guess myself that much anymore. I’m pretty confident in what I’m doing. And there’s no uncertainty and shakiness that there was before.

The teaching and mentoring aspect of the lab helped students develop independence and science confidence. For instance, another student described:

> I know students are independent learners here in the university, but I think we’ve become more independent, especially [because] you don’t want to always constantly ask Gaston and Chou etc. You become more independent. You try to learn by either observing your peers, asking questions, and then even resorting to ask Cheryl how to do something. Yeah, I think this makes you more of an independent learner and you have to become confident in your abilities when you’re actually doing the wet lab or analyzing the gel or doing a blast.

The more senior students noted that the course helped them to become a “specialist” in a specific area, which in turn made them more confident about their research skills. One student commented:

> I think that in our lab there are sort of specialists in each area. So like I'll go to [this particular student] if I need help with loading a blast or I'll go to [another particular student] with the data that they get or - and what I do is the gel. So it's like in each situation there's been sort of [an expert that] has been doing it for the whole time and they know what they're doing.

Many students were also very excited to be part of a research team that was contributing to science. Students noted that this aspect of the lab was very motivating and they liked the idea that their work would some day get published. As one student noted, "In the other classes, we just learn the concepts and. In this one, we have to contribute something." Another student added, "Exactly. This is your own work, you really want to see where it goes." Other students noted how excited they were to get published and that they wanted to see what happens with the genome project.

### *Impact on Future Research Plans*

Students had different views on how the course impacted their future research plans. For many students, the course did not change their research plans. For example, one student said, "Well, I'd like to go into professional school after I graduate, but I don't know. It might help, but I'm not sure how genomic research can help later on in life." Another student added, "I couldn't say this class had a big impact in that decision. I've interned in research labs before, so I think that had a bigger influence than this class."

For other students, particularly those that had taken the entire lab sequence, their future research plans were affected significantly. For example, one student stated:

> This is my own field of study. It's completely integrated and what I want to do. Before I took this class, the only lab class I took was LS3, which was a great place to be, and when I started this class, and then since then started working in another lab.

Students often saw this experience in a lab that, with others, helped them develop research skills and research interests. As one student revealed:

> I think because of this experience I've been way more open to -- I used to think research is something you have to do. But now it's something I like, and after this is over I'm going to try to find another research position because I like it, and I might want to continue doing it even when I'm older. I have no idea, but because of this I have a better view on research.

### *Suggestions for Improvement*

Some of the students and faculty noted that the lab was impacted by the motivation and interest level of the individual students. For example, there was one individual who came to class late in the beginning and did not participate fully in the lab. In response, one of the instructors talked with the student, and from then on s/he became a paragon of punctuality. One professor indicated that by the third quarter, they had developed a system to closely monitor and grade student work and that this would be used next year. Students also expressed a need for more faculty lectures that would bring together the work conducted in the lab. As one professor noted:

> In the coming year, we're going to introduce a lecture component and we're going to make it truly interdisciplinary in terms of that everyone's going to understand the optics behind the sequencer and the chemistry and the mathematics that is involved in that particular bio-infomatics experiment.

There was some frustration with students who did not carry their weight in the lab. One student commented:

> I just hope to have serious students coming in, not really just take it lightly, and I don't know, probably cater to the serious students more than- but cause you don't want people coming in who don't really care when you help to get it off the ground and you really care.

The professors developed a system to monitor student work that will be implemented again next year. When there are 20 students doing different things, instructors cannot keep track unless it is written down in a log book. This is also necessary to ensure that students take full advantage of all of the different types of experiments in the LS187 course; some students had the tendency to want to specialize, because it was easier to master only one experimental technique than learning to become proficient in all.

***Discussion and Future Efforts***

Student learning in the LS 187 course was enhanced by the various laboratory requirements and activities such as class presentations, collaboration with other students in the course, and hands-on participation in the laboratory. LS187 is unlike any other lab or lecture course; there is no template or precedent for a core course in a large-scale undergraduate research project. Some of the students sensed the disorganization and uncertainty of a pilot course and reported feeling confused in the beginning. However, as the course progressed, many of the students found the lab activities beneficial and reported that they aided in their learning. Not surprisingly, students who had continued in the course for two or three quarters reported finding the lab activities more helpful than those students who had only taken one quarter.

Student skill development was assessed in the areas of collaboration, presentation and teaching skills, research and analytical skills, science competence, and science confidence. Many of the students felt that they learned from their peers through collaboration, and also that they became more skilled at being able to work cooperatively in groups. They reported positive gains in presentation and teaching skills due to the numerous opportunities to present or explain a chapter or article to an individual student or lab as a whole. Students also felt that the lab helped them to develop their research and analytical skills, especially in sequencing a microbial genome. As a result of their experiences in the course, students felt increased science competence as well as increased science confidence.

Many of the students were enthralled to be part of a research project that was contributing to science. In fact, the research completed by the students in the LS 187 course will eventually be published and all of the data deposited with the National Center for Biotechnology Information, the database used daily by millions of researchers worldwide. This unique experience had varying effects on the students and their future research plans. Some students found the repetitiveness of the research boring, while other students enjoyed it because it gave them a chance to become really skilled at doing genomics research. As a result, for some the course had no impact on their plans at all, and in some cases made students realize that they did not want to do research in the future. For others, the course had a very positive impact and made these students realize that research was the path for them. In either case, students found a new appreciation for what researchers do in the laboratory and why certain discoveries can take so long.

As in all pilot years of a new curricular initiative, there were some challenges along the way, which gave rise to suggestions for improvements for future courses.  Both students and faculty recognized that the lab's effectiveness was dependent upon the motivation and interest level of its students.  A few students as well as instructors noticed that certain students just did not pull their weight in the lab (e.g., always coming late to class), a detrimental effect when the success of the whole project is contingent upon all participants doing their parts.  As a result, the instructors developed a system to monitor and grade student work, including effort and professional conduct that will be used again next year.  Another challenge mentioned by one of the instructors concerns the lack of structure in scheduling and coordinating the numerous students with the many lab tasks.  This same instructor recommended implementation of a log book to track students to ensure that all students get a chance to do everything in the lab.

The LS 187 series has improved the UCLA life science curriculum by providing opportunities for students to engage in active learning and inquiry based life science research.  Students who participated in the LS 187 lab were pushed to think independently and work cooperatively.  Students indicated that presentation, research, and analytical skills improved as a result of participating in the lab.  Finally, students noted feeling more connected to their learning experience in the lab and that they could see why the work they were doing was important and useful.  Students used new technologies in the lab and came to understand what researchers do in a life science lab, some resonating to this type of work more than others, but many developing a greater understanding and comfort with conducting research.

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**APPENDIX A**
**Student Paper Survey**

**Name: ______________________________________**

**LS 187 courses taken** (Circle all that apply)**:** **A** **B** **C**

**Gender: _____________________** **Major: ______________________**
**Ethnicity: ____________________** **College GPA: ______________________**

## PART 1: ASSESSMENT OF STUDENT LEARNING GAINS

**Instructions to students:** Circle one answer for each question on each scale: **NA = Not Applicable; 1 = lowest rating to 5 = highest rating.** You may add a comment for any item on the last sheet. Number your comments by the same numbers as the items in the questionnaire.

**How much did learning each of the following aspects of the class HELP YOUR LEARNING?**

| | NA | Was of no help | Helped a little | Helped | Helped a good deal | Helped a great deal |
|---|---|---|---|---|---|---|
| 1. How did the laboratory deepen your theoretical understanding? | NA | 1 | 2 | 3 | 4 | 5 |
| 2. The pace at which we worked | NA | 1 | 2 | 3 | 4 | 5 |
| **The lab activities** | | | | | | |
| 3. Class presentations (including lectures) | NA | 1 | 2 | 3 | 4 | 5 |
| 4. Collaboration with other students | NA | 1 | 2 | 3 | 4 | 5 |
| 5. Understanding each part of the experiment | NA | 1 | 2 | 3 | 4 | 5 |
| **Resources** | | | | | | |
| 6. Students in other levels of the course | NA | 1 | 2 | 3 | 4 | 5 |
| 7. The instructors | NA | 1 | 2 | 3 | 4 | 5 |

**Support as a learner**

| | | | | | | |
|---|---|---|---|---|---|---|
| 8. The quality of contact with the teachers | NA | 1 | 2 | 3 | 4 | 5 |
| 9. The quality of contact with other students | NA | 1 | 2 | 3 | 4 | 5 |
| 10. The way that this class was taught overall | NA | 1 | 2 | 3 | 4 | 5 |

**How much has this class ADDED TO YOUR SKILLS in each of the following?**

| | **NA** | **Nothing** | **Just a little** | **Somewhat** | **A lot** | **A great deal** |
|---|---|---|---|---|---|---|
| 11. Solving problems | NA | 1 | 2 | 3 | 4 | 5 |
| 12. Research skills both in the laboratory and on the computer | NA | 1 | 2 | 3 | 4 | 5 |
| 13. Understanding data | NA | 1 | 2 | 3 | 4 | 5 |

**To what extent did you MAKE GAINS in any of the following as a result of what you did in this class?**

| | **NA** | **Not at all** | **Just a little** | **Somewhat** | **A lot** | **A great deal** |
|---|---|---|---|---|---|---|
| 14. Understanding the main concepts | NA | 1 | 2 | 3 | 4 | 5 |
| 15. Understanding the relationship between theory and practice | NA | 1 | 2 | 3 | 4 | 5 |
| 16. Understanding the fundamentals of genomic biology | NA | 1 | 2 | 3 | 4 | 5 |
| 17. Ability to think through a problem or argument | NA | 1 | 2 | 3 | 4 | 5 |
| 18. Confidence in your ability to use computer-based tools for biology | NA | 1 | 2 | 3 | 4 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 19. Feeling comfortable with science/research | NA | 1 | 2 | 3 | 4 | 5 |
| 20. Understanding the process of science | NA | 1 | 2 | 3 | 4 | 5 |
| 21. Interest in the topics discussed | NA | 1 | 2 | 3 | 4 | 5 |
| 22. Skill in collaboration | NA | 1 | 2 | 3 | 4 | 5 |
| 23. Ability to think in different ways | NA | 1 | 2 | 3 | 4 | 5 |
| 24. Ability to be conversant about genomics | NA | 1 | 2 | 3 | 4 | 5 |

**Note to Students: Please ADD YOUR OWN COMMENTS below/on back of this page to share your thoughts about this course. If they are tied to a particular question, use the same number/letter as the question to which they apply.**

*Based on one created by Elaine Seymour, Director of Ethnography and Evaluation Research, at the University of Colorado, Boulder.

## Email Invitation for Student Web Survey

Dear student,

UCLA is always looking to create courses that are interesting to students but also provide a great learning experience for everyone involved. The Office of Undergraduate Evaluation and Research (OUER) at UCLA was created to help the College obtain feedback regarding their courses.

We are contacting you because you were previously enrolled in the LS 187A and LS 187B courses (Research Experience in Life Sciences). As you recall, these courses involved hands-on research in the laboratory. In order to learn more about your experience in these courses, we ask that you please complete the following survey. The link to the survey can be accessed at:

**http://CTLSilhouette.wsu.edu/surveys/ZS25321**

Your comments will be kept anonymous and you will never be directly identified. However, your comments may be used in our write-up as we discuss the opinions regarding this course. There are no right or wrong answers. Your comments will be used to help guide the way this course is organized in the future.

The brief survey should take approximately 15 – 20 minutes to complete. We really appreciate your participation.

Sincerely,

Marc Levis-Fitzgerald & Nida Denson

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**Student Web Survey**
**(In addition to the questions on the student paper survey)**

1. Why did you choose to take the LS 187A course?

2. Why did you decide not to continue in this series (i.e., LS 187B, LS 187C)?

3. Was there anything different/special about the quality of your interaction with the instructors, the students in the other sections of the course (LS 187A,B,C), and your peers in this class as compared to other courses you have taken?

4. How did the collaborative nature of the course influence your learning?

5. This course emphasizes hands-on and peer-mentored learning rather than instructor-based learning. How did this contribute to your overall experience in the course?

6. How did you find the mentorship experience? What were the associated challenges?

7. Has this course raised your level of understanding of genomic biology (yes/no)?

8. How has this course influenced your perception of scientific research and how scientific progress is made?

9. How has your thinking about your own field of study been influenced by this course?

10. Has this course made you more confident about your research skills (yes/no)?

11. Did the fact that you were doing real scientific research as part of this course influence you? Would the class be just as effective with "canned" labs in which the outcome is known?

12. Did your experiences in this course help you to develop your troubleshooting skills?

13. Is there anything else we haven't already talked about that you feel you have gained from this class?

***If you have any questions or comments, please feel free to email either one of us.***
***Thank you for your time and your thoughts on this course.***
***Your comments will be helpful to future course development.***

**APPENDIX B**
**Students' Focus Group Protocol**

**Introduction (~ 2 minutes)**

***A. Introduce yourself***

Hi, I'm from the Office of Undergraduate Evaluation and Research and one of the things we do is help Letters and Science gather feedback regarding their courses.

*B. Preface discussion*

UCLA is always looking to create courses that are interesting to students but also provide a great learning experience for everyone involved. So we're here today to ask you some questions regarding your opinions and experiences in this course. We hope to have an open discussion based on your opinions, comments and experiences regardless of whether they are good, bad or neutral. All your thoughts are very important to us because there are no right or wrong answers here and we want to hear everything you have to say. Your comments will be used to help guide the way this course organized in the future.

Our discussion should last about 45 minutes.

*C. Set ground rules*

Before we begin, let's set out some ground rules:

1. All your comments will be kept relatively anonymous. We will never identify you directly, however, your comments may be used in our write-up as we discuss the opinions regarding this course.
2. Again, there are no right or wrong answers. There may be differences in opinions, and in fact, we're hoping there will be. Please share any comments with us and don't worry if they're not what your neighbor is saying. Conversely, if you agree with your neighbor, we want to know that too.
3. Speak up clearly and talk one at a time. We're recording this session because we don't want to miss any of your comments, but the recording has a tendency to get garbled if more than one person speaks at once or if you speak too quietly.

***D. Questions? If not, let's get started.***

**Questions**

*Motivation and Goals (~5 minutes)*

1. Let's start by going around the group so that each of you can tell us why you chose to take this course.
2. When you began the course, what did you hope to get out of it?
    a. How did this course meet or not meet these goals?
    b. What helped to facilitate or prevent accomplishing them?

*Interaction and Collaboration (~10 minutes)*

1. Was there anything different/special about the quality of your interaction with the instructors, the students in the other sections of the course (LS 187A,B,C), and your peers in this class as compared to other courses you have taken?
2. How did the collaborative nature of the course influence your learning?

    a. Specifically, you worked as a team, and the results were dependent on working together by dividing up the sequencing experiment in stages, with the success of each stage dependent on the other. Did this setup influence your learning?
3. Did you gain a deeper understanding/appreciation of collaborative practices because of the course?
4. This course emphasizes hands-on and peer-mentored learning rather than instructor-based learning. How did this contribute to your overall experience in the course?
5. How did you find the mentorship experience? What were the associated challenges?
6. In the LS 187C course, students are required to meet with the instructors once a week in a troubleshooting/course planning and development meeting. Can you comment on that experience?

*Intellectual Development/Science Awareness, Competence and Engagement (~10 minutes)*

1. Please comment on your understanding of genomic biology.
    a. Has the course raised your level of awareness?
    b. Has it deepened the theoretical understanding you've gained from this and other courses?
2. How has this course influenced your perception of scientific research and how scientific progress is made?
3. How has your thinking about your own field of study been influenced by this course?
4. Tell us about any impact this course has had on your ability to learn or to solve intellectual problems.
5. Thinking specifically of learning, how much do you think you have learned in this course compared to other courses you have taken in terms of
    a. subject content
    b. understanding the collaborative nature of science
    c. understanding of the larger context of research
    d. ability to communicate your understanding of science

*Research and Teaching Skills/Intellectual Self-Confidence (~10 minutes)*

1. Has this course made you more confident about your research skills?
2. This course was designed, in part, because of the growing emphasis on computer-based analysis of raw data, such as analysis of sequencing gels with the eseq program. This is a skill that colleges and universities are only beginning to teach. Do you feel that this course effectively developed those skills?
3. As in most research labs, a significant part of the experience is studying the scientific literature and presenting findings to one's colleagues. Has this course given you a new skill in this area of expertise?
4. Did the fact that you were doing real scientific research as part of this course influence you? Would the class be just as effective with "canned" labs in which the outcome is known?
5. Did your experiences in this course help to develop your troubleshooting skills?

*E.* ***Other Questions? (~5 minutes)***

1. This class is unusual in that it is an ongoing research project. Are you interested in the future of this class any more than any other class you have taken in the past because of this?
2. Is there anything else we haven't already talked about that you feel you have gained from this class?
3. Overall, what do you see as the successful outcomes of the course?
4. What do you see as the challenges/problems of the course?
5. What might you add or change about the course if it was to be taught again in the future?

**Closing**

***A. Before we end, does anyone have anything to add?***
***B. Any questions?***
***C. If anyone does have anything they would like to add, feel free to email either one of us.***
***D. Thank you for your time and your thoughts on this course. Your comments will be helpful to future course development.***

**APPENDIX C**
**Faculty Interview Protocol**

**Introduction**

A. Greeting
B. Logistics
   1. Conversation will be audio taped
   2. Conversation will be relaxed
   3. Conversation should last about one hour
C. Purpose of interview – to understand the challenges and rewards associated with teaching a course using research

**Logistics**

A. What was the specific role that you played in the lab?
B. What were the course objectives?
C. Can you explain to us what you did each week? Week 1, Week 2, etc.
D. Can you explain to us the student reaction each week? Week 1, Week 2, etc.

**Motivation and Goals and Implications**

A. Do you believe the experience of doing real research as opposed to a more typical lab exercise engaged your students more deeply?
B. Did participating in the research project help to foster a sense of collaboration or community among your students?

**Learning**

A. How do you think the research experience has affected the students' understanding of science?
B. How do you think the experience has affected the students' analytic and research skills?
C. How do you think the course has affected the students' self-confidence (before and after the course) about research/genomic biology?
D. How do you think the course has affected the students' research aspirations/attitude toward research?

**Other Questions?**

A. What do you see as successful outcomes of this interaction among courses?
B. What were the challenges?

**Closing**

A. Any questions?
B. Any additional comments?
C. Thanks for your time!