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Supplemental Materials
for
Comparing the Impact of Course-Based and Apprentice-Based Research Experiences in a Life Science Laboratory Curriculum

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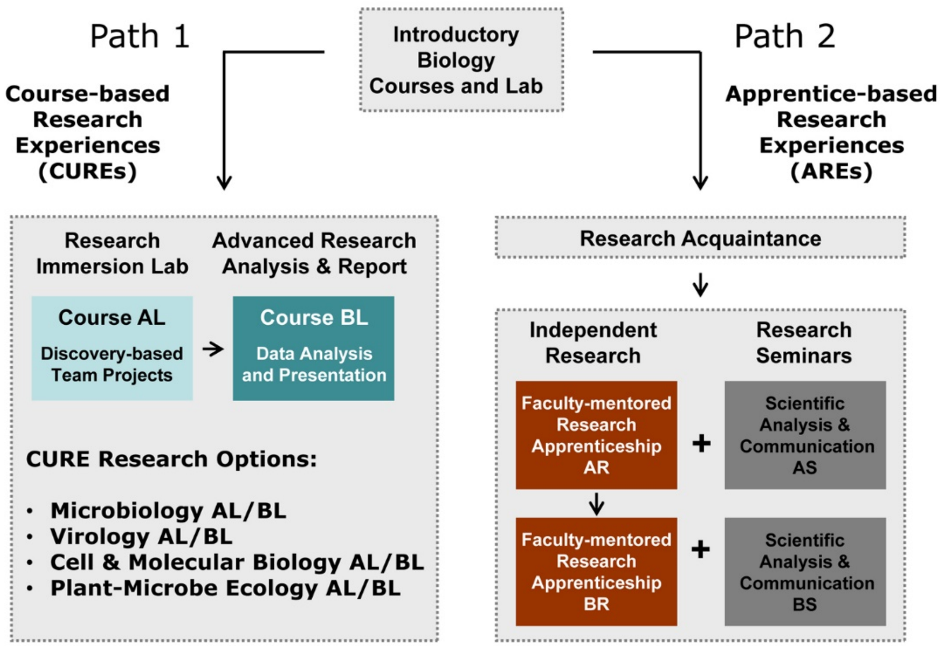
Appendix 1:

Overview of the Competency-Based Research Laboratory Curriculum (CRLC).



Upon completion of the requisite lower-division core courses ("Introductory Biology Courses and Lab"), students fulfill their departmental major's laboratory requirements by one of two research paths.

Path 1 is open to all third and fourth year students, who may choose to enroll in any one of four laboratory courses referred to as "Research Immersion Labs" (Path 1, AL courses). Activities span two 10-week terms with each "Research Immersion Lab" followed by an "Advanced Research Analysis & Report" course (Path 1, BL courses). While the first course offers hands-on experience collecting data, analyzing preliminary results, and reading the scientific literature, the second course emphasizes rigorous quantitative and computational analysis of data generated in the requisite AL course. During these investigations, students use bioinformatics tools or mathematical modeling software to interpret, expand, or refine their data sets. Throughout both terms, Path 1 students participate in team oral presentations and the discussion of research ideas with the class as well as document their research accomplishments in final written reports. Each pair of Path 1 AL and BL courses together make up a course-based research experience (CURE) in which students experience the process of scientific discovery as members of a research team (each typically 3-4 students). All four CUREs are focused on different research projects (see **Table 1**).

Path 2 creates an opportunity for students to participate in an apprentice-based research experience (ARE) for major credit. Students engage in at least two consecutive 10-week terms of letter-graded research (Path 2 courses AR and BR) and concurrently participate in research seminars (courses AS and BS) designed to help students develop in-depth knowledge about their research project. To facilitate achievement of this goal, students read and discuss relevant scientific literature, as well as orally present and formally write about their individual research projects.

Unlike Path 1, which is open to all third and fourth year students, an application process is a requisite for entry into Path 2. Students in their third year who develop an interest in research while participating in a

“Research Acquaintance” experience in a faculty mentor’s laboratory and who meet the eligibility requirements (see Path 2 requisites in yellow box of **Figure 1**) are urged to submit applications (see **Appendices 2-3** for application forms, including Project Proposal Guidelines and the Faculty Mentoring Agreement). Exceptions are made for transfer students, who are encouraged to apply either in their first or second year after matriculating to UCLA. Faculty sponsors are provided a rubric (see **Appendix 4**) and are encouraged to utilize this assessment tool during discussions with their mentees throughout the two terms, with the aim of helping students stay on track as far as expectations of conduct and research accomplishments in the laboratory. Eligible students approved to begin Path 2 coursework are exempt from participating in Path 1. Not all applications are approved, with decisions by the departmental curriculum committees influenced by the strength and clarity of the research proposal as well as the reputation of the research sponsor in effectively mentoring past undergraduates.

In addition to presenting their work orally during both terms, all CRLC students share their research achievements with peers and faculty by presenting a poster at a symposium sponsored by the departments near the end of the second term, a culminating or capstone-like experience meant to provide students an opportunity to synthesize the entirety of their two-term research efforts.

More information about the CRLC is available on the program website: www.crlc.ucla.edu.

Further inquiries may be forwarded to the corresponding author.

Significant Contributions to the Development & Implementation of the CRLC

Implementation committee members:
Stephen Smale, Luisa Iruela-Arispe, Erin Sanders, Pamela Hurley, and Bridget Wells

Path 2 syllabus committee members:
Ann Hirsch, Hanna Mikkola, Jau-Nian Chen, and Beth Lazazzera

Faculty who contributed significantly to Path 1curriculum development efforts:
Erin Sanders, Jordan Moberg Parker, Ann Hirsch, Pei Yun Lee, Gaston Pfluegl, and Todd Lorenz

Teaching Assistants who contributed significantly to Path 1 curriculum development efforts:
Janahan Vijanderan and William Villella

Faculty who contributed significantly to Path 2 curriculum development efforts:
Stephen Smale, Erin Sanders, Daniel Cohn, Steve Jacobsen, and Jau-Nian Chen

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Philip Postovoit, Kris Reddi, and numerous undergraduate laboratory assistants

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Division of Life Sciences in the College of Letters and Science

Appendix 2:

Path 2 project proposal guidelines.

- Proposals should be one-page, typed with 1-inch margins, single-spaced, and 11-pt Arial font
- Proposals should have a cover page with the following information:
    - Title of proposed project
    - Student name, signature, UID, and email address
    - Faculty research sponsor's full name, signature, phone number, and email address
- The proposal should be written in your own words, reflecting your understanding of the project. If you utilize materials written by someone else, such as sections of a grant proposal or research article, make sure you cite them appropriately (include in-text citations plus a bibliography). It is a form of academic dishonesty to turn in material written by someone else without giving them proper credit.
- The intent in writing a research project proposal is to convince a review panel, this case the undergraduate curriculum committee, that the topic and approach are sound and have a clear relationship to previous work in the same field. Students should spend considerable time thinking about their projects, discussing their projects with their research mentors, and producing multiple drafts of the proposal since the quality of this document influences whether or not the Path 2 application is approved.
- The proposed project should be appropriate in scope for a 20-week project (10 weeks in AR plus 10 weeks in BR) and reflect accomplishments expected by both student and faculty advisor.
- A proposal should begin with a problem statement – a clear description of the larger question or problem within which the research project is situated.
- A description of the project should follow. This should include a rationale for the project that incorporates existing bodies of literature (published works) that will set the project into context, showing how the proposed work builds upon previous studies. This discussion should set the stage for the hypothesis(es) to be tested. The description should incorporate specific aims explaining what you plan to accomplish and how. This section should include a succinct account of methods that will be used to generate data (how will the data be collected and subsequently analyzed?) as well as a justification for why this approach is appropriate (how does it address your hypothesis or address the research question?).
- The proposal must make clear the precise role that the student will play in the research project, including how much and what part of the data collection the student him/herself will complete.
- The project should reasonably fit the research and writing components within a two-term framework imposed by AR and BR and require no less than 12 hours per week in the lab. The faculty sponsor should provide an estimate of approximately how many hours per week (for the duration of one term) the proposed project is expected to involve. That estimate should be included in the project proposal.
- Append the acknowledgement form and faculty mentor agreement with signatures from both student and faculty sponsors to the project proposal and submit materials to the departmental office by 5:00 PM on Friday of 5th week.
- Project proposals will be reviewed by the departmental curriculum committee. Students will be informed of their decision within 3 weeks of submitting application.
- To help applicants understand the expectations for the project proposal, students may request a sample document written by a past applicant.

Appendix 3:

Path 2 faculty mentoring agreement.

Undergraduates applying for Path 2 must provide a copy of the
Mentoring Responsibilities and Agreement Form to their proposed research sponsor.
A signed copy of the agreement must be included with the Path 2 application materials.

Mentoring Responsibilities

Undergraduates participating in the Path 2 curriculum will do discovery-based or hypothesis-driven research with faculty mentors actively contributing to their scholarly development as scientists. By signing the agreement on page 2 thereby accepting a Path 2 research student into their laboratory, faculty sponsors consent to follow the guidelines outlined below.

- ☐ Directly supervise undergraduate or designate a post-doctoral scholar, graduate student or technical assistant with mentoring experience as direct supervisor.
- ☐ Evaluate student performance as follows:
  - Discuss learning goals and expectations at the beginning of research experience.
  - Keep students informed by meeting regularly to discuss progress and provide feedback about project and overall performance in the laboratory. These activities will help students gauge their strengths and weaknesses as well as recognize areas in need of improvement.
    [see **Assessment Guidelines for Path 2 Faculty Mentors**].
- ☐ Review and sign off on all reports & posters prepared by student mentees for AR & BR. Also pay for printing costs associated with posters presented by students during the second term.
- ☐ Ensure student gives an oral presentation at least once during AR or BR in a journal club or lab meeting.
- ☐ Review slides and abstracts prepared by student for AS and BS seminar courses to ensure student understands scientific content, experimental approach and outcomes.
  - Help students identify journal articles that will provide background knowledge needed to achieve broader sense of project and explain overall problem/question being addressed during their presentations.
  - Make sure student understands overall experimental strategy as well as specific techniques they are performing in the laboratory.
  - Ensure students are able to describe the results and conclusions derived from their data.
- ☐ Communicate with AS and BS seminar instructors, who will be monitoring student progress on their research project. This responsibility may involve responding to short questionnaires or engaging in short discussions by email or phone.
- ☐ Submit grades to the registrar at the end of courses AR and BR.

Faculty Mentoring Agreement

Research Course (Circle One): course AR or BR

Quarter Enrolled (Circle One): Fall Winter Spring Year _________

Name of Student (print): ____

Student UID: __________________________________

Student's E-mail address: ____

Faculty Mentor's Name (print): ____

Faculty Mentor's Department: ____

Faculty Mentor's E-mail Address & Phone:

____

Name of Student's Direct Research Supervisor (Print):

____
(Designated Graduate Student, Post-doc, or Technical Assistant)

I accept the mentoring responsibilities outlined on page 1 of this agreement and will actively participate in the research experience for the above named undergraduate.

____
Signature of Faculty Research Mentor (Instructor of Record for courses AR & BR)

____
Date

Appendix 4:

Assessment guidelines for Path 2 faculty mentors.

Learning Goals	Student Performance		
	Needs Improvement	Satisfactory	Excellent
Understanding of the subject matter. The student should show progress in his/her knowledge of the project from beginning to end. Progress can be monitored in one-on-one meetings with a research mentor, in his/her performance on Power Point presentations for research seminars and lab meetings. Improvements also can become evident in their ability to describe the project in writing assignments (proposal, abstract, progress reports, final paper, poster, etc.). *Possible outcomes:*			
Student understands the basic scientific question or problem being addressed.			
Student can relate question to bigger picture/has broader sense of project.			
Student reads and understands relevant primary literature.			
Notes clarifying performance score:			
Practical experience. Through hands-on experience, the student should develop technical expertise. *Possible outcomes:*			
Student masters or starts to master the methodologies (wet-lab skills, computer analysis skills) required for their project.			
Student works independently and does not need continual monitoring by direct supervisor.			
Student respects the lab equipment and experimental organism.			
Notes clarifying performance score:			
Problem-solving skills. The student should improve their ability to troubleshoot experiments. *Possible outcomes:*			
Student demonstrates the ability to think through an experimental protocol, identifying necessary controls, equipment or materials needed to complete the experiment.			
Student deals with problems or protocol changes as they arise.			
Student displays ability to plan an experiment strategically within time or resource (budget, equipment availability) constraints, other project responsibilities, or work being conducted by other lab members.			
Student seeks counsel from someone with more experience or finds other ways to do an experiment if the original approach failed.			
Notes clarifying performance score:			

Assessment guidelines for Path 2 faculty mentors.

Learning Goals	Student Performance		
	Needs Improvement	Satisfactory	Excellent
Keeping a lab notebook. The students should learn how to maintain an organized, up-to-date lab notebook. *Possible outcomes:*			
Notebook contains a table of contents, dated experiments which include the experimental aims, procedure (flow diagrams), data, and conclusions.			
Notes are not jotted down on scrap paper, but neatly transcribed into bound pages of the notebook.			
Primary data such as gel images, plate pictures, or graphical output are included with each experiment.			
Data are properly labeled and affixed to notebook pages.			
The information in the notebook is easy to read and complete enough for future repetition of experiments.			
Electronic data files are stored in designated location in the research laboratory, not on personal laptop or storage devices.			
Notes clarifying performance score:			
Oral presentation skills. The student improves their ability to present and discuss his/her research experience. *Possible outcomes:*			
Student introduces the research problem so that the audience can understand it.			
The presentation is clearly organized and contains high quality graphics (not blurry or pixelated), which the student describes in sufficient and accurate detail.			
Student speaks to the audience and not to the projection screen or board.			
Student addresses questions from audience honestly and with confidence and tries to cultivate discussion about points outside the immediate scope of the presentation.			
Student leaves the audience with a clear understanding of the research study or provides a sense that independent research has been accomplished.			
Notes clarifying performance score:			

Assessment guidelines for Path 2 faculty mentors.

Learning Goals	Student Performance		
	Needs Improvement	Satisfactory	Excellent
Writing skills. The student improves their ability to write about his/her project. *Possible outcomes:*			
Student correctly organizes the work into proper sections (e.g., Summary/Abstract, Introduction, Experimental Procedures, Results, Discussion, & References).			
The data are accurately presented in text form and in figures (including labels and legends).			
The text is written in proper English and lacks grammatical/spelling errors.			
The student seeks editorial (and technical) comments from the faculty advisor or postdoc/graduate student mentor before submitting the final draft.			
Notes clarifying performance score:			
Team player. Although independence and autonomy are valuable characteristics to develop in a research laboratory, the student also should learn to value collaborations and/or be collegial with other colleagues in their work environment. *Possible outcomes:*			
If the student is a member of group (postdoc, graduate student, undergraduate), he/she is a team player, making equitable and high quality contributions towards achievement of the project goals.			
If the student works more independently, he/she gets along well with other lab members.			
Student makes insightful and constructive comments during lab meetings when others are present.			
Student helps with mundane, but essential, lab tasks such as packing tips, filling water baths, etc.			
Student keeps his/her work-space clean and tidy and overall contributes to the general well-being of the group work area.			
Student appreciates that lab notebooks, data files, and lab supplies are the property of the faculty mentor, not personal property; thus, the student does not take these materials outside the lab without permission from the faculty mentor.			
Notes clarifying performance score:			

Appendix 5:
CRLC entry survey.

Part I. Degree Aspirations

1. If you plan to continue your formal education after completing your undergraduate degree, please indicate your degree aspiration: (Please select all that apply)

   - ☐ Ph.D. in a life science (including biophysics, biochemistry, etc.)
   - ☐ Ph.D. in the physical sciences (including math, engineering, computer science, etc.)
   - ☐ Ph.D./M.D. (joint)
   - ☐ M.D. degree
   - ☐ M.S. or M.A. in the life sciences (including biophysics, biochemistry, etc.)
   - ☐ M.S. or M.A. in the physical sciences (including math, engineering, computer science, etc.)
   - ☐ Ph.D. in a field other than life or physical sciences
   - ☐ M.S. or M.A in a field other than life or physical sciences
   - ☐ Professional degree such as law (J.D.) or business (M.B.A.)
   - ☐ Professional program such as dentistry, optometry, pharmacy, nursing, public health, etc.
   - ☐ Teaching credential
   - ☐ I do not plan to continue my formal education.
   - ☐ Other: ______________________________

2. Please list any of the science-related programs in which you have been or are currently involved (e.g. PEERS, EXROP, etc.).

3. Please list any of the science-related programs to which you intend to apply in the next academic year.

Part II. Impressions of Science

22 Questions from CURE Survey

Lopatto, D. (2007) Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sci. Educ*. **6**: 297–306.

Lopatto, D., C. Alvarez, D. Barnard, C. Chandrasekaran, H.-M. Chung, C. Du, T. Eckdahl, A. L. Goodman, C. Hauser, C. J. Jones, O. R. Kopp, G. A. Kuleck, G. McNeil, R. Morris, J. L. Myka, A. Nagengast, P. J. Overvoorde, J. L. Poet, K. Reed, G. Regisford, D. Revie, A. Rosenwald, K. Saville, M. Shaw, G. R. Skuse, C. Smith, M. Smith, M. Spratt, J. Stamm, J. S. Thompson, B. A. Wilson, C. Witkowski, J. Youngblom, W. Leung, C. D. Shaffer, J. Buhler, E. Mardis, and S. C. R. Elgin (2008) Genomics Education Partnership. *Science* **322**: 684–685.

1 Question from BioCLASS Survey

Semsar, K., J. K. Knight, G. Birol, and M. K. Smith (2011) The Colorado Learning Attitudes about Science Survey (CLASS) for Use in Biology. *CBE-Life Sci. Educ*. **10**: 268–278.

Part III: Research Expectations

1. What do you hope to learn from your participation in this research experience?

2. Do you expect your research project will present any intellectual or technical challenges? If so, briefly explain your response.

3. In your opinion, what are three important characteristics of high quality, reliable research results?

Part IV. Course Expectations

1. Please indicate how important each reason was for selecting research Path 1 or Path 2 to complete your science major? (Please circle the appropriate response)

	Not Important	Moderately Important	Very Important	Essential	Not Applicable
To fulfill a major requirement	1	2	3	4	5
Need it for graduate or professional school	1	2	3	4	5
Need it for desired employment after college	1	2	3	4	5
To learn laboratory techniques and get hands-on research experience	1	2	3	4	5
To experience the scientific research process (e.g. reading literature, designing experiments, analyzing data, presenting results, etc.)	1	2	3	4	5
Path 1 students only:					
The course and/or the instructor has a good reputation	1	2	3	4	5
The subject matter or research project of the course interests me	1	2	3	4	5
Path 2 students only:					
The research laboratory and/or mentor has a good reputation	1	2	3	4	5
The research project is on something I'm interested in learning more about	1	2	3	4	5

Other (please explain): ____

Part V. Skills

Please give an estimate of your level of ability as you begin this course. Your current level of ability may be a result of courses taken in high school or college, or may be a result of other experiences such as jobs or special programs. Please circle the appropriate answer for each skill listed below.

	None at All	To Some Extent	To a Great Extent
Science Competence			
Reading science textbooks	1	2	3
Understanding science class lectures	1	2	3
Discussing reading materials in science classes	1	2	3
Placing current scientific issues in historical context	1	2	3
Working on scientific problems sets	1	2	3

Taking tests in science classes	1	2	3
Using knowledge you acquired in other courses	1	2	3
Perception of scientific research as a career	1	2	3

Critical Thinking and Problem Solving

Understanding the relationship between theory and practice	1	2	3
Understanding primary scientific literature	1	2	3
Analyzing scientific literature critically	1	2	3
Analyzing and solving scientific problems	1	2	3
Thinking through a problem or argument	1	2	3
Thinking creatively	1	2	3

Writing and Presentation Skills

Presenting results in a science poster	1	2	3
Writing about my own experimental results in a lab report	1	2	3
Writing a research proposal	1	2	3
Writing about scientific findings reported in the literature	1	2	3
Writing an abstract	1	2	3
Orally presenting my own experimental data	1	2	3
Orally presenting scientific findings reported in the literature	1	2	3

Research Skills

Developing a hypothesis based on published scientific data	1	2	3
Devising hypotheses based upon your own experimental observations	1	2	3
Designing scientific experiments to test a hypothesis	1	2	3
Performing scientific lab techniques	1	2	3
Collecting scientific data	1	2	3
Maintaining a science lab notebook	1	2	3
Analyzing scientific data	1	2	3
Conducting scientific research in an ethical manner	1	2	3
Understanding how scientists think	1	2	3
Finding relevant scientific literature using online databases such as PubMed or Google Scholar	1	2	3

Community

Working as part of a team	1	2	3
Teaching others	1	2	3
Mentoring peers	1	2	3
Critiquing the science work of other students	1	2	3
Becoming responsible for part of project	1	2	3

Science Confidence

Comfortable discussing scientific research	1	2	3
Comfortable with technical research skills	1	2	3
Solving scientific problems independently	1	2	3
Solving scientific problems collaboratively	1	2	3

Part IV. Quantitative Reasoning

8 Questions from ASMCUE Questionnaire

Bergevin, C. (2010) Towards improving the integration of undergraduate biology and mathematics education. *J. Microbiol. Biol. Educ.* **11**: 28–33.

Part V: Experiences

1. Please provide your current level of experience as you begin this course or program.

	No experience or feel inexperienced	Little experience	Some experience	Much experience	Extensive experience or mastered this	N/A
1. Computer modeling.	1	2	3	4	5	6
2. Use of bioinformatics tools.	1	2	3	4	5	6
3. Performing quantitative analysis of data on a computer.	1	2	3	4	5	6

Part VI. Additional Feedback

1. Please offer any additional feedback in the space below.

Appendix 6:

CRLC exit survey.

Part I. Degree Aspirations

1. If you plan to continue your formal education after completing your undergraduate degree, please indicate your degree aspiration: (Please select all that apply)

- ☐ Ph.D. in a life science (including biophysics, biochemistry, etc.)
- ☐ Ph.D. in the physical sciences (including math, engineering, computer science, etc.)
- ☐ Ph.D./M.D. (joint)
- ☐ M.D. degree
- ☐ M.S. or M.A. in the life sciences (including biophysics, biochemistry, etc.)
- ☐ M.S. or M.A. in the physical sciences (including math, engineering, computer science, etc.)
- ☐ Ph.D. in a field other than life or physical sciences
- ☐ M.S. or M.A in a field other than life or physical sciences
- ☐ Professional degree such as law (J.D.) or business (M.B.A.)
- ☐ Professional program such as dentistry, optometry, pharmacy, nursing, public health, etc.
- ☐ Teaching credential for K-12 system
- ☐ I do not plan to continue my formal education
- ☐ Other (please explain): ____

2a. If you are entering a graduate or professional program, what specific institution and program will you start for graduate/professional study in [year]?

Institution:

Department:

Degree to be obtained:

Predicted Graduation Year:

2b. If you are not starting graduate or professional school in [year- such as 2011/12], please indicate what will you be doing in the year immediately following graduation:

- ☐ I plan to enter a post-baccalaureate program.
- ☐ I plan to start working or looking for a job in an academic or industry lab.
- ☐ I plan to start working or looking for a job related to science but not in a lab.
- ☐ I plan to start working or looking for a job not related to science.
- ☐ Other: ____

3. What quarter and year do you intend to graduate from UCLA?

4. How has your experience in research programs associated with Path 1 or Path 2 prepared you for your future degree/career goals?

Part II. Impressions of Science

22 Questions from the CURE Survey

Lopatto, D. (2007) Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sci. Educ*. **6**: 297–306.

Lopatto, D., C. Alvarez, D. Barnard, C. Chandrasekaran, H.-M. Chung, C. Du, T. Eckdahl, A. L. Goodman, C. Hauser, C. J. Jones, O. R. Kopp, G. A. Kuleck, G. McNeil, R. Morris, J. L. Myka, A. Nagengast, P. J. Overvoorde, J. L. Poet, K. Reed, G. Regisford, D. Revie, A. Rosenwald, K. Saville, M. Shaw, G. R. Skuse, C. Smith, M. Smith, M. Spratt, J. Stamm, J. S. Thompson, B. A. Wilson, C. Witkowski, J. Youngblom, W. Leung, C. D. Shaffer, J. Buhler, E. Mardis, and S. C. R. Elgin (2008) Genomics Education Partnership. *Science* **322**: 684–685.

1 Question from the BioCLASS Survey

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Part III. Open-ended Questions

1. Imagine that you obtained an unexpected result in one of your experiments. What could this mean? What steps might you take to resolve this unexpected result? What shouldn't you do?

2. Is there any value in reproducing an experiment that has already been done? Please explain.

3. What are some ethical issues that concern research scientists?

4. How has your experience in the laboratory impacted your professional aspirations? Please explain.

5. What do you see as some of the potential positives of a career in scientific research? What are some of the potential negatives or challenges associated with a research career?

6. Has your research experience thus far met or exceeded your expectations? Please elaborate. What developments would you like to see in your current research activities? What about in future research positions?

Part IV. Skills

Please indicate the extent to which your level of ability in the following areas has changed as a result of your participation in Path 1 or Path 2 research experiences? Circle the appropriate answer for each skill listed below.

	None at All	**To Some Extent**	**To a Great Extent**
Science Competence			
Reading science textbooks	1	2	3
Understanding science class lectures	1	2	3
Discussing reading materials in science classes	1	2	3
Placing current scientific issues in historical context	1	2	3
Working on scientific problems sets	1	2	3
Taking tests in science classes	1	2	3

Using knowledge you acquired in other courses	1	2	3
Perception of scientific research as a career	1	2	3

Critical Thinking and Problem Solving

Understanding the relationship between theory and practice	1	2	3
Understanding primary scientific literature	1	2	3

Describe the process you use to understand what other scientists write about in the literature?

____

Analyzing data in scientific literature critically	1	2	3

What criteria must be satisfied for you to have confidence in the results and conclusions made by other scientists?

____

Analyzing and solving scientific problems	1	2	3
Thinking through a problem or argument	1	2	3
Thinking creatively	1	2	3

What are the hallmarks of creative thinking in science?

____

Writing and Presentation Skills

Presenting results in a science poster	1	2	3
Writing about my own experimental results in a lab report	1	2	3
Writing a research proposal	1	2	3
Writing about scientific findings reported in the literature	1	2	3
Writing an abstract	1	2	3
Orally presenting my own experimental data	1	2	3
Orally presenting scientific findings reported in the literature	1	2	3

Research Skills

Developing a hypothesis based on published scientific data	1	2	3
Devising hypotheses based upon your own experimental observations	1	2	3
Designing scientific experiments to test a hypothesis	1	2	3
Performing scientific lab techniques	1	2	3
Collecting scientific data	1	2	3
Maintaining a science lab notebook	1	2	3
Analyzing scientific data	1	2	3
Conducting scientific research in an ethical manner	1	2	3
Understanding how scientists think	1	2	3
Finding relevant scientific literature using online databases such as PubMed or Google Scholar	1	2	3

Community

Working as part of a team	1	2	3

(1) Circle the category from the list that best describes your team as it applies to your research efforts:

a. Group of undergraduates
b. Undergraduate paired with a graduate student
c. Post-doc or technician
d. I worked on my project independently; however I was part of a larger research laboratory

(2) Was this experience what you expected? Yes or No

(3) Would you want to try working in a different environment? Yes or No
If "yes", which one and why?

Teaching others	1	2	3
Mentoring peers	1	2	3

Who did you teach or mentor during your research experience?

Critiquing the science work of other students	1	2	3

What types of assignments did you critique? What did you gain from this experience?

Become responsible for part of project	1	2	3

How do you think having this type of responsibility contributes to your overall undergraduate science education?

Science Confidence

Comfortable discussing scientific research	1	2	3

Whom do you feel comfortable talking to? Rank them on a scale with 1 being most comfortable and 5 (or 6 if add category by "other") being least comfortable.

___ Other undergraduates
___ Graduate students
___ Post-docs
___ Research faculty mentor
___ Other research faculty
___ Friends / peers / family
___ Other: ________________________

Comfortable with technical research skills	1	2	3

If you feel you have become more comfortable with techniques than when you started, what did you do during your research experience that helped you?

Solving scientific problems independently	1	2	3
Solving scientific problems collaboratively	1	2	3

Do you prefer to work independently or collaboratively on research projects? Why?

Part V. Quantitative Reasoning

8 Questions from ASMCUE Questionnaire

Bergevin, C. (2010) Towards improving the integration of undergraduate biology and mathematics education. *J. Microbiol. Biol. Educ.* **11**: 28–33.

Part VI: Experiences

Please provide your current level of experience at the end of this course or program.

	No experience or feel inexperienced	Little experience	Some experience	Much experience	Extensive experience or mastered this	N/A
1. Computer modeling.	1	2	3	4	5	6
2. Use of bioinformatics tools.	1	2	3	4	5	6
3. Performing quantitative analysis of data on a computer.	1	2	3	4	5	6

For each item below please rate your own agreement with the item.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A
1. These courses provided a good way to learn about the subject matter.	1	2	3	4	5	6
2. These courses provided a good way to learn about the process of scientific research.	1	2	3	4	5	6
3. These courses had a positive effect on my interest in science.	1	2	3	4	5	6
4. I was able to ask questions in these courses and get helpful responses.	1	2	3	4	5	6
5. I became more resourceful about seeking out answers to scientific questions on my own.	1	2	3	4	5	6
6. I learned to work constructively in a group.	1	2	3	4	5	6
7. I learned to work more independently on my project.	1	2	3	4	5	6

Part VII: Research Expectations

1. What did you expect to learn from your participation in this research experience? Did the program meet your expectations? Briefly explain your response.

2. Did your research project present any intellectual or technical challenges? If so, briefly explain your response.

3. In your opinion, what are three important characteristics of high quality, reliable research results? Do you feel you produced results that met these characteristics?

4. Did you make any scientific discoveries during your research experience?

5. Please describe your overall impressions of the research experience. Were there any valuable skills or abilities you developed as a result of participating in this research program? If so, briefly describe them as well as what aspect of the program helped you develop this skill or ability.

6. Based on your experience in this program, would you consider participating in other research experiences or programs at UCLA? If so, what are you considering?

Part VIII. Additional Feedback

1. Please offer any additional feedback in the space below.

Appendix 7:

Factor analysis of survey items.

Overview
Confirmatory factor analysis was conducted as previously described (Cronbach 1951, Cortina 1993, Thompson 2004) and elaborated in the text. The total sample size for the confirmatory analysis was 713, corresponding to the number of CRLC students who completed both courses of the two-term curriculum between winter 2011 and fall 2014 and who completed at least 10% of the surveys. All SLOs, using both entry and exit survey data, had Cronbach's Alpha scores ranging between 0.69 and 0.85, which were above the minimum standard cut-off of 0.6. Shown below are factor loadings for entry and exit survey data. Some survey items could be categorized into more than one SLO. Factor analysis results supported groupings as shown in the tables below. Cronbach's Alpha scores for exit survey data (**Table S10-1b**) are also listed in **Table 2** of the manuscript.

Table S7-1A. Confirmatory Factor Analysis of *Entry* Survey Items Grouped by Student Learning Outcome (SLO)

SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems (*N*=7).	Factor Loadings
Taking tests in science classes	0.71
Reading science textbooks	0.70
Understanding science class lectures	0.73
Discussing reading materials	0.79
Placing current scientific issues in historical context	0.77
Using knowledge you acquired in other courses while conducting research	0.73
Understanding primary scientific literature	0.63
Cronbach's Alpha	**0.81**
SLO 3: Develop technical expertise/confidence through hands-on experience (*N*=5).	Factor Loadings
Performing scientific lab techniques	0.63
Collecting scientific data	0.83
Maintaining a science lab notebook	0.85
Comfortable with technical research skills	0.62
Conducting scientific research in an ethical manner	0.80
Cronbach's Alpha	**0.80**
SLO 4: Develop problem-solving skills associated with conducting experiments (*N*=6).	Factor Loadings
Analyzing and solving scientific problems	0.71
Thinking through a problem or argument	0.79
Thinking creatively	0.72
Analyzing scientific data	0.49
Solving scientific problems independently	0.72
Solving scientific problems collaboratively	0.75
Cronbach's Alpha	**0.80**

SLO 5-1: Address scientific questions using inquiry-related skills (*N*=6).	Factor Loadings
Working on scientific problems sets	0.52
Analyzing data in scientific literature critically	0.69
Developing a hypothesis based on published data	0.69
Devising hypotheses based upon your own research	0.78
Designing scientific experiments to test a hypothesis	0.79
Finding relevant scientific literature using online search tools	0.71
Cronbach's Alpha	**0.77**

SLO 5-2: Address scientific questions using quantitative and computational skills (*N*=3).	Factor Loadings
Computer modeling	0.71
Use of bioinformatics tools	0.81
Performing quantitative analysis of data	0.75
Cronbach's Alpha	**0.80**

SLO 6: Improve presentation skills (oral communication needed for seminar and poster presentations) (*N*=5).	Factor Loadings
Presenting results in a science poster	0.65
Orally presenting scientific findings reporting in the literature	0.72
Orally presenting my own experimental data	0.78
Critiquing the science work of other students	0.69
Comfortable discussing scientific research	0.64
Cronbach's Alpha	**0.69**

SLO 7: Improve scientific writing abilities (writing skills needed for research proposals and papers) (*N*=4).	Factor Loadings
Writing about scientific findings reported in the literature	0.78
Writing an abstract	0.78
Writing about my own experimental results in a lab report	0.74
Writing a research proposal	0.79
Cronbach's Alpha	**0.79**

SLO 8: Effectively work in both individual and collaborative contexts (*N*=3).	Factor Loadings
Teaching others	0.76
Mentoring peers	0.85
Become responsible for part of a project	0.75
Cronbach's Alpha	**0.71**

Table S7-1B. Confirmatory Factor Analysis of *Exit* Survey Items Grouped by Student Learning Outcome (SLO)

SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems (*N*=7).	Factor Loadings
Taking tests in science classes	0.75
Reading science textbooks	0.72
Understanding science class lectures	0.82
Discussing reading materials	0.74
Placing current scientific issues in historical context	0.63
Using knowledge you acquired in other courses while conducting research	0.70
Understanding primary scientific literature	0.57
Cronbach's Alpha	**0.83**

SLO 3: Develop technical expertise/confidence through hands-on experience (*N*=5).	Factor Loadings
Performing scientific lab techniques	0.85
Collecting scientific data	0.87
Maintaining a science lab notebook	0.83
Comfortable with technical research skills	0.61
Conducting scientific research in an ethical manner	0.78
Cronbach's Alpha	**0.85**

SLO 4: Develop problem-solving skills associated with conducting experiments (*N*=6).	Factor Loadings
Analyzing and solving scientific problems	0.82
Thinking through a problem or argument	0.80
Thinking creatively	0.77
Analyzing scientific data	0.62
Solving scientific problems independently	0.67
Solving scientific problems collaboratively	0.64
Cronbach's Alpha	**0.81**

SLO 5-1: Address scientific questions using inquiry-related skills (*N*=6).	Factor Loadings
Working on scientific problems sets	0.55
Analyzing data in scientific literature critically	0.68
Developing a hypothesis based on published data	0.83
Devising hypotheses based upon your own research	0.82
Designing scientific experiments to test a hypothesis	0.77
Finding relevant scientific literature using online search tools	0.70
Cronbach's Alpha	**0.81**

SLO 5-2: Address scientific questions using quantitative and computational skills (*N*=3).	Factor Loadings
Computer modeling	0.85
Use of bioinformatics tools	0.89
Performing quantitative analysis of data	0.89
Cronbach's Alpha	**0.84**

SLO 6: Improve presentation skills (oral communication needed for seminar and poster presentations) (*N*=5).	Factor Loadings
Presenting results in a science poster	0.75
Orally presenting scientific findings reporting in the literature	0.85
Orally presenting my own experimental data	0.84
Critiquing the science work of other students	0.63
Comfortable discussing scientific research	0.69
Cronbach's Alpha	**0.80**

SLO 7: Improve scientific writing abilities (writing skills needed for research proposals and papers) (*N*=4).	Factor Loadings
Writing about scientific findings reported in the literature	0.85
Writing an abstract	0.85
Writing about my own experimental results in a lab report	0.84
Writing a research proposal	0.73
Cronbach's Alpha	**0.82**

SLO 8: Effectively work in both individual and collaborative contexts (*N*=3).	Factor Loadings
Teaching others	0.85
Mentoring peers	0.85
Become responsible for part of a project	0.66
Cronbach's Alpha	**0.70**

References

Cortina, J.M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology* **78**: 98–104.

Cronbach L.J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika* **16** (3): 297–334.

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* Washington, DC, US: American Psychological Association.

Appendix 8:

Qualitative analysis of open-ended responses.

Overview

Students were prompted to describe any valuable skills or abilities they developed as a result of participating in the research program, and to state what aspect of the program helped them develop a particular skill or ability. Of the 292 Path 1 and 141 Path 2 students who answered this question in full or in part, 232 Path 1 and 123 Path 2 students responded to the first section of the prompt, identifying "valuable skills or abilities". A smaller portion of students (*N*=63 for Path 1, *N*=47 for Path 2) went further to describe what aspect of the program helped them develop the skill or ability that they specified. Analysis of open-ended data involved an iterative, multi-step process following previously described procedures (Hammersley and Atkinson 1995, p. 210; Creswell 2009, p. 185). **Table 5** in the text summarizes student responses from the first part of the question. The following supplementary tables categorize student responses to the second section of the prompt, identifying what aspects of the program helped them develop a particular skill or ability. Following each table are samples of student responses, by path, to this multi-part, open-ended question.

Table S8-1A. Program Aspects Contributing to Skill/Ability Development for *Path 1* Students (*N*=63 [a])

Theme	**Frequency**	**Percent** [b]
Lab work or applied learning contributed to	**26**	**29.0**
- research skills	20	22.2
- independence, teamwork, dedication, perseverance	2	2.2
- unspecified or other	2	2.2
- information literacy	1	1.1
- presentation and communication skills	1	1.1
Presentations contributed to	**19**	**21.1**
- presentation and communication skills	11	12.2
- independence, teamwork, dedication, perseverance	5	5.6
- unspecified or other	3	3.3
Challenges contributed to	**18**	**20.0**
- independence, teamwork, dedication, perseverance	10	11.1
- analysis, critical thinking, thinking like a scientist	4	4.4
- research skills, lab techniques, computer skills	4	4.4
Interactions with others contributed to	**10**	**11.1**
- presentation and communication skills	2	2.2
- independence, teamwork, dedication, perseverance	2	2.2
- unspecified or other	2	2.2
- analysis, critical thinking, thinking like a scientist	1	1.1
- research skills, lab techniques, computer skills	1	1.1
- scientific knowledge (topical, general, field-specific)	1	1.1
- writing skills	1	1.1

Independent learning or course structure contributed to	**7**	**7.8**
- independence, teamwork, dedication, perseverance	3	3.3
- analysis, critical thinking, thinking like a scientist	2	2.2
- research skills, lab techniques, computer skills	2	2.2
Writing or peer review of writing contributed to	**7**	**7.8**
- writing skills	4	4.4
- analysis, critical thinking, thinking like a scientist	2	2.2
- research skills, lab techniques, computer skills	1	1.1

[a] There may be multiple responses per student. [b] Percent of all responses (*N*=90), rounded to nearest tenth.

Sample Student Responses for Path 1

Research Skills, Lab Techniques, Computer Skills

- … I gained a lot of experience in dealing with technical issues, performing experimental procedures, and working in a lab. Going through the procedure throughout the two courses let me understand the process better and has helped me in my own research.
- … I learned many techniques that I only knew the name of but never really understood. Such as PCR or plaque assays.
- [Working] in the lab on a weekly basis greatly allowed me to feel more comfortable in that environment and taught me scientific techniques and methods.
- I loved the wet lab and learned a lot from it (methods, techniques, analyzing data, notebook organization).
- The program is really good for providing hands on experience in conjunction with material that is often learned in other class lectures.

Independence; teamwork; dedication, perseverance

- I learned a lot about teamwork and the long hours that go into producing a single smidgeon of data. Research has a lot to do with pure grit.
- It is very stressful, but I learned how to deal with stress efficiently and how to work through it.
- I learned that research is a lot about patience and persistence. I have really developed these skills but I really need to work on my focus if I plan to excel as a researcher.
- It was definitely an interesting course and I got valuable experience working with peers and taking time step-by-step to work towards and end goal.
- Some valuable skills that I developed as a result of participating in this research program were the abilities to work collaboratively and efficiently in a group setting.

Presentation and Communication Skills

- I felt that the many presentations and most importantly the journal club presentations really helped me become more confident and improve my presentation skills. Although it was a daunting task, the reward was definitely worth it.
- I strongly developed my speaking skills, particularly with presenting PowerPoints to the class. Having to present the journal club article helped me greatly.
- Yes, gained a lot of skill in public speaking/ delivering presentations, working hard to generate and clearly explain results.
- Presenting our work and other primary sources helped with learning how to use PowerPoint and being able to talk about science in front of an audience and tackle their questions.

Analysis, Critical Thinking, Thinking Like a Scientist

- This was the only class I had at UCLA which kept me on my toes to analyze results I obtained rather than just simply to accept them.
- I think this program was very valuable. It taught me how to analyze scientific literature and form my own questions about things presented to me.
- I really appreciated the course. It was more than a research experience. I felt as if it helped me grow as a scientist.
- It is a stressful, strenuous, experience that makes you strain your brain for answers to problems not fully understood. And it's amazing and I would do it again. The skills gained were applicable to every part of life.

Writing Skills

- [I gained] a better understanding of the process of writing a scientific paper and communicating results and findings to other scientist/individuals…
- [It] gave me experience with doing journal club presentations, and presenting our research, and writing a final manuscript that's comprehensive with all the things we did during the quarter.

Multiple Skills and Abilities

- I can confidently say that I am more skilled at critical thinking and at performing the practical scientific techniques expected of life science major undergraduates. I enjoyed the vast array of techniques, procedures, and levels of analysis compacted into course. I know the application of PCR, how to analyze a gel, clone a PCR'ed product into *E. coli*, and culture bacteria. The entire program forced me to develop these skills and think about the reasoning behind each one.
- I learned how to do PCRs, run gels, do restriction digests, RT-PCRs... I think the biggest skill I gained was putting all of this information together and understanding how each prior step was connected to the future steps.
- Not only did I learn various research techniques, but was also able to refine my skills in public speaking, critical thinking, problem solving, and working within a team.
- I learned how to think critically, interpret results in different ways, give effective presentations, just to mention a few. The fact that the program 'forced' us to think outside the box, just because we didn't know what any of the outcomes would be, pushed us to our utmost potential.

Table S8-1B. Program Aspects Contributing to Skill/Ability Development for *Path 2* Students (N=47 [a])

Theme	Frequency	Percent [b]
Presentations contributed to	**21**	**25.6%**
- presentation and communication skills	9	11.0%
- analysis, critical thinking, thinking like a scientist	5	6.1%
- scientific knowledge (topical, general , field)	3	3.7%
- research skills, lab techniques, computer skills	2	2.4%
- information literacy	1	1.2%
- unspecified or other	1	1.2%
Interactions with others contributed to	**16**	**19.5%**
- analysis, critical thinking, thinking like a scientist	4	4.9%
- research skills, lab techniques, computer skills	3	3.7%
- independence, teamwork, dedication, perseverance	3	3.7%
- presentation and communication skills	2	2.4%
- writing skills	2	2.4%
- information literacy	1	1.2%
- unspecified or other	1	1.2%
Lab work or applied learning contributed to	**14**	**17.1%**
- research skills	8	9.8%
- analysis, critical thinking, thinking like a scientist	2	2.4%
- independence, teamwork, dedication, perseverance	2	2.4%
- unspecified or other	1	1.2%
- writing skills	1	1.2%
Writing or peer review of writing contributed to	**9**	**11.0%**
- writing skills	3	3.7%
- analysis, critical thinking, thinking like a scientist	2	2.4%
- information literacy	1	1.2%
- presentation and communication skills	1	1.2%
- research skills, lab techniques, computer skills	1	1.2%
- scientific knowledge (topical, general , field)	1	1.2%
Independent learning or course structure contributed to	**8**	**9.8%**
- research skills, lab techniques, computer skills	2	2.4%
- unspecified or other	2	2.4%
- analysis, critical thinking, thinking like a scientist	1	1.2%
- independence, teamwork, dedication, perseverance	1	1.2%
- presentation and communication skills	1	1.2%
- writing skills	1	1.2%

[a] There may be multiple responses per student. [b] Percent of all responses (N=82), rounded to nearest tenth.

Sample Student Responses for Path 2

Presentation and Communication Skills

- I really liked this research experience because it taught me how to present my research in different aspects: poster, PowerPoint, and through writing.
- The presentations we had to give and the papers we had to write gave me a lot of insight into how to convey my ideas, and later my results, properly.
- Being able to explain my research project to others is one really valuable skill I've gained. Presenting to the class really helped me develop this.
- Definitely learned how to orally present my research project in a concise and clear manner.
- One valuable skill I developed is how to present research. Mainly, it was [instructor's] feedback and criticism that allowed me to pinpoint the areas of weakness in my presentation style. For example, [s/he] taught me how to present a message and to stick with the flow of that message smoothly throughout the entire talk.
- The most valuable skills I picked up were communication skills, including class presentations, presenting at group meetings, and meeting with collaborators.
- I learned how to effectively communicate scientific knowledge with others. This was huge for me as it allowed me to really break things down and make them digestible for others.

Analysis, Critical Thinking, Thinking Like a Scientist

- I have learned how to think more critically and ask more relevant questions, and this has come from listening to my classmates' presentations.
- Problem-solving skills were developed. Analytical reading of research papers improved, [as did] thinking outside of the box in terms of the application of my project to other topics. The class discussions and presentation (especially) contributed to this development.
- The professors were both amazing and the questions they asked during each of the presentations really allowed for me to think more critically about each student's research project (including my own).
- I learned how to think more critically, as result interpretation really forced me to think about why I got the results I did.
- Incredibly valuable class that is unlike any other offered through UCLA. Learned not to take data/punchlines at face value, and instead analyze them critically.
- I think I have come away with thinking critically and not just taking things for face value. Reading papers and seeing how people's current projects question many of the fundamental claims has helped that.
- I think I developed mentally as a scientist a lot. Thanks to having more independence on my project, I was able to think through my experiments and overcome any challenges.
- I learned to be creative in thinking about problems and looking at issues from multiple angles.

Research Skills, Lab Techniques, Computer Skills

- I learned many new molecular biology and biochemical techniques from my research mentor as well as from my peers during their in-class presentations. The program exposed us to what other students are doing in their laboratories. It was interesting to see the vast array of techniques available that are different from the ones I know.
- Yes. I learned how to further design and execute experiments on my own. The program helped me by exposing me to how other scientists do this and by giving me the opportunity to do this myself.
- Everything I've learned is valuable--lab techniques/methods, how to develop good controls, etc...
- Yes, [I] learned how to conduct research. The program allowed me to gain a better understanding of the process, as well as the meticulous nature one must adopt in order to be effective and efficient.

Writing Skills

- Everything was really helpful, most of all the design of a research paper based on research performed. The interaction with classmates and instructor helped to support this.
- I learned how to write an article of publishable quality.
- I think this course helped me write a better and more full scientific report and give a more complete presentation.

Multiple Skills and Abilities

- I developed my public speaking skills through the project and poster presentations I did. I learned to work cooperatively as part of a research team, through the partner-based research curriculum and through sharing information with my fellow colleagues. I learned to think critically and to analyze primary literature as part of my research. I developed my writing skills due to having to write a comprehensive research report and undergo peer review just like a scientific paper entails. These skills and abilities will help me in my future endeavors in graduate school.
- I really have gained a better respect for the scientific process. I have learned so many valuable skills, such as learning how to read scientific papers, learning how to articulate my knowledge to my peers, and learning how to think outside of the box in order to solve problems.
- It's an excellent class, I learned a lot about how to carry out scientific research, poster, presentation, and how to write scientific report. Moreover, the discussion atmosphere was great.
- Overall I was impressed with the quality of my research experience. I gained valuable training in various research techniques such as tissue culturing, siRNA transfections and qPCR. In addition, I was able to improve my scientific writing and presenting abilities.

References

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Hammersley, M., & Atkinson, P. (1995). *Ethnography: Principles in practice* (2nd ed.). New York: Routledge.

Appendix 9:

Presentation rubrics.

Overview
A total of four rubrics were used in the evaluation of embedded students assignments, detailed as follows:

APPENDIX 9.1: Path 1 Presentation Rubric for Course AL

APPENDIX 9.1: Path 1 Presentation Rubric for Course BL

APPENDIX 9.3: Path 2 Presentation Rubric for Course AS

APPENDIX 9.4: Path 2 Presentation Rubric for Course BS

Each rubric item was classified according to Bloom's Taxonomy as either higher order cognitive skills (HOCS) or lower order cognitive skill (LOCS) (Anderson and Krathwohl 2001, Crowe et al. 2008). Rubric items also were grouped by CRLC-specific student learning outcomes (SLOs).

References

Anderson LW, Krathwohl DR, Airasian PW, Cruikshank KA, Mayer RE, Pintrich PR, Raths J, and Wittrock MC (2001). *A Taxonomy for Learning, Teaching, and Assessing – A Revision of Bloom's Taxonomy of Educational Objectives.* Abridged Ed., Addison Wesley Longman, Inc., New York, NY.

Crowe A, Dirks C, and Wenderoth MP (2008) Biology in Bloom: Implementing Bloom's Taxonomy to Enhance Student Learning in Biology. *CBE-Life Sci Educ* 7: 368-381

APPENDIX 9.1: Path 1 Presentation Rubric for Course AL

SLO	Indicator	Bloom's Category	Needs Work 1	Satisfactory 2	Excellent 3	Score
			Student Performance			
SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems	Describe background information that is relevant to project.	LOCS	Missing several key points about the organism or experimental system.	Lacking a few details about the organism or experimental system.	Concisely summarize information about the organism(s) or experimental system	
		LOCS	Insufficient number of citations describing the history of discovery or establishment of techniques or research strategies used in the project.	A minimal but sufficient number of references are cited but no additional effort made to incorporate literature in broader scope.	Extensively incorporate primary literature describing the history of discovery and the establishment of techniques or research strategies used in the project (What has been done in the field? How did the discipline get here? Cite references).	
					TOTAL:	
SLO 2: Demonstrate knowledge of research project	Discuss "big picture" research question being addressed by the project.	LOCS	Question or problem not stated.	Question or problem stated but vague.	Scientific merit: Clearly state research question or problem.	
		HOCS	Significance not addressed.	Significance of the research question or problem not obvious.	Scientific merit: Establish **significance** of the research question or problem (Why are <u>scientists</u> motivated to study the research question?).	
		HOCS	Do not establish how project impacts society or daily lives.	Attempt to address how project impacts society or daily lives.	Broader impacts: Address **relevance** of the research project; connect project to needs of society (How does this project potentially impact society? Our daily lives? Who benefits?).	
	State project goal(s).	LOCS	Project goal not stated.	Project goal stated but not obvious how it relates to research question or problem.	Clearly state the goals of the project as it relates to the research question or problem.	
	Devise experimental approach.	LOCS	Plan not provided	Plan provided but confusing or some are missing.	What did student do? Outline project plan designed to test hypothesis or address research question	
		LOCS	No attempt made to break down experimental approach into steps	Break down steps in project plan, but lack sufficient procedural detail.	How did student do it? Break down steps in project plan, incorporating experimental detail for key steps that accomplish task.	
		HOCS	Relationship not stated.	Relationship vague.	Why did student do it? Provide rationale for key experimental steps in project plan.	

APPENDIX 9.1: Path 1 Presentation Rubric for Course AL

SLO	Indicator	Bloom's Category	Student Performance			
			Needs Work 1	Satisfactory 2	Excellent 3	Score
		HOCS	No outcomes stated.	Expected outcomes stated but not clear how they relate to hypothesis/question/ problem.	What outcomes are expected if experiment goes as planned? State expected results and how an outcome relates to hypothesis or research question/problem.	
					TOTAL:	
SLO 4: Develop problem-solving skills associated with conducting experiments	Critically think through experimental approaches.	LOCS	Do not discuss what experimental steps could go wrong or what procedure may not work as expected	Incomplete discussion about experimental steps that could go wrong or what procedure may not work as expected	What went wrong? Discuss what experimental steps went wrong or what procedures did not work as expected.	
		HOCS	Troubleshooting and optimization efforts not stated or described completely.	Troubleshooting and optimization efforts acknowledged but insufficient explanation or justification provided.	How solve the problem? Describe **troubleshooting** efforts and optimization procedures.	
		HOCS	No explanation provided.	Provide explanations but evidence may not be from a sufficiently reliable source or rationale may not be compelling.	Why did the experiment go wrong? Provide possible explanations for protocol deviations or optimization efforts based on evidence (literature cited) or a sound scientific rationale (observations, deductive reasoning).	
					TOTAL:	
SLO 5: Address scientific questions using quantitative, computational, and inquiry-related skills	Generate an original hypothesis.	HOCS	Hypothesis not stated or may be confused with goals; no measurable outcomes stated	Hypothesis stated but not well developed (vague); not obviously connected to measurable outcomes	Hypothesis explicitly stated (well thought out, highly developed, engaging and interesting; incorporates measurable outcomes)	
		HOCS	No rationale provided for hypothesis	Inappropriate literature or superfluous lab observations used as rationale	Use literature (citations evident) or observations in lab as rationale	
		LOCS	Hypothesis not testable	Testable hypothesis by current technologies but not with resources available in research lab	Testable hypothesis using resources in research lab	
	Analyze data.	HOCS	Quality of analysis poor or not done.	Unbalanced reporting of quantitative and qualitative data	Report data **quantitatively** (numerical values, statistics) and **qualitatively** (images).	
	Interpret and discuss results.	HOCS	No summary provided (per individual slide or a final summary slide).	Summary missing some key points or includes excessive or unrelated (irrelevant) information.	Concisely & insightfully summarize trends/patterns from graph/table or datasets	
		HOCS	Do not identify key results	Discuss results but do not distinguish between the most important findings and extraneous data	Present relevant data and key results; do not focus on extraneous data	

APPENDIX 9.1: Path 1 Presentation Rubric for Course AL

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
		HOCS	No **comparison** made between data and controls, standard thresholds, and/or statistical significance on few or no experiments	**Relationship** between data and controls, standard thresholds, and/or statistical significance not addressed for most, if not all, experiments.	Make apparent the relationship between data and **controls**, standard **thresholds**, and/or **statistical significance**.	
SLO 5 (Cont.): Address scientific questions using quantitative, computational, and inquiry-related skills	Understand significance of results (scientific merit).	HOCS	Do not relate the results to original hypothesis or research question	Attempt to connect the results to original hypothesis or research question but relationship unsubstantiated by the results or not clear	Relate the results to aspects of the original hypothesis (support? refute?) or research question.	
		LOCS	Do not recognize discoveries as novel or results as interesting or fail to point out relationship of results to previous findings	Discoveries, interesting results, or results consistent with previous findings are mentioned but discussion not well developed	Recognize discoveries as novel or results as interesting or point out results support previous findings	
		HOCS	Not clear student understands next steps in project plan	Future directions stated but little creative thought incorporated into project plans.	State next steps in the experimental plan (future directions); both immediate (BL) and longer term plans (post-course) mentioned using creative license	
					TOTAL	
SLO 6: Improve presentation skills (Seminar and Poster presentations, oral communication¶)	Incorporate style and format guidelines of a professional presentation into visual display (slides) of research project.	LOCS	Physical appearance of slides make text and images difficult to read or view properly	Some improvements to color selection could be made but overall layout good	Use pleasing color scheme and effective layout (easy to read, good contrast and spacing of text & images)	
		HOCS	Content poorly organized and presented in lengthy, illogical progression	Content generally well-organized and concise but order and length of some slides could be improved	Content well-organized, concise, and presented in logical progression	
		LOCS	Use non-sans-serif font and small type; most slides need improvement	Inconsistent use of sans-serif font but type size ok; only some slides need improvement	Use sans-serif font of appropriate size for all text (18 pt type or larger)	
		LOCS	Do not use headings and most titles do not reflect slide content accurately.	Use headings for slides but some titles not informative or reflecting slide content accurately or effectively	Use appropriate & descriptive headings, clearly delineating slides with informative titles that accurately reflect content.	
		LOCS	Use low-quality figures (images pixilated, font too small, no size bars included, labels missing, panels misaligned)	Inconsistent quality for figures (some images too small, some pixilated due to improper sizing efforts, some labels too small or missing, some missing size bars, some panels not aligned properly)	Incorporate high-quality figures, tables, and graphs (proper resolution & size; images not pixilated, image labels not too small, include size bars, panels aligned properly)	
	¶ Oral communication skills will be evaluated using independent scoring form.				**TOTAL:**	

APPENDIX 9.1: Path 1 Presentation Rubric for Course AL

SLO	Indicator	Bloom's Category	Student Performance			
			Needs Work **1**	**Satisfactory** **2**	**Excellent** **3**	**Score**
SLO 8: Effectively work in both individual and collaborative contexts	Create a cohesive team presentation.	LOCS	Organization illogical or incoherent and style, format and tone inconsistent because no obvious collaboration took place when putting presentation together; quality differs depending on individual student contribution.	Presentation requirements generally are met but slides reflect distinct styles indicative of individual efforts rather than a cohesive team effort.	Slides are cohesive; entire presentation has same style (writing and graphics), format, tone, and organization (consistent look/flow); not obvious that different sections made by different students in a team.	
					TOTAL:	

APPENDIX 9.2: Path 1 Presentation Rubric for Course BL

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems	Describe background information that is relevant to project.	LOCS	Missing several key points about the organism or experimental system.	Lacking a few details about the organism or experimental system.	Concisely summarize information about the organism(s) or experimental system.	
		LOCS	Insufficient number of citations describing the history of discovery or establishment of techniques or research strategies used in the project.	A minimal but sufficient number of references are cited but no additional effort made to incorporate literature in broader scope.	Extensively incorporate primary literature describing the history of discovery and the establishment of techniques or research strategies used in the project (What has been done in the field? How did the discipline get here? Cite references).	
					TOTAL:	
SLO 2: Demonstrate knowledge of research project	Discuss "big picture" research question being addressed by the project.	LOCS	Question or problem not stated.	Question or problem stated but vague.	Scientific merit: Clearly state research question or problem.	
		HOCS	Significance not addressed.	Significance of the research question or problem not obvious.	Scientific merit: Establish **significance** of the research question or problem (Why are scientists motivated to study the research question?).	
		HOCS	Do not establish how project impacts society or daily lives.	Attempt to address how project impacts society or daily lives.	Broader impacts: Address **relevance** of the research project; connect project to needs of society (How does this project potentially impact society? Our daily lives? Who benefits?).	
	State project goal(s).	LOCS	Project goal not stated.	Project goal stated but not obvious how it relates to research question or problem.	Clearly state the goals of the project as it relates to the research question or problem.	
	Devise experimental approach.	LOCS	Plan not provided	Plan provided but confusing or some are missing.	What did student do? Outline project plan designed to test hypothesis or address research question	
		LOCS	No attempt made to break down experimental approach into steps	Break down steps in project plan, but lack sufficient or accurate procedural detail.	How did student do it? Break down steps in project plan, incorporating experimental detail for key steps that accomplish task (identify bioinformatics programs correctly).	
		HOCS	Relationship not stated.	Relationship vague.	Why did student do it? Provide rationale for key experimental steps in project plan.	

APPENDIX 9.2: Path 1 Presentation Rubric for Course BL

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
		HOCS	No outcomes stated.	Expected outcomes stated but not clear how they relate to hypothesis/ question/ problem.	What outcomes are expected if experiment goes as planned? State expected results and how an outcome relates to hypothesis or research question/problem.	
					TOTAL:	
SLO 4: Develop problem-solving skills associated with conducting experiments	Critically think through experimental approaches.	LOCS	Do not discuss what experimental steps could go wrong or what procedure may not work as expected	Incomplete discussion about experimental steps that could go wrong or what procedure may not work as expected	What went wrong? Discuss what experimental steps went wrong or what procedures did not work as expected.	
		HOCS	Troubleshooting and optimization efforts not stated or described completely.	Troubleshooting and optimization efforts acknowledged but insufficient explanation or justification provided.	How solve the problem? Describe **troubleshooting** efforts and optimization procedures.	
		HOCS	No explanation provided.	Provide explanations but evidence may not be from a sufficiently reliable source or rationale may not be compelling.	Why did the experiment go wrong? Provide possible explanations for protocol deviations or optimization efforts based on evidence (literature cited) or a sound scientific rationale (observations, deductive reasoning).	
					TOTAL:	
SLO 5: Address scientific questions using quantitative, computational, and inquiry-related skills	Generate an original hypothesis.	HOCS	Hypothesis not stated or may be confused with goals; no measurable outcomes stated	Hypothesis stated but not well developed (vague); not obviously connected to measurable outcomes	Hypothesis explicitly stated (well thought out, highly developed, engaging and interesting; incorporates measurable outcomes)	
		HOCS	No rationale provided for hypothesis	Inappropriate literature or superfluous lab observations used as rationale	Use literature (citations evident) or observations in lab as rationale	
		LOCS	Hypothesis not testable	Testable hypothesis by current technologies but not with resources available in research lab	Testable hypothesis using resources in research lab	
	Analyze **AL** data.	HOCS	Quality of analysis poor or not done.	Unbalanced reporting of quantitative and qualitative data; missing required components of dataset.	Report data **quantitatively** (numerical values, statistics) and **qualitatively** (images).	
	Analyze **BL** data.	HOCS	Quality of analysis poor or not done.	Unbalanced reporting of quantitative and qualitative data; missing required components of dataset.	Report data **quantitatively** (numerical values, statistics) and **qualitatively** (images).	

APPENDIX 9.2: Path 1 Presentation Rubric for Course BL

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
		HOCS	Insufficient breath of bioinformatics tools employed in the analysis; not using online resources to fullest extent.	Incorporate required bioinformatics tools and computational strategies into data analysis (genome maps, statistics, dot plots, gene list, phylogenetic tree).	Demonstrates initiative by supplementing required analysis with additional bioinformatics tools and computational strategies (gene function pie charts).	
SLO 5 (Cont.): Address scientific questions using quantitative, computational, and inquiry-related skills	Interpret and discuss results.	HOCS	No summary provided (per individual slide or a final summary slide).	Summary missing some key points or includes excessive or unrelated (irrelevant) information.	Concisely & insightfully summarize trends/patterns from graph/table or datasets	
		HOCS	Do not identify key results	Discuss results but do not distinguish between the most important findings and extraneous data	Present relevant data and key results; do not focus on extraneous data	
		HOCS	No **comparison** made between data and controls, standard thresholds, and/or statistical significance on few or no experiments	**Relationship** between data and controls, standard thresholds, and/or statistical significance not addressed for most, if not all, experiments.	Make apparent the relationship between data and **controls** (reference genomes), standard **thresholds**, and/or **statistical significance**.	
	Understand significance of results (scientific merit).	HOCS	Do not relate the results to original hypothesis or research question	Attempt to connect the results to original hypothesis or research question but relationship unsubstantiated by the results or not clear	Relate the results to aspects of the original hypothesis (support? refute?) or research question.	
		LOCS	Do not recognize discoveries as novel or results as interesting or fail to point out relationship of results to previous findings	Discoveries, interesting results, or results consistent with previous findings are mentioned but discussion not well developed	Recognize discoveries as novel or results as interesting or point out results support previous findings	
		HOCS	Not clear student understands next steps in project plan	Future directions stated but little creative thought incorporated into project plans.	State next steps in the experimental plan (future directions); immediate and longer term plans mentioned using creative license.	
					TOTAL:	

APPENDIX 9.2: Path 1 Presentation Rubric for Course BL

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
SLO 6: Improve presentation skills (Seminar and Poster presentations, oral communication¶)	Incorporate style and format guidelines of a professional presentation into visual display (slides) of research project.	LOCS	Physical appearance of slides make text and images difficult to read or view properly	Some improvements to color selection could be made but overall layout good	Use pleasing color scheme and effective layout (easy to read, good contrast and spacing of text & images)	
		HOCS	Content poorly organized and presented in lengthy, illogical progression	Content generally well-organized and concise but order and length of some slides could be improved	Content well-organized, concise, and presented in logical progression	
		LOCS	Use non-sans-serif font and small type; most slides need improvement	Inconsistent use of sans-serif font but type size ok; only some slides need improvement	Use sans-serif font of appropriate size for all text (18 pt type or larger)	
SLO 6 (Cont.): Improve presentation skills (Seminar and Poster presentations, oral communication¶)	Incorporate style and format guidelines of a professional presentation into visual display (slides) of research project.	LOCS	Do not use headings and most titles do not reflect slide content accurately.	Use headings for slides but some titles not informative or reflecting slide content accurately or effectively	Use appropriate & descriptive headings, clearly delineating slides with informative titles that accurately reflect content.	
		LOCS	Use low-quality figures (images pixilated, font too small, no size bars included, labels missing, panels misaligned)	Inconsistent quality for figures (some images too small, some pixilated due to improper sizing efforts, some labels too small or missing, some missing size bars, some panels not aligned properly)	Incorporate high-quality figures, tables, and graphs (proper resolution & size; images not pixilated, image labels not too small, include size bars, panels aligned properly)	
	¶ Oral communication skills will be evaluated using independent scoring form. Above criteria apply to format and style of slides itself.				**TOTAL:**	

APPENDIX 9.2: Path 1 Presentation Rubric for Course BL

SLO	Indicator	Bloom's Category	Student Performance			
			Needs Work 1	**Satisfactory** 2	**Excellent** 3	**Score**
SLO 8: Effectively work in both individual and collaborative contexts	Create a cohesive team presentation.	LOCS	Organization illogical or incoherent and style, format and tone inconsistent because no obvious collaboration took place when putting presentation together; quality differs depending on individual student contribution.	Presentation requirements generally are met but slides reflect distinct styles indicative of individual efforts rather than a cohesive team effort.	Slides are cohesive; entire presentation has same style (writing and graphics), format, tone, and organization (consistent look/flow); not obvious that different sections made by different students in a team.	
					TOTAL:	

Appendix 9.3: Path 2 Presentation Rubric for Course AS

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems	Describe background information that is relevant to project.	LOCS	Missing several key points about the organism or experimental system.	Lacking a few details about the organism or experimental system.	Adequate overview of information about the organism(s) or experimental system	
		LOCS	Does not include information about gene(s) or pathway	Information missing for some of the gene(s) or steps in a pathway	Provide introduction about gene(s) or pathway	
		HOCS	No connection established between the research question or problem and the background information.	Connection between research question or problem and background information not strongly established.	Make obvious connection between the research question or problem and the background information.	
		LOCS	Insufficient number of citations describing the history of discovery or establishment of techniques or research strategies used in the project.	A minimal but sufficient number of references are cited but no additional effort made to incorporate literature in broader scope.	Extensively incorporate primary literature describing the history of discovery and the establishment of techniques or research strategies used in the project (What has been done in the field? How did the discipline get here?).	
					TOTAL:	
SLO 2: Demonstrate knowledge of research project	Discuss "big picture" research question being addressed by the project.	LOCS	Question or problem not stated.	Question or problem stated but vague.	Scientific merit: Clearly state research question or problem.	
		HOCS	Significance not addressed.	Significance of the research question or problem not obvious.	Scientific merit: Establish **significance** of the research question or problem (Why are scientists motivated to study the research question?).	
		HOCS	Do not establish how project impacts society or daily lives.	Attempt to address how project impacts society or daily lives.	Broader impacts: Address **relevance** of the research project; connect project to needs of society (How does this project potentially impact society? Our daily lives? Who benefits?).	
	State project goal(s).	LOCS	Project goal not stated.	Project goal stated but not obvious how it relates to research question or problem.	Clearly state the goals of the project as it relates to the research question or problem.	
	Devise specific aims of student project.	LOCS	Aims not stated	Aims stated but confusing, vague, or some are missing.	Show clear list of aims designed to test hypothesis or address research goals	

Appendix 9.3: Path 2 Presentation Rubric for Course AS

SLO	Indicator	Bloom's Category	Needs Work 1	Satisfactory 2	Excellent 3	Score
			Student Performance			
		HOCS	No attempt made to relate experimental approach to the specific aims	Not clear how experimental approach relates to specific aims	Incorporate experimental approaches designed to address specific aims.	
					TOTAL:	
SLO 5: Address scientific questions using quantitative, computational, and inquiry-related skills	Generate an original hypothesis.	HOCS	Hypothesis not stated or only implied	Hypothesis stated but not well developed or relevant; may be confused with specific aims	Hypothesis explicitly stated (well thought out, highly developed, engaging and interesting; not confused with specific aims, based on literature or observations in lab)	
		LOCS	No outcomes stated	Predicted outcomes stated but not directly addressing hypothesis	Predict outcomes if results support hypothesis	
	Analyze data.	LOCS	No data shown or figures/tables selected for presentation not relevant or important.	Data comes from only one source	Show relevant data from 2-3 sources (self-generated or from 2-3 scientific papers).	
		LOCS	No summary provided on any data slides.	Summary missing on some slides or some key points not stated or slide includes excessive or unrelated (irrelevant) information.	Concisely & insightfully summarize trends/patterns from graph/table on every slide (Is the key result highlighted in slide title? Are there bullet points breaking down complex figures?)	
	Interpret and discuss results.	LOCS	No summary provided.	Summary missing some of the key points from data analysis or includes excessive, wordy detail.	Summary slide includes take-home messages concisely surmised from analysis of data	
		HOCS	Do not discuss key results	Discuss results but do not distinguish between the most important findings and extraneous data	Discuss key results; do not focus on extraneous data	
		HOCS	Interpretation not supported by relationship between data and controls, standard thresholds on any experiment	Meaning for most experiments is inferred based the relationship between data and controls, standard thresholds (Did they make sense of the data?)	Meaning for all experiments is inferred based the relationship between data and controls, standard thresholds (Did they make sense of the data?)	
					TOTAL:	

Appendix 9.3: Path 2 Presentation Rubric for Course AS

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
SLO 6: Improve presentation skills (Seminar and Poster presentations, oral communication¶)	Incorporate style and format guidelines of a professional presentation into visual display (slides) of research project.	LOCS	Physical appearance of slides make text and images difficult to read or view properly	Some improvements to color selection could be made but overall layout good	Use pleasing color scheme and effective layout (easy to read, good contrast and spacing of text & images)	
		HOCS	Content poorly organized and presented in lengthy, illogical progression	Content generally well-organized and concise but order and length of some slides could be improved	Content well-organized, concise, and presented in logical progression	
		LOCS	Use non-sans-serif font and small type; most slides need improvement	Inconsistent use of sans-serif font but type size ok; only some slides need improvement	Use sans-serif font of appropriate size for all text (18 pt type or larger)	
		LOCS	Do not use headings or most titles do not reflect slide content accurately.	Use headings for slides but some titles not informative or reflecting slide content accurately or effectively	Use appropriate & descriptive headings, clearly delineating slides with informative titles that accurately reflect content.	
		LOCS	Use low-quality figures (images pixilated, font too small, labels missing, panels misaligned)	Inconsistent quality for figures (some images too small, some pixilated due to improper sizing efforts, some labels too small or missing, some panels not aligned properly)	Consistently incorporates high-quality figures, tables, and graphs (proper resolution & size; images not pixilated, image labels not too small, panels aligned properly)	
	¶ Oral communication skills will be evaluated using independent scoring form.				**TOTAL:**	

APPENDIX 9.4: Path 2 Presentation Rubric for Course BS

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
SLO 1: Demonstrate knowledge of key disciplinary concepts and their relationship to biological systems	Describe background information that is relevant to project.	LOCS	Missing several key points about the organism or experimental system.	Lacking a few details about the organism or experimental system.	Adequate overview of information about the organism(s) or experimental system	
		LOCS	Does not include information about gene(s) or pathway	Information missing for some of the gene(s) or steps in a pathway	Provide introduction about gene(s) or pathway	
		HOCS	No connection established between research question and the background information.	Connection between research question and background information not strongly established.	Make obvious connection between the research question and background information.	
		LOCS	No background citations provided.	Some background citations missing	All background information is properly cited	
					TOTAL:	
SLO 2: Demonstrate knowledge of research project	Discuss "big picture" research question being addressed by the project.	LOCS	Question or problem not stated.	Question or problem stated but vague.	Clearly state research question or problem.	
		HOCS	Significance not addressed.	Significance of the research question or problem not obvious.	Establish significance of the research question or problem (Why is it important? Why are scientists motivated to study the research question?).	
		HOCS	Do not establish how project impacts modern science, society or daily lives.	Attempt to address how project impacts modern science, society or daily lives.	Address broader impacts of the project by showing relevance of the research question or problem (How would answering this question or addressing this problem potentially impact modern science? Society? Our daily lives?).	
	State project goal(s).	LOCS	Project goal not stated.	Project goal stated but not obvious how it relates to research question or problem.	Clearly state the overall goal of the project as it relates to the research question or problem.	

APPENDIX 9.4: Path 2 Presentation Rubric for Course BS

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
	Devise specific aims of student project.	LOCS	Aims not stated	Aims stated but confusing, vague, or some are missing.	Show clear list of aims designed to test hypothesis or address research question	
		HOCS	No attempt made to relate experimental approach to the specific aims	Not clear how experimental approach relates to specific aims	Incorporate experimental approaches designed to address specific aims.	
					TOTAL:	
SLO 5: Address scientific questions using quantitative, computational, and inquiry-related skills	Generate an original hypothesis.	HOCS	Hypothesis not stated or only implied	Hypothesis stated but not well developed or relevant; may be confused with specific aims	Hypothesis explicitly stated (well thought out, highly developed, engaging and interesting; not confused with specific aims, based on literature or observations in lab)	
		LOCS	No outcomes stated	Predicted outcomes stated but not directly addressing hypothesis	Predict outcomes if results support hypothesis	
	Analyze data.	LOCS	No data shown or figures/tables selected for presentation not relevant or important.	Data shown but not necessarily highlighting key experiments or findings	How relevant data (self-generate or from scientific papers).	
		LOCS	No summary provided on any data slides.	Summary missing on some slides or some key points not stated or slide includes excessive or unrelated (irrelevant) information.	Concisely & insightfully summarize trends/patterns from graph/table on every slide (Is the key result highlighted in slide title? Are there bullet points breaking down complex figures?)	
		HOCS	Quality of analysis poor or not done.	Unbalanced reporting of quantitative and qualitative data	Report data quantitatively (numerical values, statistics) and qualitatively (trends).	
	Interpret and discuss results.	LOCS	No summary provided.	Summary missing some of the key points from data analysis or includes excessive, wordy detail.	Summary slide includes take-home message concisely surmised from analysis of data	
		HOCS	Do not identify key results	Discuss results but do not distinguish between the most important findings and extraneous data	Present key results; do not focus on extraneous data	

APPENDIX 9.4: Path 2 Presentation Rubric for Course BS

SLO	Indicator	Bloom's Category	Student Performance: Needs Work 1	Satisfactory 2	Excellent 3	Score
		HOCS	Interpretation not supported by relationship between data and controls, standard thresholds on any experiment	Meaning for most experiments is inferred based on the relationship between data and controls, standard thresholds (Did they make sense of the data?)	Meaning for all experiments is inferred based on the relationship between data and controls, standard thresholds (Did they make sense of the data?)	
	Understand significance of results.	HOCS	Do not relate the results to original hypothesis or research question	Attempt to connect the results to original hypothesis or research question but relationship unsubstantiated by the results or not clear	Relate the results to original hypothesis (support? refute?) or research question.	
					TOTAL:	
SLO 6: Improve presentation skills (Seminar and Poster presentations, oral communication¶)	Incorporate style and format guidelines of a professional presentation into visual display (slides) of research project.	LOCS	Physical appearance of slides make text and images difficult to read or view properly	Some improvements to color selection could be made but overall layout good	Use pleasing color scheme and effective layout (easy to read, good contrast and spacing of text & images)	
		HOCS	Content poorly organized and presented in lengthy, illogical progression	Content generally well-organized and concise but order and length of some slides could be improved	Content well-organized, concise, and presented in logical progression	
		LOCS	Use non-sans-serif font and small type; most slides need improvement	Inconsistent use of sans-serif font but type size ok; only some slides need improvement	Use sans-serif font of appropriate size for all text (18 pt type or larger)	
		LOCS	Do not use headings and most titles do not reflect slide content accurately.	Use headings for slides but some titles not informative or reflecting slide content accurately or effectively	Use appropriate & descriptive headings, clearly delineating slides with informative titles that accurately reflect content.	
		LOCS	Use low-quality figures (images pixilated, font too small, labels missing, panels misaligned)	Inconsistent quality for figures (some images too small, some pixilated due to improper sizing efforts, some labels too small or missing, some panels not aligned properly)	Incorporate high-quality figures, tables, and graphs (proper resolution & size; images not pixilated, image labels not too small, panels aligned properly)	
	¶ Oral communication skills will be evaluated using independent scoring form.				**TOTAL:**	