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2014 Assessment Report

What are UCI students learning about science? Assessment of general education student learning outcomes in science courses

Abstract
As part of the UCI science and technology general education learning outcomes, students are expected to demonstrate an understanding of fundamental laws of science and natural phenomena and apply scientific knowledge, analyze data, and draw conclusions. In order to assess whether UCI students are achieving these outcomes, students' knowledge and skills were assessed using a pre- and post-test study design in three biology and four earth system science courses in the 2014-2015 academic year. The results of this study showed that while students' scores on the content knowledge portion of the pre-post test significantly increased in all courses studied, scores on scientific literacy questions did not significantly change in any course studied. Further work is underway to determine how best to teach these courses to achieve gains in both scientific literacy skills and content knowledge.

Introduction

General education Category II: Science and Technology courses at UCI aim to provide students with "an understanding of the nature of scientific inquiry and the operation of the biological, physical, and technological world that is essential for making personal and public policy decisions in a technological society (UCI General Education Course Learning Outcomes)." In other words, students are expected to acquire scientific content knowledge and to develop scientific literacy skills. In accordance with this goal, the course specific outcomes for Category II courses state:

1. Demonstrate an understanding of fundamental laws of science OR principles underlying design and operation of technology.
2. Demonstrate an understanding of natural phenomena, related to the course discipline, that surround and influence our lives.
3. Students will be able to do ONE OR MORE of the following:
    a. Describe how scientists within the course discipline approach and solve problems.
    b. Apply scientific knowledge/theoretical models used in the course discipline to solve problems and draw conclusions using qualitative and/or quantitative analysis of data and concepts.
    c. Explain the scope and limitations of scientific inquiry and the scientific method as evidenced in the course discipline.

The goal of this project was to assess whether students that complete UCI Category II courses achieved these learning outcomes.

Assessment Methods

This assessment project used a pre- and post-test design to assess students' gains in course-specific content knowledge and scientific literacy skills to determine if students achieved the Category II learning objectives. Four UCI faculty members who taught seven different courses to 2871 students across the sciences during the 2014-2015 academic year participated in this study (Table 1). To assess students' content knowledge and scientific literacy skills, students completed a low-stakes test during the first and last weeks of class through either a EEE quiz or in discussion sections. The test consisted of 20 multiple choice questions, ten from the Test of Scientific Literacy Skills (TOSLS), a validated instrument that is used to assess scientific literacy skills (Gormally et al.), and ten from discipline-specific concept inventories (Garvin-Doxas et al., Libarkin et al., Nadelson et al, Perez et al.) or written by the instructors. The ten TOSLS questions were identical in every course, but the content questions differed to match the course subject matter. Students were given a small amount of points (<1% of the final grade) for completing the tests. To be included in this study, students had to consent to being in the study and complete both the pre- and post-test for the class they were enrolled in. Overall, 2142 students (75%) met these conditions and thus were included in this study.

Course	Course Title	Students	Students in study (n, % of enrolled)	Quarter
Bio Sci 93	DNA to Organisms (3 sections)	Biology majors	329 (83%) / 329 (76%) / 15 (58%)	Fall 2014
Bio Sci 9B	Biochemistry of Food and Cooking	Non-majors	202 (68%)	Winter 2015
Bio Sci 75	From Conception to Birth	Non-majors	80 (77%)	Spring 2015
ESS 1A	Introduction to Earth System Sciences	Non-majors	306 (77%)	Fall 2015
ESS 3	Oceanography	Non-majors	286 (73%)	Winter 2015
ESS 5	The Atmosphere	Non-majors	319 (73%)	Spring 2015
ESS 21	On Thin Ice	Non-majors	276 (76%)	Winter 2015

Table 1: 2014-2015 courses that participated in the study

For each course, the average percent correct on the pre-test and average percent correct on the post-test were calculated for the entire test, the discipline-specific questions, and the scientific skills questions. Paired t-tests were used to compare the pre- and post-test scores in order to determine if students performed any differently on the post-tests compared to the pre-tests. Excel and R were used for the analysis.

Results

Figure 1 shows the average scores on the course-specific content questions on the post-test compared to the pre-test, organized by biology majors courses (A), biology non-majors courses (B), and ESS non-majors courses (C). In each course, students' scores on the post-test were significantly higher than on the pre-test.

Figure 2 shows the average scores on the scientific literacy skills on the post-test compared to the pre-test, organized by biology majors courses (A), biology non-majors courses (B), and ESS non-majors courses (C). In each course, students' scores on the post-test were not significantly different than on the pre-test. Since these questions were identical in each class, comparisons can be made between classes. Bio 93 honors students (Figure 2A) scored the highest on these questions, whereas ESS 21 students scored the lowest (Figure 2C). Despite the ranges in scores on the scientific literacy skills questions, again no changes were observed for any course in this study.

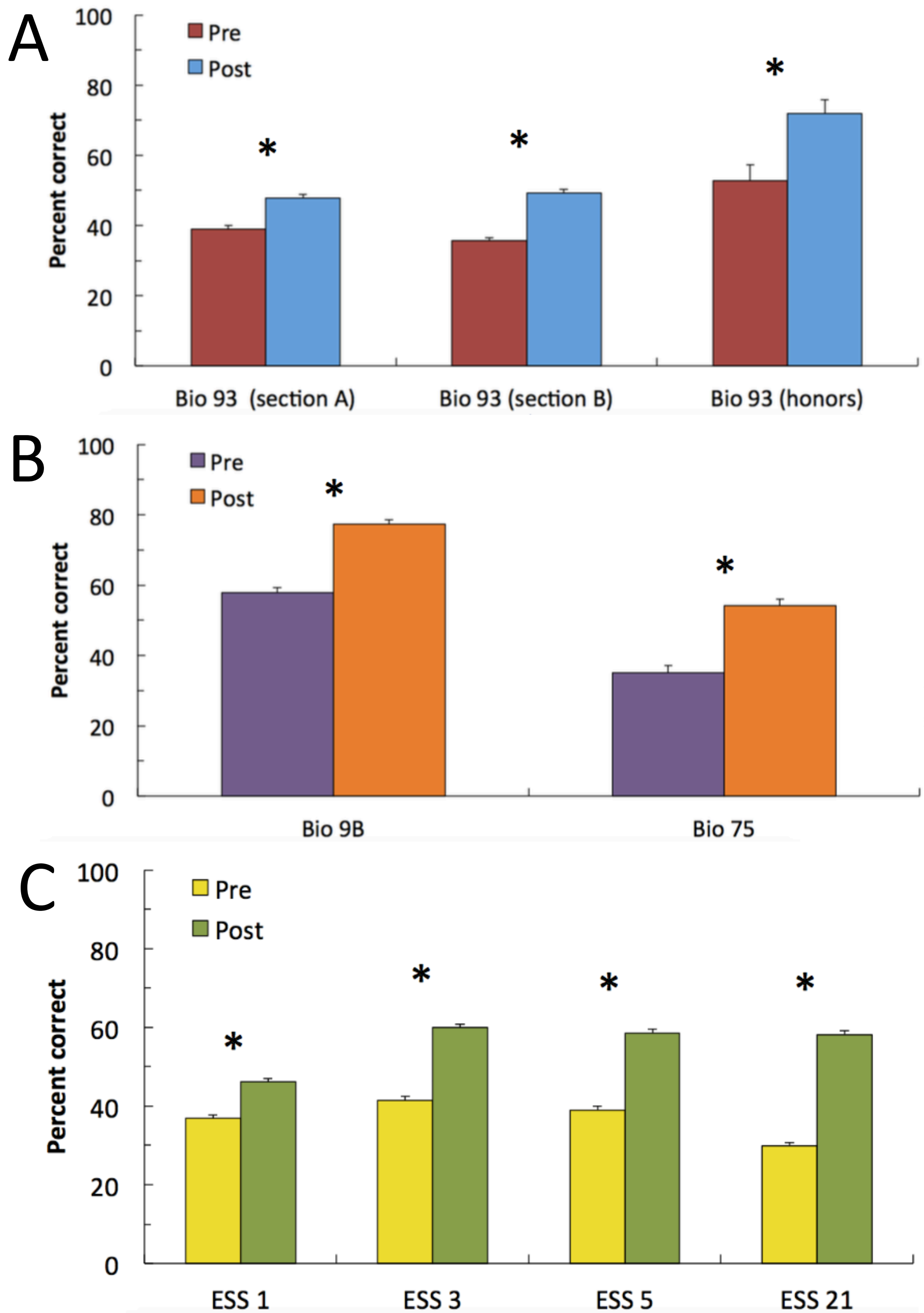

Figure 1: Students significantly improved on discipline specific-content questions. In the majors biology course (A), non-majors biology courses (B), and non-majors ESS courses (C), students significantly improved their scores on discipline-specific content questions on the post-test compared to the pre-test. Data are displayed as mean ± SEM. * $p < 0.05$.

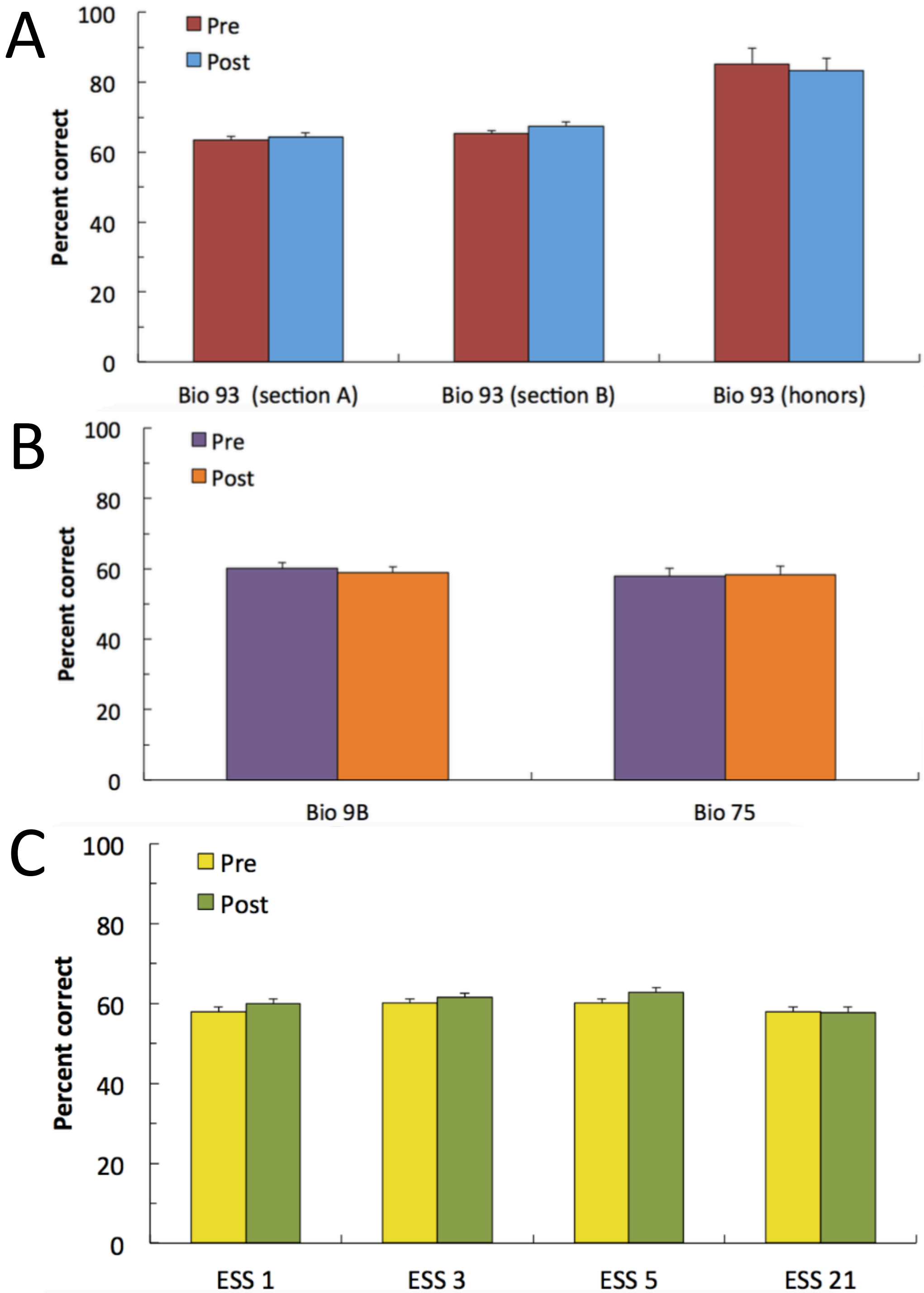

Figure 2: Students did not significantly improve on scientific literacy skills questions. In the majors biology course (A), non-majors biology courses (B), and non-majors ESS courses (C), students scores did not significantly change on scientific literacy skills questions on the post-test compared to the pre-test. Data are displayed as mean ± SEM.

Discussion
The main conclusion from this study is that while students were able to achieve gains in content knowledge over the course of a ten-week science course, they were unable to achieve significant gains in scientific literacy skills (as measured by the ten TOSLS questions). These results suggest that students are achieving General Education Category II learning outcomes 1 and 2, but not 3. However, there are many other aspects of assessment in these courses, including homework assignments, quizzes, and exams, which may (and likely do) demonstrate that students are achieving all three outcomes.

While it was surprising to see that there were no significant gains in scientific literacy skills questions in any of the courses in this study, it was especially so for Bio Sci 93, section B. This course was taught with a heavy emphasis on scientific literacy, including pre-class assignments and textbook readings dealing with experimental design and data analysis, in-class analysis of data from scientific articles, and summative exams that required students to use scientific literacy skills. It may be that students are demonstrating acquisition and mastery of scientific literacy skills on these higher stakes assignments, but are failing to provide the effort on the low-stakes test used in this study. This lack of effort may especially be noticeable on the post-test, as students are asked to complete the post-test during week 10 when final exams and other major assignments for their courses may be due, such that they do not put their best foot forward when taking the test.

Another reason for the lack of gains in scientific literacy skills is that 10-weeks is simply not enough time to develop sound and measurably scientific literacy skills. Indeed, Gormally et al. found gains using the TOSLS in all but two classes – one was an honors introductory biology class with a high TOSLS score on the pre- and post-test (similar to Bio 93 honors in this study) and also one that was taught on a ten-week quarter system (all of the other courses were taught on a 16-week semester system).

Despite potential explanations for why gains in scientific literacy skills were not observed, this study demonstrates the need to closely examine the way that these courses are taught and to try to develop methods that address and effectively teach scientific literacy. One possibility is to develop (or use preexisting) modules that focus on scientific literacy skills and implement them in these courses and compare the changes in scientific literacy skills to courses that do not use these modules. Conversations and planning with other UCI faculty about this issue are currently underway. Another project that warrants implementing is to try a different instrument or method of evaluating scientific literacy skills. Perhaps this set of 10 multiple-choice questions is not sufficient to measure gains in these courses whereas another instrument may.

Dissemination of results
These results have been shared through a variety of formats over the past six months. Dr. Shaffer presented some initial findings from the Bio 93 and Bio 9B courses to the Society for Developmental Biology Regional Meeting in Yosemite, CA in March 2015. Dr. Julie Ferguson (of the ESS department) who collaborates with Dr. Shaffer on this project co-authored and presented two poster presentations about this work. First, a poster was presented at the Geosciences Education Rendezvous in Boulder, CO in June 2015 and a second poster was presented at the Society for the Advancement of Biology Education Research in Minneapolis, MN in July 2015. The reception to the study was positive, useful feedback was collected, and potential collaborators were identified.

References

Garvin-Doxas K, Klymkowsky, MW. *CBE – Life Sciences Education*, &: 227 – 233, 2008.

Gormally C, Brickman P, Lutz M. *CBE – Life Sciences Education*, 11: 364-377, 2012.

Libarkin JC, Anderson SW. *J Geoscience Education*, 53: 39 – 401, 2005.

Nadelson LS, Southerland SA. *J Exp Education*, 78: 151 – 190, 2010.

Perez KE, et al. *CBE – Life Sciences Education*, 12: 665 – 675, 2013.

UCI General Education Course Learning Outcomes.
http://www.assessment.uci.edu/assess/documents/GESLOs_000.pdf