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2013 Assessment Report

Are UCI students scientifically literate? 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 be able to apply scientific knowledge, analyze data, and draw conclusions. In short, they are expected to be scientifically literate. In order to assess if UCI students are developing these skills, the Test of Scientific Literacy Skills (TOSLS) was implemented in a pre- and post-test design in seven non-majors science courses and one upper-division biological sciences course during the Winter 2014 quarter. The results of this study identified many significant factors that influence students' scientific literacy skills (including SAT score, GPA, major, class level, and number of prior science courses). However, no significant gains were observed on the TOSLS after students completed these courses. Future work is currently underway to determine the significance of these results.

Introduction
General education Category II: Science and Technology courses at UCI aim to provide students with "an understanding of the nature of scientific inquiry…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 develop scientific literacy skills. In accordance with this goal, the third course specific outcome for Category II courses states:

"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."

However, it is currently unknown if students actually achieve this learning outcome in category II courses and thus improve their scientific literacy skills. In order to determine if students are actually developing scientific literacy skills, the Test of Scientific Literacy Skills (TOSLS) was implemented in a pre-post test fashion in seven Category II courses and one upper-division biological sciences course in the Winter 2014 quarter. The TOSLS is a 28-question multiple choice test that assesses students in nine skill areas related to scientific literacy: identify a valid scientific argument; evaluate the validity of sources; evaluate the use and misuse of scientific information; understand elements of research design; create graphical representations of data; solve problems using quantitative skills; understand and interpret basic statistics; and justify references, predictions, and conclusions based on quantitative evidence (Gormally et al.). The results from using the TOSLS in a pre-post test design yielded valuable information about what factors contribute to students' scientific literacy skills. However, no gains were observed in any of the courses studied.

Assessment Methods
This assessment project used the TOSLS in a pre- and post-test design to assess students' scientific literacy skills at the beginning of the quarter and to determine if students achieved the third Category II learning objective. Six UCI faculty members who taught eight different courses to 2314 students across the sciences during the Winter 2014 quarter participated in this study (Table 1). To assess students' scientific literacy skills, students completed the TOSLS during the first and last weeks of class through a EEE survey. The TOSLS was advertised through

announcements and emails from the course instructors and students were given a small amount of course points (<1% of the final grade) for completing the tests. Overall, 994 students (43%) and 740 students (32%) completed the pre-test and post-test, respectively, and agreed to participate in this study. A total of 542 students (23%) completed both the pre- and post-tests.

Course	Course Title	Enrollment	Pre / Post / Both (n)
Bio Sci 9B	Biochemistry of Food and Cooking	310	168 / 126 / 104
Bio Sci 41	Aspects of Mood Disorders	72	34 / 30 / 17
Bio Sci 75	From Conception to Birth	46	19 / 16 / 12
Bio Sci 94	Organisms to Ecosystems	400	225 / 191 / 153
Bio Sci 100	Scientific Writing	389	143 / 128 / 80
Chem 1A	General Chemistry	372	144 / 61 / 50
ESS 3	Oceanography	395	138 / 114 / 79
ESS 21	On Thin Ice	330	123 / 74 / 47

Table 1: Winter 2014 courses that implemented the TOSLS

Aggregate pre-test scores were calculated for each individual course as well as for all students that took the pre-test. Changes in pre- to post-test scores were calculated using only the matched data (i.e. students that took both the pre- and post-tests in a given course). Two-tailed t-tests were used to determine significant differences between pre- and post-test scores at the course level.

Student demographic data was obtained from the UCI Registrar, including gender, ethnicity, major, class level, UCI GPA, and SAT scores (total, math, reading, writing). These data were used in a multiple linear regression model to predict the significant factors contributing to the pre-test scores. The statistical software programs JMP and R were used for the analysis.

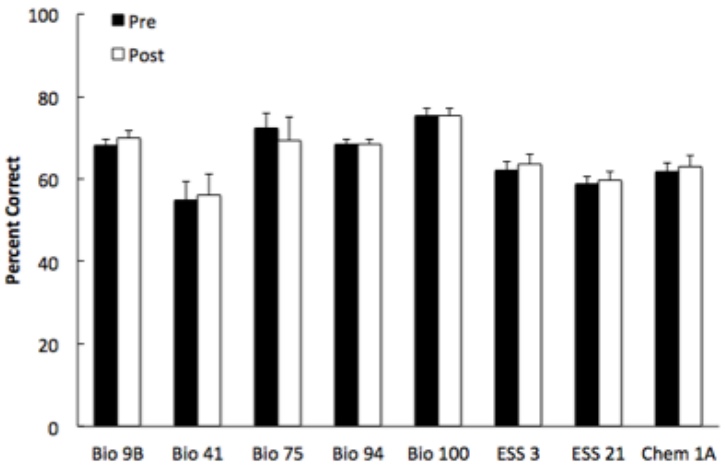

Figure 1: Average pre- and post-TOSLS scores for the classes in this study. No significant differences were observed for any classes.

Results

The overall average score for the pre-test was 63.5% ± 0.55% (SEM, n = 994). This result is consistent with those reported in non-majors biology courses at other universities in the United States (Gormally

et al.) suggesting that UCI students have similar scientific literacy skills as other undergraduate students in the country.

Figure 1 shows the results of the post-test scores compared to the pre-test scores for all courses in this study (data are shown as course averages, +/- SEM). No significant changes were observed between the pre- and post-tests for any of the courses. Notably, the scores were highest for Bio 100, an upper-division biological sciences writing course that contained mostly juniors and seniors.

The results of the pre-test were analyzed to determine if specific factors contributed to students' scientific literacy skills. Student UCI GPA, SAT scores (math, reading writing, and total), gender, ethnicity, major, class level, and number of previous science courses were used in a multiple linear regression model to predict the pre-test scores. Of these parameters, SAT math, SAT reading, UCI GPA, major, class level, and number of previous science courses emerged as significant (data not shown). SAT reading and SAT math were the strongest predictors of scores on the pre-test.

Figure 2 shows how major, class level, and number of previous science courses affected student pre-test scores (data are shown as averages +/- SEM). Biological sciences students scored the highest on the test, followed by other science and engineering students and then by non-science majors (Figure 2A). Students with senior class standing scored the highest, followed sequentially by juniors, sophomores, and freshman (Figure 2B). Finally, the number of previous science courses correlated with pre-test scores as well (Figure 2C). All results were significant to at least $p < 0.05$, and were controlled for the other variables described above (SAT, gender, etc.).

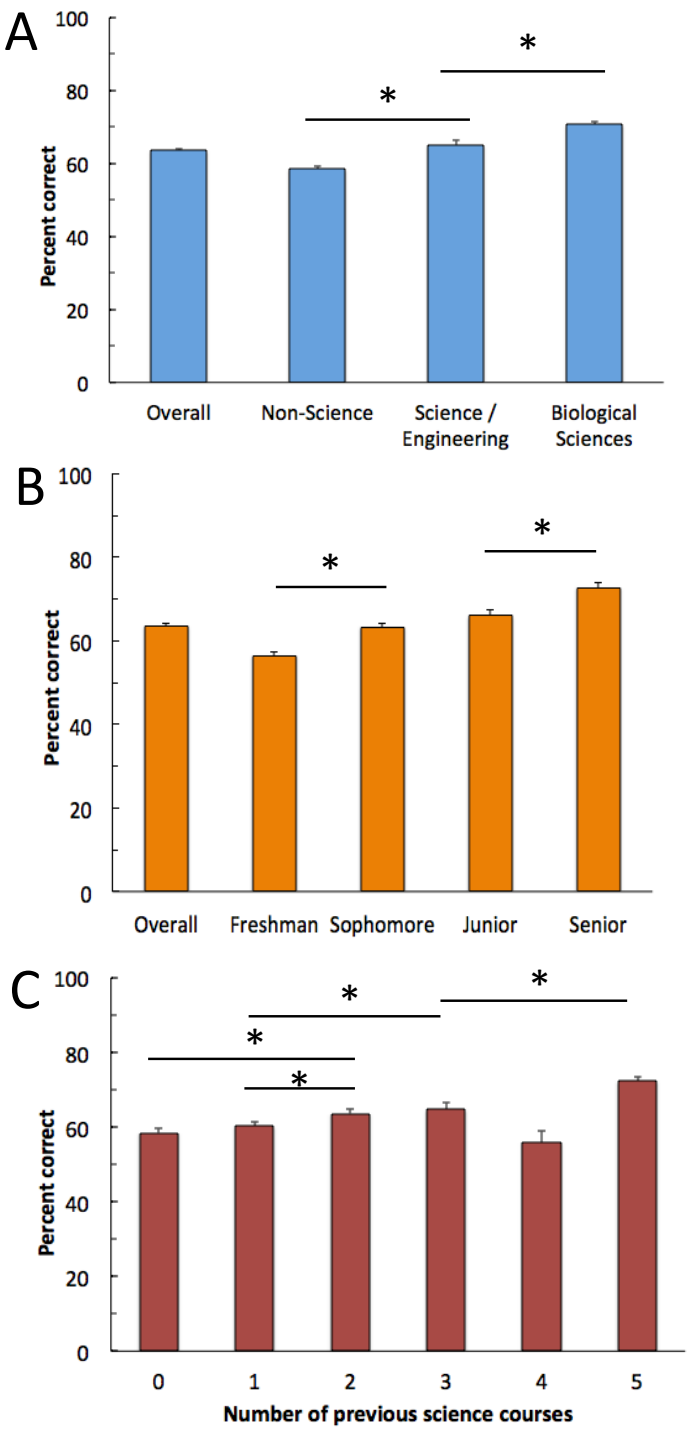

Figure 2: (A) Average pre-test scores of different majors. (B) Average pre-test scores of students of differing class level. (C) Average pre-test scores of students with different numbers of previous science courses. Asterisks denote significant differences ($p < 0.05$).

Conclusions

The main conclusions from this assessment project are 1) students that took both pre- and post-tests did not improve on average in the courses studied and 2) many factors,

including SAT math, SAT reading, UCI GPA, major, class level, and number of previous science courses, significantly contributed to students' scores on the pre-test. These results have provided valuable insights into what students' scientific literacy skills are.

While it was not surprising to see that factors such as SAT math, GPA, major, etc. contributed to scores on the TOSLS, it was surprising to observe a lack significant gains in any of the courses that took part in this study. Possible hypotheses to explain these results include 1) these courses explicitly taught these skills but no performance gains were observed, 2) these courses did not explicitly teach these skills and thus no performance gains were observed, or 3) students did not take the test seriously and thus the data may be flawed. Future work (described below) needs to be carried out to test these hypotheses and to determine the validity of these results.

Some caveats may apply as to whether this form of assessment accurately reflects student performance in Category II courses. It is possible that the pre-post test design does not capture students' true abilities, as it was implemented outside of a high-stakes exam and thus student motivation may not be maximal when taking these tests. Additionally, students may have developed scientific literacy skills during these courses, but that those skills were domain-specific, and they had difficulty transferring their skills to the TOSLS questions. Future work is also needed to investigate this possibility.

Future Directions

The results from this study are intriguing and lead to many questions to be assessed. First, I am interested in whether or not students are gaining content knowledge but not developing scientific skills in these courses. This question is the subject of a 2014 UCI Assessment grant that I was awarded. To address this question, this study is going to be repeated in part, but instead of asking only scientific literacy questions on the pre- and post-tests, content questions specific for each course will be included as well. This study is currently underway in the 2014-2015 academic year. Secondly, I am interested in how the implementation of these low-stakes pre- and post-tests may affect the outcomes. I have been working with Biological Sciences colleagues to determine if student motivation level (participation points versus graded tests, e.g.), testing conditions (online versus in class), or instrument length (number of questions) affect the results. The results obtained from these future studies will provide further insight into how well students are achieving Category II learning objectives at UCI.

References

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