Transferring skills: Assessing the impact of a paper reading module (DEEPR) on students’ abilities to read primary literature and communicate science.

We previously created a paper reading module (DEEPR - DEmonstration and Evaluation of Paper Reading) for our upper division laboratory courses to increase students’ abilities to read and analyze primary literature. DEEPR illustrates to students how researchers approach a paper, including the areas that we focus on and the types of questions we ask. Assessment of DEEPR, supported by a UCI Assessment Grant, demonstrated that students who enrolled in a DEEPR-containing lab course outperformed their peers on a primary literature based exam in a later class, a longitudinal gain rarely reported in STEM education studies (1). With this year’s assessment grant, we had two goals to supplement this finding:

1. Incorporate the DEEPR module in other Biological Sciences laboratory courses taught by other instructors to see whether the DEEPR technique is transferrable.
2. Develop an assessment test, EVALS, capable of measuring students’ abilities to read primary literature and communicate scientific principles.

I. Expansion of DEEPR to other lab courses

The study co-authors (BKS, PK) initially implemented DEEPR in three courses, Biological Sciences M114L (Biochemistry lab), M116L (Molecular Biology lab), and M118L (Microbiology lab). During the 2014-15 academic year, this was expanded to an additional course, Bio Sci D111L (Developmental & Cell Biology lab), and one of the previous study courses (M114L) was taught by a new instructor.

Our study design was as follows:

<table>
<thead>
<tr>
<th>Fall Quarter</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemistry Lab</td>
<td>Biochemistry Lab</td>
<td>Biochemistry Lab</td>
</tr>
<tr>
<td>Molecular Bio Lab</td>
<td>Molecular Bio Lab</td>
<td>Molecular Bio Lab</td>
</tr>
<tr>
<td>Microbiology Lab</td>
<td>Microbiology Lab</td>
<td>Microbiology Lab</td>
</tr>
<tr>
<td>Developmental/Cell Lab</td>
<td>Developmental/Cell Lab</td>
<td>Developmental/Cell Lab</td>
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**First-timer** – Student who is taking a DEEPR-containing lab course for the first time

**Returner** – Student who has previously taken at least one DEEPR-containing lab course

In each course (taught by instructors A-D), students’ primary literature reading skills were assessed with a Paper Quiz, an exam centered on an assigned paper for that quarter and course. Paper Quiz scores could then be compared between first-timer and returner students.
Our assessment focused on two research questions:

1. When controlling for student demographics (GPA, ethnicity, gender), do returners outperform their first-time peers on the Paper Quiz?
2. Are returner gains seen with individual instructors (A-D)? In other words, does a student who took a course from Instructor A, then see gains as a returner regardless of the subsequent lab course he/she enrolls in?

To assess the above research questions, we collected data in the four study courses in Fall 2014, Winter 2015 and Spring 2015. This included Paper Quiz scores from each student along with student demographics. Surprisingly, when examining Paper Quiz scores of returners and non-returners, there was not a statistically significant difference in performance between the two groups (Figure 1). This was also observed in a multiple regression model including student demographic data (data not shown). Similarly, when comparing performance of returners from individual instructor’s courses, returners did better than first-timers, but not to a statistically significant degree (Table 1).

![Figure 1. Performance of first-timer and returner students on the Paper Quiz. First-timers are students who have not taken a DEEPR containing lab course. Returners have taken at least one DEEPR lab course previously.](image)

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Intercept</th>
<th>Instructor A</th>
<th>22.93 (&lt;0.001)</th>
<th>16.32 (0.007)</th>
<th>15.83 (0.050)</th>
<th>18.27 (0.050)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeater status</td>
<td>0.52 (0.979)</td>
<td>2.58 (0.382)</td>
<td>1.28 (0.527)</td>
<td>2.47 (0.15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td>12.19 (&lt;0.001)</td>
<td>14.58 (&lt;0.001)</td>
<td>14.32 (&lt;0.001)</td>
<td>13.69 (&lt;0.001)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Multiple regression analysis examining the impact of returner status, GPA, gender, and ethnicity on Paper Quiz performance. Estimate and p value (in parentheses) are indicated for the intercept, repeater status, and GPA for students who initially took each of the above instructors (A-D). Gender and ethnicity were included in the model but not in the table as these variables were not significant predictors of Paper Quiz performance. No repeater, Caucasian, and Female were used as the baseline values. GPA was treated as a continuous variable, while repeater status (yes or no), gender (male or female), and ethnicity (Caucasian, East Asian, South Asian, URM – Hispanic, African-American, Native-American) were treated as categorical variables.

We are currently exploring a few different avenues to explain our inability to replicate the longitudinal gains of DEEPR in our own courses and the courses of other newly adopting instructors. One issue is that each instructor took a slightly different approach when implementing DEEPR. While we do not yet know the “best” approach to teach students how to read scientific papers, further discussion amongst faculty can only improve our instructional abilities. Another issue related to Q2 of our analysis is that splitting repeater students into groups by their initial lab instructor resulted in small sample sizes, making it more difficult to observe statistically significant results. Finally, a number of lower division Bio Sci courses have recently been revamped with one modification being an increased emphasis on data analysis and critical thinking. Because of this prior exposure, it is possible that the impact of DEEPR has been impacted as students are arriving in our labs better prepared to read primary literature. We plan to continue our experiment and analysis in the 2015-2016 academic year to see whether greater sample sizes and more
experience with DEEPR implementation results in the expected longitudinal gains for our students.

II. Development of EVALS, a primary literature based assessment test

For the above analysis, we examined performance of returner and first-time students on an exam specific for a given lab course in a given quarter. While this allows for in-class comparisons of students and measurement of longitudinal learning, we wanted to generate an assessment that could be used to measure gains in critical thinking abilities in a topic-independent manner within a single quarter. To this end, we generated EVALS (Evaluating Analysis and Literature reading Skills), a ten-question test constructed primarily using data from the published literature that measures students abilities’ to analyze data, write a hypothesis, design an experiment, and evaluate experimental design.

To begin validation of EVALS, we gave the test to a sample of undergraduates, graduate students, and faculty. Graduate students and faculty performed significantly better on EVALS (Figure 2), illustrating that experts are capable of successfully completing the assessment.

We then implemented EVALS in a pre-/post-test fashion in four different courses focused on primary literature in the Biological Sciences, each using a distinct method to train students in this skill. Bio Sci M116L and M118L were DEEPR courses, as described above. Bio Sci M126 (Primary Literature in Mol Bio & Biochemistry) implemented the CREATE method (2). And Bio Sci D140 (Reading Scientific Papers in Developmental & Cell Biology) utilized Figure Facts (3). Each of these methods has been published as a technique, which increases students’ paper reading abilities. Our goal was to use EVALS to determine whether these techniques could be successfully implemented at UCI.

Based on our data, statistically significant gains were seen with each method from pre- to post-test (Figure 3). From this data, we can conclude that each of the above paper reading training techniques can be utilized to improve students’ scientific analysis skills.

Our next step is to continue to implement EVALS in primary literature and critical thinking-based courses. This data will allow for further instrument validation. Colleagues at other institutions are now administering EVALS, and we will be gathering feedback to further modify the instrument. In this way, we hope to generate a broadly utilized assessment test for critical thinking and primary literature analysis skills in the Biological Sciences.
References


3. Round JE, Campbell AM. 2013. Figure Facts: Encouraging Undergraduates to Take a Data-Centered Approach to Reading Primary Literature. CBE-Life Sciences Education 12:39-46.