Assessment of student scientific literacy skills in non-majors science courses

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6.7.14
What is scientific literacy?

The National Research Council (NRC) defines scientific literacy as the ability to “use evidence and data to evaluate the quality of science information and arguments put forth by scientists and in the media”

The Programme for International Student Assessment describe scientific literacy as “the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity”

http://youtu.be/5gK2EEwzjPQ

Gormally et al, 2012
A student is interested in the behavior of fish. He has 4 fish bowls and 20 goldfish. He puts 8 fish in the first bowl, 6 fish in the second bowl, 4 fish in the third bowl and 2 fish in the fourth bowl. He places each fish bowl under light, he keeps the temperature at 75°F for all four bowls, and he observes the behavior of the fish.

<table>
<thead>
<tr>
<th>Number of fish</th>
<th>8 fish</th>
<th>6 fish</th>
<th>4 fish</th>
<th>2 fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>75°F</td>
<td>75°F</td>
<td>75°F</td>
<td>75°F</td>
</tr>
</tbody>
</table>

What can the student find out from doing just this experiment?

A. If the number of fish in the fish bowl affects the behavior of the fish.
B. If the temperature of the fish bowl affects the behavior of the fish.
C. If the temperature of the fish bowl and the amount of light affect the behavior of the fish.
D. If the number of fish, the temperature, and the amount of light affect the behavior of the fish.

58% of students grades 9 – 12 students answered correctly
84% of intro bio students at UNC Chapel Hill answered correctly
88% of anatomy students at UC Irvine answered correctly

But...
23% of non-majors intro bio students at NC A&T State University answered correctly
All college students have to take science classes, even if they are non-science majors.

Below is the third learning outcome of UCI General Education Category II (Science and Technology) classes:

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.

In other words, students **should be** developing scientific literacy skills in non-majors science courses. But are they?
Questions

1. How scientifically literate are UCI students?
2. Do UCI students become “more” scientifically literate by taking non-majors science classes?
3. How do UCI students compare to students at other universities?
Study Design

1. Students enrolled in GE II courses completed a pre-course instrument assessing scientific literacy skills at the beginning of the Winter 2014 quarter

2. The same students (ideally) completed the same instrument at the end of the Winter 2014 quarter

3. Analyze data and measure changes
Instrument

Developing a Test of Scientific Literacy Skills (TOSLS): Measuring Undergraduates’ Evaluation of Scientific Information and Arguments

Cara Gormally,* Peggy Brickman,† and Mary Lutz‡

Cara Gormally
Gauladet University

Peggy Brickman
University of Georgia

Coming to UCI
Oct 30 2014
TOSLS

- 28-question multiple choice test
- Assessing scientific literacy skills in nine areas

Identify a valid scientific argument
Evaluate the validity of sources
Evaluate the use and misuse of scientific information
Understand elements of research design and how they impact scientific findings/conclusions

Create graphical representations of data
Read and interpret graphical representations of data
Solve problems using quantitative skills, including probability and statistics
Understand and interpret basic statistics
Justify inferences, predictions, and conclusions based on quantitative data
6. When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?
   a. The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles.
   b. The Malathion killed the tadpoles, so the beetles had more food and their population increased.
   c. The Malathion killed the beetles, causing fewer tadpoles to be eaten.
   d. The Malathion killed the beetles, causing the tadpole population to prey on each other.
8. Creators of the Shake Weight, a moving dumbbell, claim that their product can produce “incredible strength!” Which of the additional information below would provide the strongest evidence supporting the effectiveness of the Shake Weight for increasing muscle strength?
   a. Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week.
   b. Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product.
   c. Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells.
   d. Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial.

22. Your doctor prescribed you a drug that is brand new. The drug has some significant side effects, so you do some research to determine the effectiveness of the new drug compared to similar drugs on the market. Which of the following sources would provide the most accurate information?
   a. the drug manufacturer’s pamphlet/website
   b. a special feature about the drug on the nightly news
   c. a research study conducted by outside researchers
   d. information from a trusted friend who has been taking the drug for six months
Execution

• Six instructors (all LPSOE!) teaching eight GE II courses in the Winter 2014 quarter participated
  – Bio Sci 9B: Bio and Chem of Food and Cooking (n = 324)
  – Bio Sci 41: Aspects of Mood Disorders (73)
  – Bio Sci 75: From Conception to Birth (47)
  – Bio Sci 94: Organisms to Ecosystems (400)
  – Bio Sci 100: Scientific Writing (389)
  – Chem 1A: General Chemistry (373)
  – ESS 3: Oceanography (396)
  – ESS 21: On Thin Ice (333)

NOTE: Bio 94 is the second intro biology course for majors, although anyone can take it
NOTE: Bio 100 is an upper-division writing class for biology majors (“positive control”)


Execution

• TOSLS pre-survey was opened in week 1 to students in all classes on EEE (our online LMS)
  – Students received some credit for taking the survey
• TOSLS post-survey was opened in week 10 online
  – Students received some credit for taking the survey
• On both surveys, students had to agree to participate in the study by answering “yes” to the last question
• Participant data was collected from the Registrar
  – Major, class level, SAT score, GPA, gender, race, Winter 2014 study list

Still waiting on this!!!
How many students took the survey?

**Pre-survey**
- 2335 possible students
- 1592 took pre-survey

**Post-survey**
- 2335 possible students
- 1394 took post-survey

In the middle of the survey, the students were asked a “are you paying attention?” question!

- Only 82.5% overall answered correctly!

As you are taking this test, you should be carefully reading the questions and choosing the best answer for each question. The correct answer for this question is choice D. Please answer with choice D then move on to the next question.

- 1355 answered correctly
- 1140 agreed to participate
- 619 took both pre- and post-surveys
- 1109 answered correctly
- 824 agreed to participate
1. How did all of the students do on the pre-survey?

<table>
<thead>
<tr>
<th></th>
<th>Average score (% correct)</th>
<th>Stdev</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-survey (all)</td>
<td>56.9</td>
<td>20.3</td>
<td>1404</td>
</tr>
<tr>
<td>Pre-survey (participated)</td>
<td>61.2</td>
<td>19.5</td>
<td>981</td>
</tr>
<tr>
<td>Pre-survey (participated &amp; paid attention)</td>
<td>64.2</td>
<td>17.8</td>
<td>884</td>
</tr>
<tr>
<td>Post-survey (all)</td>
<td>53.7</td>
<td>22.6</td>
<td>1303</td>
</tr>
<tr>
<td>Post-survey (participated)</td>
<td>61.5</td>
<td>21.3</td>
<td>759</td>
</tr>
<tr>
<td>Post-survey (participated &amp; paid attention)</td>
<td>65.1</td>
<td>19.2</td>
<td>679</td>
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Scores improve as you filter the data

Chem 1A data not included
Was there any variation by class?

Starting here, only looking students who participated and paid attention (unless otherwise noted)

<table>
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<th>Course</th>
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<tr>
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<td>64.6</td>
<td>17.6</td>
<td>184</td>
</tr>
<tr>
<td>Bio 41</td>
<td>62.1</td>
<td>18.4</td>
<td>36</td>
</tr>
<tr>
<td>Bio 75</td>
<td>67.5</td>
<td>17.2</td>
<td>20</td>
</tr>
<tr>
<td>Bio 94</td>
<td>67.2</td>
<td>16.4</td>
<td>228</td>
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<tr>
<td>Bio 100</td>
<td><strong>72.2</strong></td>
<td>16.2</td>
<td>142</td>
</tr>
<tr>
<td>Chem 1A</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>ESS 3</td>
<td><strong>56.7</strong></td>
<td>18.2</td>
<td>146</td>
</tr>
<tr>
<td>ESS 21</td>
<td><strong>58.2</strong></td>
<td>16.5</td>
<td>127</td>
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There were differences based on class enrollment
## 2. Were there any changes?  In short: NO

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Was there variation by class?

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<td>18.0</td>
<td>191</td>
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<td>19.1</td>
<td>128</td>
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<tr>
<td>Chem 1A</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>ESS 3</td>
<td>59.2</td>
<td>19.0</td>
<td>114</td>
</tr>
<tr>
<td>ESS 21</td>
<td>59.2</td>
<td>18.1</td>
<td>74</td>
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Did students improve?

No significant changes for any classes
But what if we refine the data further?

- Did specific groups of students improve, based on major or class standing?

Analysis of Bio Sci 9B: The biology and chemistry of food and cooking (324 students)
104 students took both the pre- and post-surveys

- Use only these students in following analyses

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Learning Gain \(<g> = 1.8\% \pm 48\%

Effect size (Cohen’s d) = 0.11

No significant differences on individual questions either
Does class standing matter?

Significant differences (p < 0.05)
Pre: Freshman and senior
Post: Freshman and senior

Seniors scored higher than freshman
No significant changes from pre- to post for any group
Does major matter?

Significant differences (p < 0.05)
Pre: Bio and non-science
Post: Bio and non-science

Biologists scored higher than non-science majors
No significant changes from pre- to post for any group
Are we actually teaching students these skills?

• Instructors were asked to say how much they agreed / disagreed with the statements “in this course, my students learned how to…”

• Students were asked on the post-test to say how much they agreed / disagreed with the statements “in this course, I learned how to…”

Statements reflected the nine areas of scientific literacy defined by the TOSLS

Was there alignment between students and instructors?
3. How do UCI students compare to other students?

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Our students are doing about par for the course

Gormally et al, 2012
Next steps / Questions

• Repeat analysis for all classes
• Get registrar data and analyze data further
• Re-do the study (or parts of it)
  – Do surveys in class

• Are students trying / caring / motivated?
• Is 8 - 10 weeks enough to show an improvement?
• Should we even worry about this?
Acknowledgments

• Collaborators
  – Nancy Aguilar-Roca
  – Amanda Brindley
  – Julie Ferguson
  – Debra Mauzy-Melitz
  – Andrea Nicholas

• Colleagues
  – Pavan Kadandale
  – Brian Sato
  – Adrienne Williams

UCI STEM-LEC Group!