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

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6.7.14

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What is scientific literacy?

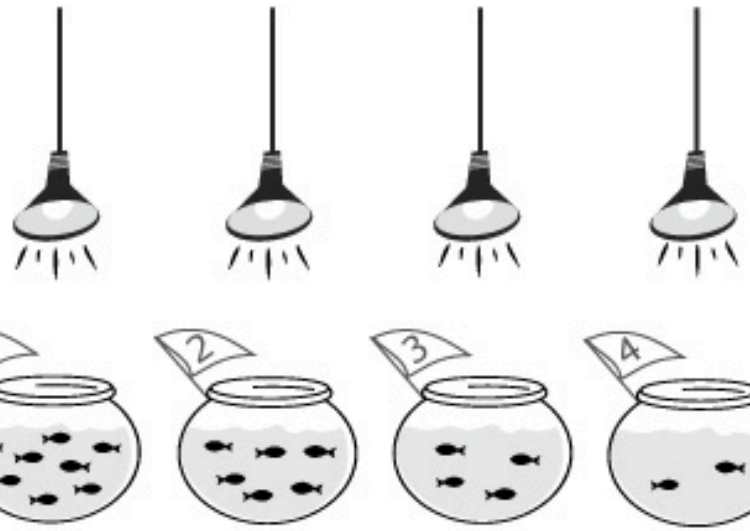
The National Research Council (NRC) defines scientific literacy as the ability to "use evidence and data to evaluate the quality of science information and arguments put forth by scientists and in the media"

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.



Number of fish	8 fish	6 fish	4 fish	2 fish
Temperature	75°F	75°F	75°F	75°F

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

Project 2061 AAAS

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

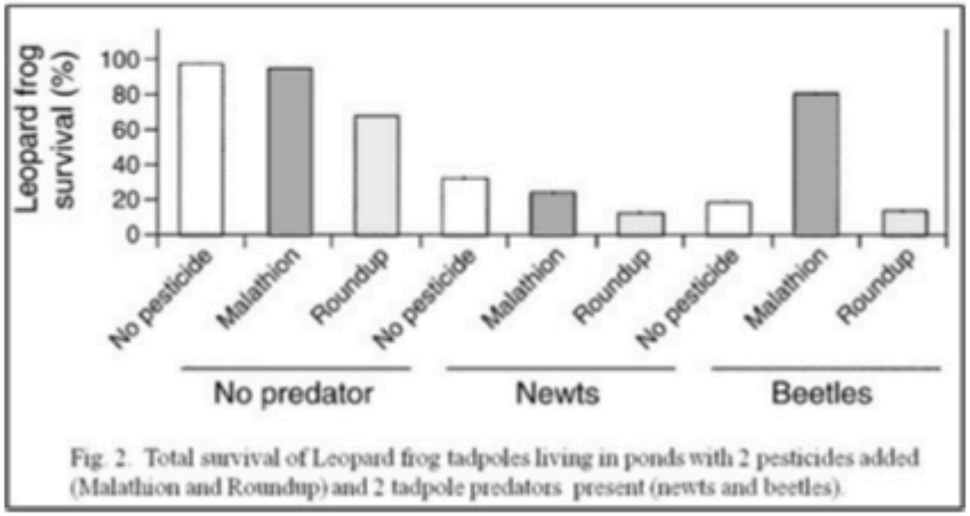


Fig. 2. Total survival of Leopard frog tadpoles living in ponds with 2 pesticides added (Malathion and Roundup) and 2 tadpole predators present (newts and beetles).

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 LPSOEs!) 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	Post-survey
2335 possible students	2335 possible students
1592 took pre-survey	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	1109 answered correctly
1140 agreed to participate	824 agreed to participate

619 took both pre- and post-surveys

1. How did all of the students do on the pre-survey?

	Average score (% correct)	Stdev	n
Pre-survey (all)	56.9	20.3	1404
Pre-survey (participated)	61.2	19.5	981
Pre-survey (participated & paid attention)	64.2	17.8	884
Post-survey (all)	53.7	22.6	1303
Post-survey (participated)	61.5	21.3	759
Post-survey (participated & paid attention)	65.1	19.2	679

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)

	Average score (% correct)	Stdev	n
Bio 9B	64.6	17.6	184
Bio 41	62.1	18.4	36
Bio 75	67.5	17.2	20
Bio 94	67.2	16.4	228
Bio 100	72.2	16.2	142
Chem 1A	n/a	n/a	n/a
ESS 3	56.7	18.2	146
ESS 21	58.2	16.5	127

There were differences based on class enrollment

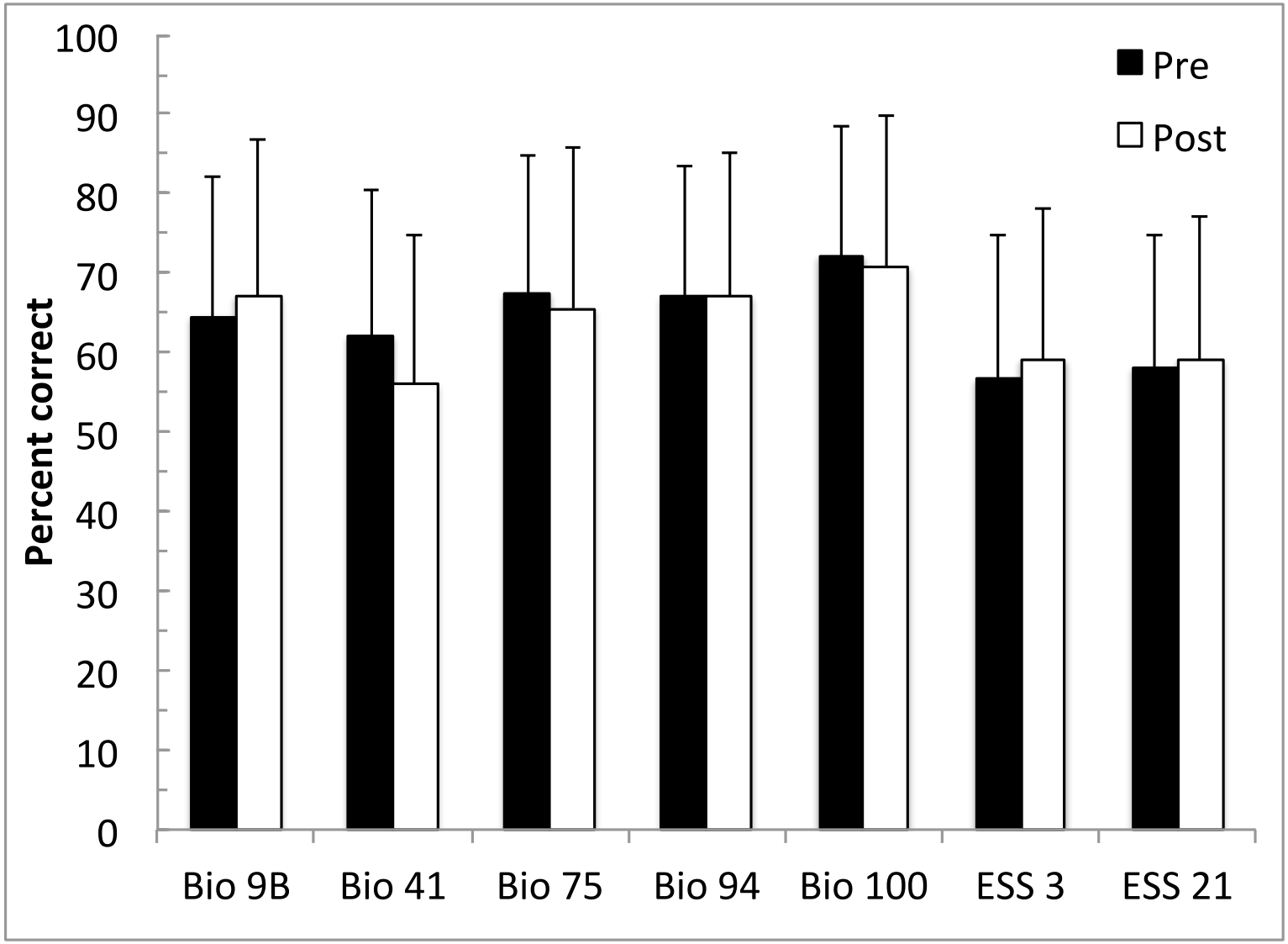
2. Were there any changes? In short: NO

	Average score (% correct)	Stdev	n
Pre-survey (all)	56.9	20.3	1404
Pre-survey (participated)	61.2	19.5	981
Pre-survey (participated & paid attention)	64.2	17.8	884
Post-survey (all)	53.7	22.6	1303
Post-survey (participated)	61.5	21.3	759
Post-survey (participated & paid attention)	65.1	19.2	679

Was there variation by class?

	Average score (% correct)	Stdev	n
Bio 9B	67.2	19.5	126
Bio 41	56.1	18.6	30
Bio 75	65.6	20.3	16
Bio 94	67.2	18.0	191
Bio 100	70.8	19.1	128
Chem 1A	n/a	n/a	n/a
ESS 3	59.2	19.0	114
ESS 21	59.2	18.1	74

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)

Bio Sci 9B

- 104 students took both the pre- and post-surveys
  - Use only these students in following analyses

	Average score (% correct)	Stdev	n
Pre-survey	68.1	16.6	104
Post-survey	70.0	18.2	104

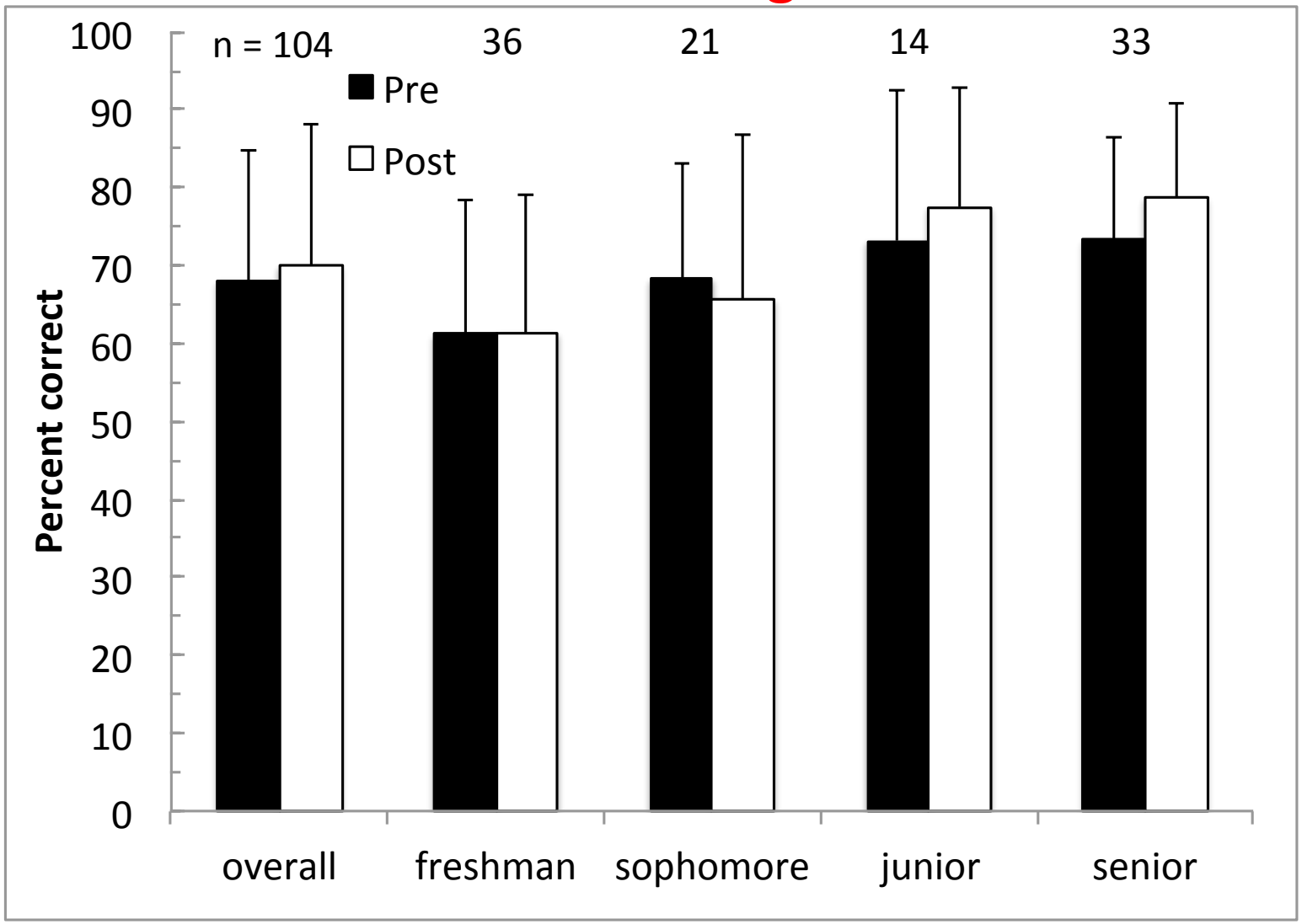
Learning Gain <g> = 1.8% +/- 48%

Effect size (Cohen's d) = 0.11

No significant difference

No significant differences on individual questions either

Does class standing matter?



Significant differences ($p < 0.05$)

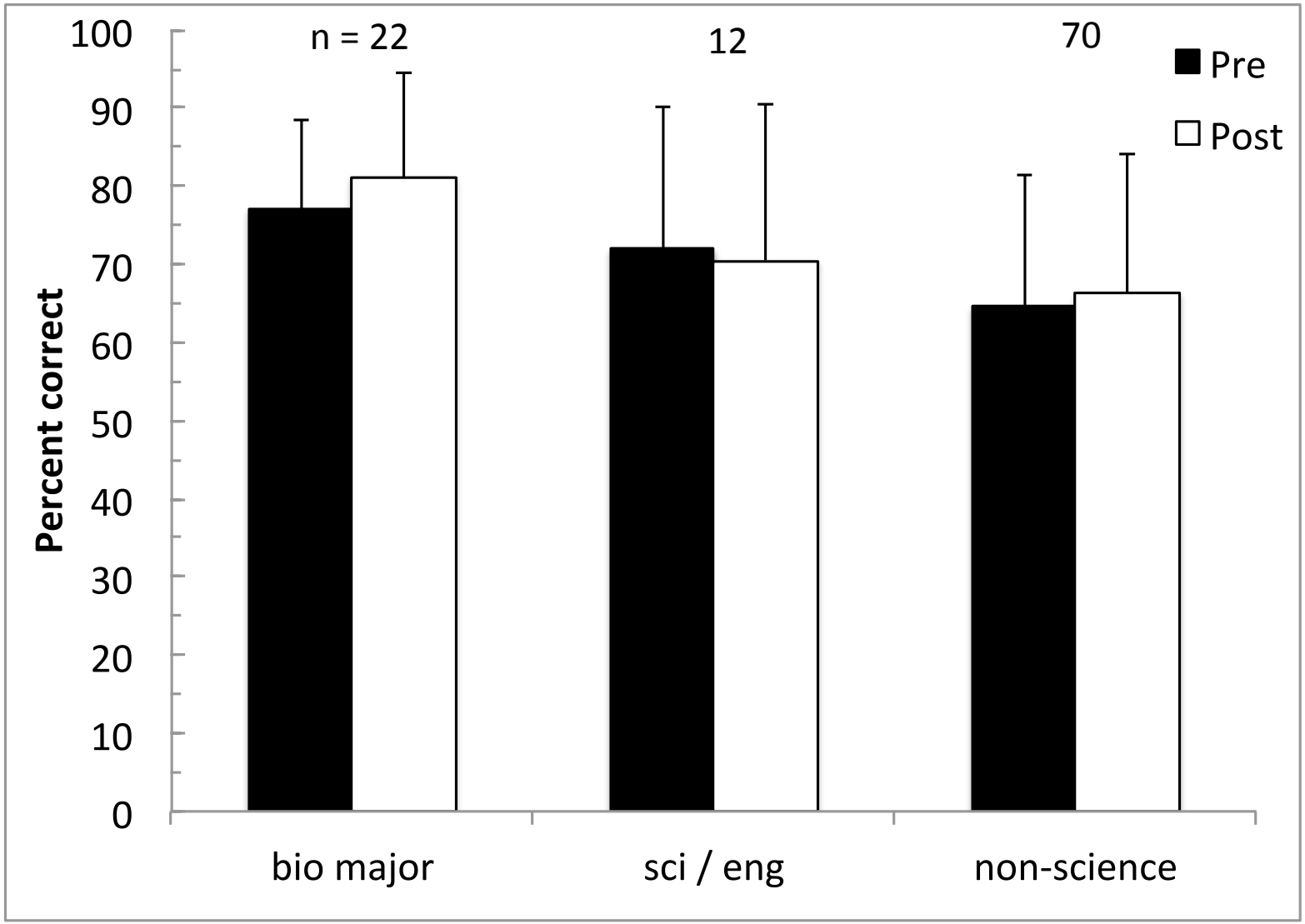
Pre: Freshman and senior

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?

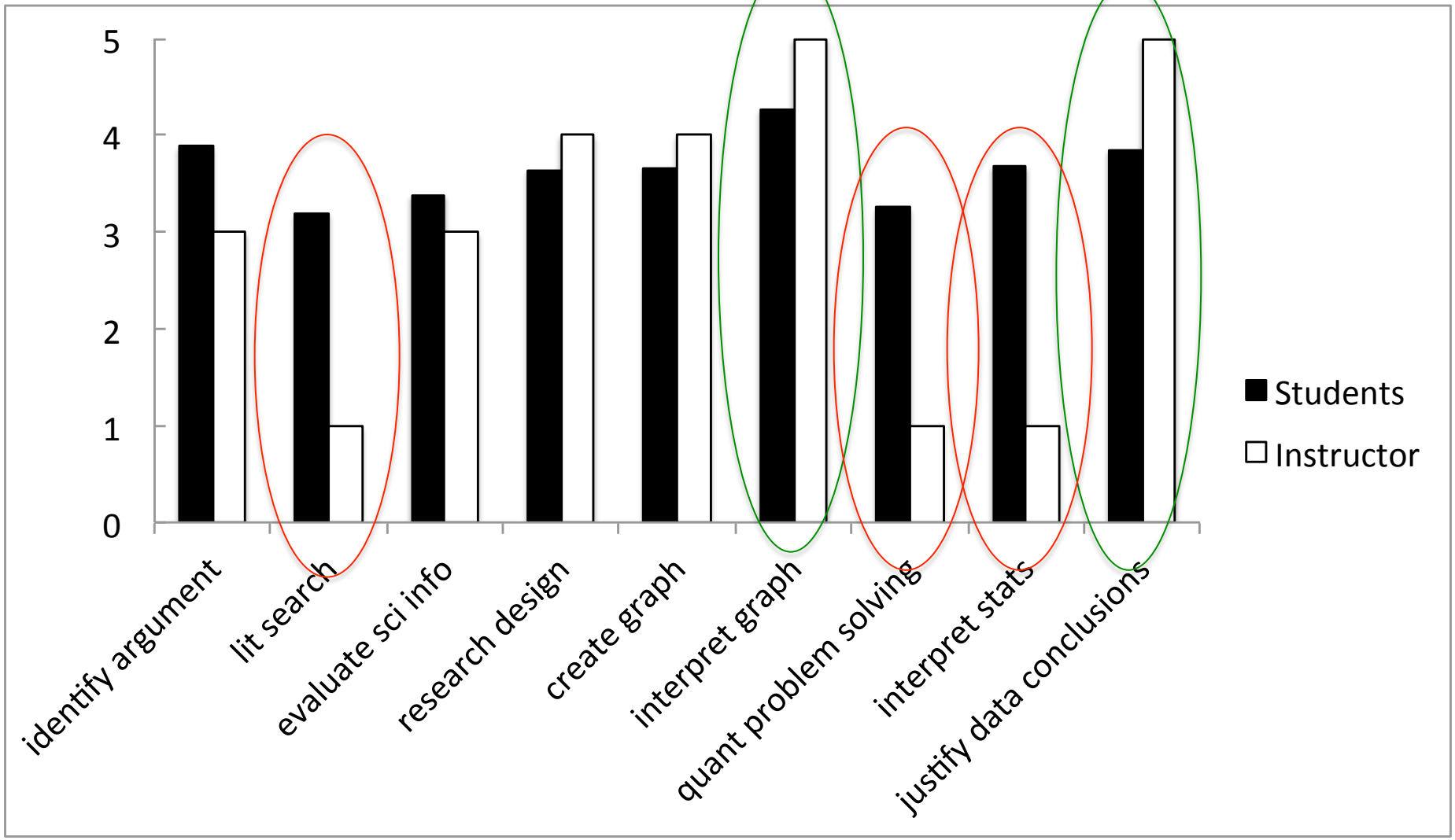
- Instructors were asked to say how much they agreed / disagreed with the statements "in this course, my students learned how to…"

- 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?

For Bio Sci 9B



3. How do UCI students compare to other students?

	Average score (% correct)	Stdev	n
Pre-survey	64.2	17.8	884
Post-survey	65.1	19.2	679

Table 5. Mean pre- and posttest scores of students from each course with calculated *t* value and effect size, as well as scores from biology faculty experts[a]

	Mean % correct (SE)				Internal consistency	
	Pretest	Posttest	t[b]	Effect size	Pretest	Posttest
Project-based nonmajors at public research university	61.71 (1.05)	70.76 (0.96)	10.51*	0.83	0.734	0.758
Traditional nonmajors at public research university	58.33 (0.99)	65.45 (0.92)	9.65*	0.48	0.718	0.713
Private research university	84.63 (1.30)	84.95 (1.34)	0.32	0.03	0.581	0.632
Midsized state college	44.29 (1.70)	42.50 (1.56)	1.22	0.12	N/A	N/A
Biology majors at public research university	61.72 (0.71)	67.13 (0.75)	7.65*	0.33	0.682	0.761
Biology experts	N/A	91.43 (0.98)	N/A		N/A	N/A

[a]Pre- and posttest internal consistency is shown.

[b]*$p < 0.05$ (indicates significant gains).

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!

ASSESSMENT, RESEARCH & EVALUATION GROUP

UNIVERSITY OF CALIFORNIA, IRVINE