In testing the null hypothesis, both Monte Carlo simulations and empirical field-based observations were used to assess the feasibility of the heteroproximity paradigm. As seen in the inset of Fig. 8H, the model captures most essential features of the data aside from an idiopathic discontinuity at high temperatures. After applying Bonferroni's correction for multiple comparisons, three treatment conditions proved statistically distinct from the baseline ($p<0.05$). One may surmise that McDowell's concern about inappropriate seeding of model parameters (Yoder et al., 2005) is not relevant here and, furthermore, that previous speculations that replication is resource-limited (Parkwood et al., 2007) are largely correct. Nevertheless this study is limited in its choice of spec-

How can instructors help students read the primary literature?

Greg Crowther (UW Dept. of Medicine)

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Genetics Education

Innovations in Teaching and Learning Genetics

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Selective Use of the Primary Literature Transforms the Classroom Into a Virtual Laboratory

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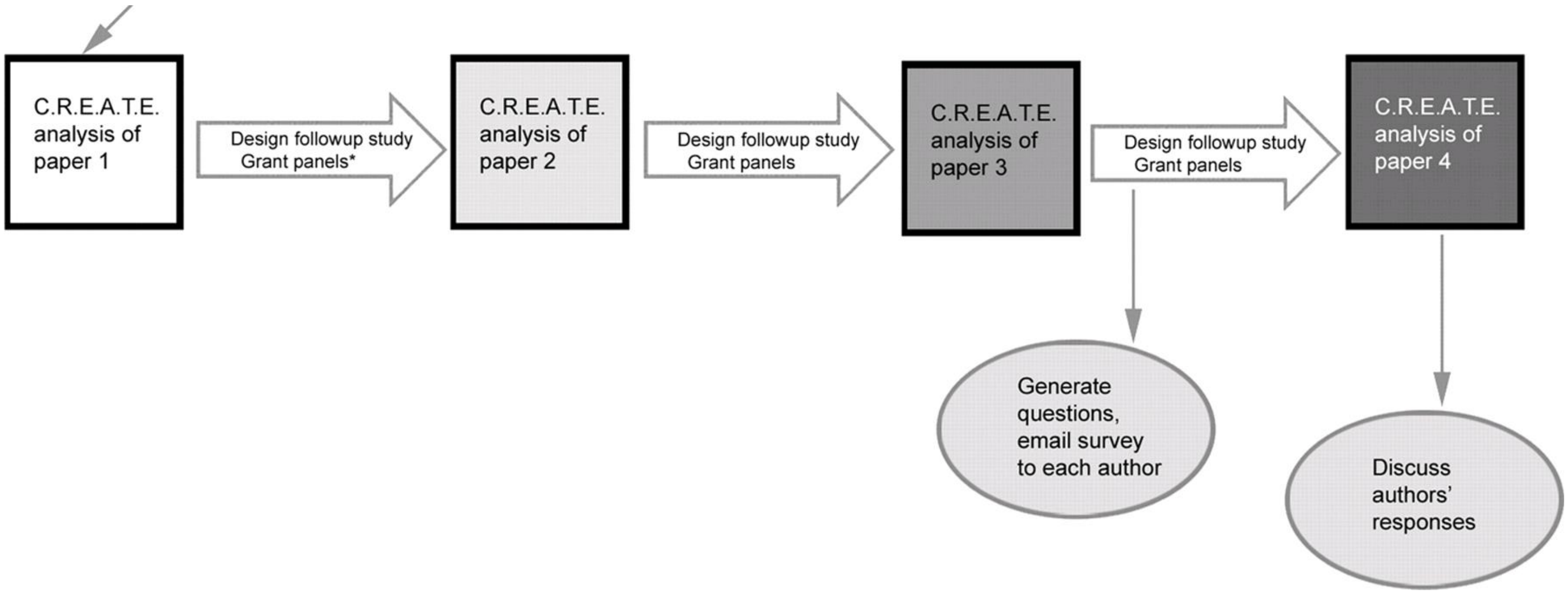
ABSTRACT

CREATE (*c*onsider, *r*ead, *e*lucidate hypotheses, *a*nalyze and interpret the data, and *t*hink of the next *e*xperiment) is a new method for teaching science and the nature of science through primary literature. CREATE uses a unique combination of novel pedagogical tools to guide undergraduates through analysis of journal articles, highlighting the evolution of scientific ideas by focusing on a module of four articles from the same laboratory. Students become fluent in the universal language of data analysis as they decipher the figures, interpret the findings, and propose and defend further experiments to test their own hypotheses about the system under study. At the end of the course students gain insight into the individual experiences of article authors by reading authors' responses to an e-mail questionnaire generated by CREATE students. Assessment data indicate that CREATE students gain in ability to read and critically analyze scientific data, as well as in their understanding of, and interest in, research and researchers. The CREATE approach demystifies the process of reading a scientific article and at the same time humanizes scientists. The positive

Introducing C.R.E.A.T.E.

- Consider, Read, Elucidate hypotheses, Analyze and interpret data, Think of the next Experiment
- 1 line of research (4 articles) from 1 lab
- students learn about…
  - analysis of scientific info
  - nature of science
  - creativity of research



Interesting aspects of C.R.E.A.T.E. method

- abridgement of articles
  - “In our previous experience, when students were assigned to read research articles, they often read only the abstract, introduction, and discussion, merely glanced at the figures and tables, and accepted the authors’ conclusions without developing a thorough understanding of the experimental results on which they were based. To avoid this problem, we do not initially provide CREATE students with the articles’ titles, abstracts, discussion/conclusion sections, or the authors’ names.”
- concept mapping and cartooning at several stages
- T.E.: student grant review panels judge proposals
- email interviews with authors
- analysis templates for figures/tables (see next slide)

ANALYSIS TEMPLATE—Fill one in for *each* figure or table

Figure or Table Number: _____

1) "Official" title for this figure or table (from the caption):

2) My (simplified, decoded, in regular language) title for this figure or table:

3) The *specific hypothesis being tested*, or *specific question being asked* in the experiment represented here is:

ANALYSIS: **First**, refer to your cartoon of what the experimenters did, and to your annotated figure, and to the information you wrote in above. **Then**, answer the following for each figure or table:

4a) For descriptive studies,

If we compare panel(s)__________ and __________, or columns __________ and

___________, we learn about ____

If we compare panel(s)__________ and __________, or columns __________ and

___________, we learn about ____

If we compare panel(s)__________ and __________, or columns __________ and

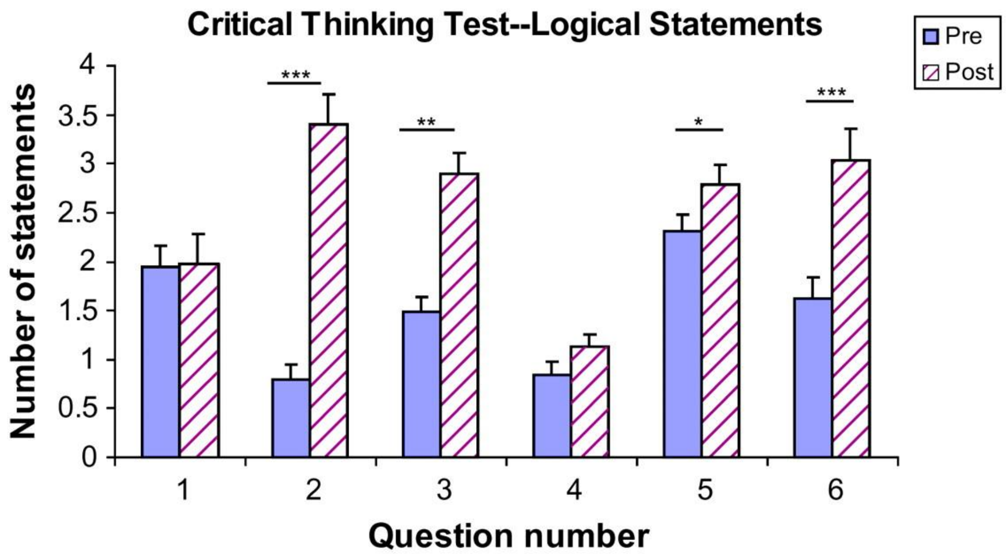
___________, we learn about ____

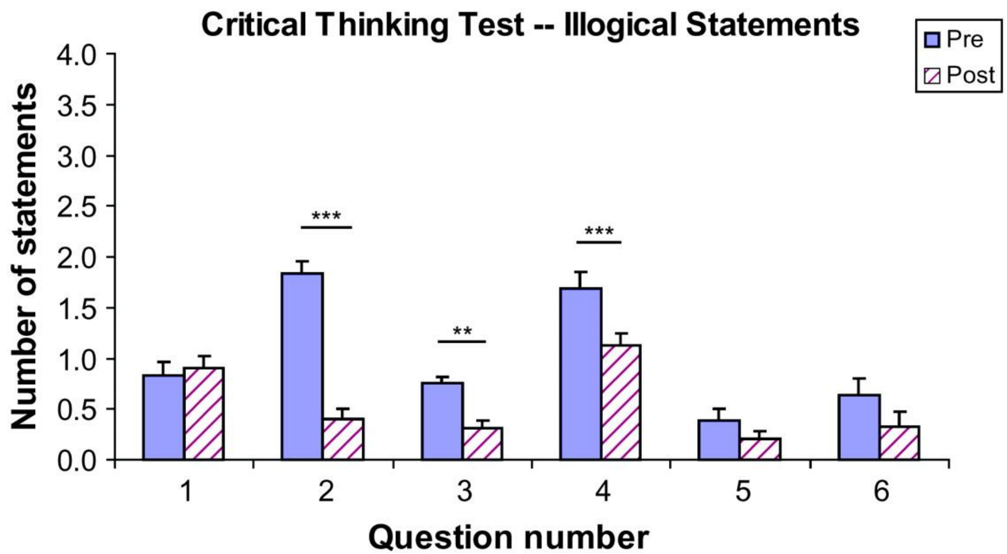
4b) For experimental tests,

The *controls* in this experiment are:

They are represented (in which part of the chart or graph, or what figure panels?)

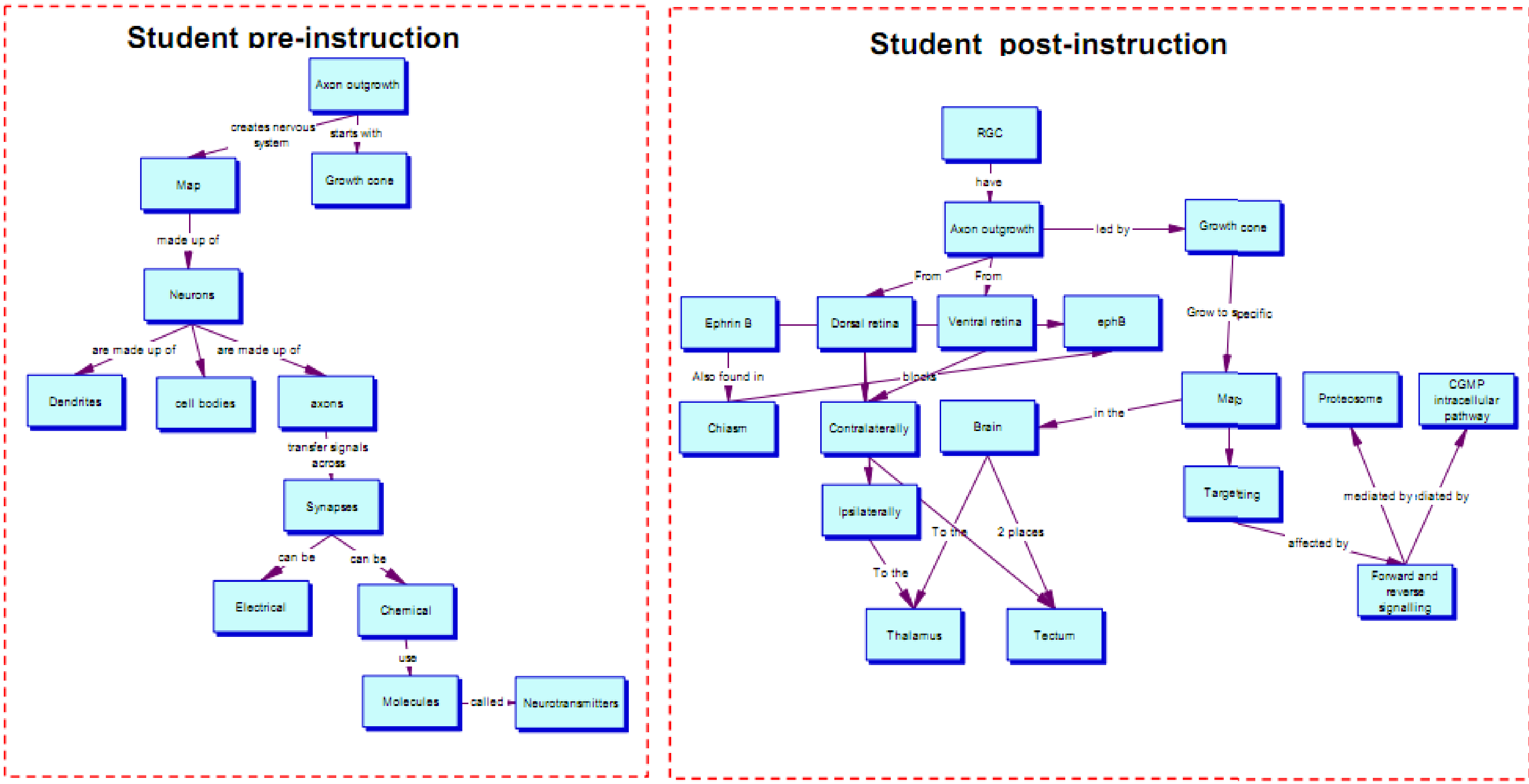
Critical Thinking Tests (CTTs)





Growth of students' concept maps

Figure S2



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Article

The C.R.E.A.T.E. Approach to Primary Literature Shifts Undergraduates' Self-Assessed Ability to Read and Analyze Journal Articles, Attitudes about Science, and Epistemological Beliefs

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The C.R.E.A.T.E. (Consider, Read, Elucidate hypotheses, Analyze and interpret data, Think of the next Experiment) method uses intensive analysis of primary literature in the undergraduate classroom to demystify and humanize science. We have reported previously that the method improves students' critical thinking and content integration abilities, while at the same time enhancing their self-reported understanding of "who does science, and why." We report here the results of an assessment that addressed C.R.E.A.T.E. students' attitudes about the nature of science, beliefs about learning, and confidence in their ability to read, analyze, and explain research articles. Using a Likert-style survey administered pre- and postcourse, we found significant changes in students' confidence in their ability to read and analyze primary literature, self-assessed understanding of the nature of science, and epistemological beliefs (e.g., their sense of whether knowledge is certain and scientific talent innate). Thus, within a single semester, the inexpensive C.R.E.A.T.E. method can shift not just students' analytical abilities and understanding of scientists as people, but can also positively affect students' confidence with analysis of primary literature, their insight into the processes of science, and their beliefs about learning.

Your guide to the tables (Hoskins et al. 2011)

Category	Survey statements	Pre/post results
Summary items	Table 2	Not presented!
Skill and attitude items (non-epistemological)	Table 3	Table 4
Skill and attitude items (epistemological)	Table 5	Table 6

Table 3. Items from the C.R.E.A.T.E. survey arranged according to a PCA with varimax rotation[a]

Factor	Item	Factor loading	Cronbach's alpha
1 Decoding Primary Literature	The scientific literature is difficult to understand (R).	0.776	
	When I see scientific journal articles, it looks like a foreign language to me (R).	0.593	
	I am not intimidated by the scientific language in journal articles.	0.558	
	I am confident in my ability to critically review scientific literature.	0.500	0.71
	I am comfortable defending my ideas about experiments.	0.328	
2 Interpreting Data	It is easy for me to transform data, like converting numbers from a table to percents.	0.796	
	If I see data in a table, it is easy for me to understand what it means.	0.680	
	If I am shown data (graphs, tables, charts), I am confident that I can figure out what it means.	0.622	0.72
	It is easy for me to relate the results of a single experiment to the big picture.	0.352	
3 Active Reading	I could make a simple diagram that provides an overview of an entire experiment.	0.763	
	If I am assigned to read a scientific paper, I typically look at the methods section to understand how the data were collected.	0.584	
	I do not know how to design a good experiment (R).	0.522	0.63
	The way that you display your data can affect whether or not people believe it.	0.345	
4 Visualization	When I read scientific information, I usually look carefully at the associated figures and tables.	0.694	
	When I read scientific material it is easy for me to visualize the experiments that were done.	0.649	0.75
	If I look at data presented in a paper, I can visualize the method that produced the data.	0.592	
	When I read a paper, I have a clear sense of what physically went on in a lab to produce the results and information I am reading.	0.584	
5 Thinking Like a Scientist	After I read a scientific paper, I don't think I could explain it to somebody else (R).	0.735	
	I am confident I could read a scientific paper and explain it to another person.	0.655	
	I enjoy thinking of additional experiments when I read scientific papers.	0.394	0.59
	I accept the information about science presented in newspaper articles without challenging it (R).	0.231	
6 Research in Context	Experiments in "model organisms" like the fruit fly have led to important advances in understanding human biology.	0.774	
	Progress in curing diseases has been made as a result of experiments on lower organisms like worms and flies.	0.597	0.35
	I understand why experiments have controls.	0.540	

[a] Items followed by an (R) are reverse-scored. Cronbach's alpha, an index of inter-item consistency, is also shown.

Your guide to the tables

Category	Survey statements	Pre/post results
Summary items	Table 2	Not presented!
Skill and attitude items (non-epistemological)	Table 3	Table 4
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Decoding Primary Literature
Interpreting Data
Active Reading
Visualization
Thinking Like a Scientist
Research in Context

Table 4. The results of paired-difference *t* tests for raw data totals for each of the six factors in Table 3

Factor	Pretest mean (SD)	Posttest mean (SD)	Statistical significance	Mean difference/ SD of the difference[a]
1	15.5 (3.6)	19.2 (2.9)	$p < 0.001$	0.93
2	13.6 (2.5)	16.4 (2.1)	$p < 0.001$	1.00
3	13.6 (2.2)	16.2 (2.4)	$p < 0.001$	0.84
4	13.2 (2.5)	15.8 (2.3)	$p < 0.001$	0.96
5	13.5 (2.3)	16.2 (2.1)	$p < 0.001$	0.97
6	12.6 (1.7)	14.0 (1.3)	$p < 0.001$	0.74

[a]Estimate of the magnitude of the effect.

Your guide to the tables

Category	Survey statements	Pre/post results
Summary items	Table 2	Not presented!
Skill and attitude items (non-epistemological)	Table 3	Table 4
Skill and attitude items (epistemological)	Table 5	Table 6

Table 6. The results of paired-difference *t* tests for items (certain knowledge, innate ability, and attitude toward science) in Table 5

Item	Pretest mean (SD)	Posttest mean (SD)	Statistical significance	Mean difference/SD of the difference[a]
Certain knowledge	19.7 (2.2)	20.7 (2.7)	$p < 0.001$	0.40
Innate ability	7.5 (1.7)	8.1 (1.5)	$p < 0.001$	0.36
Creativity	4.1 (0.85)	4.4 (0.73)	$p < 0.001$	0.30
Sense of scientists	3.1 (0.93)	3.8 (0.77)	$p < 0.001$	0.70
Sense of motives	3.6 (0.95)	4.0 (1.0)	$p < 0.001$	0.31
Known outcomes	4.0 (0.82)	4.3 (0.81)	$p < 0.001$	0.30
Collaboration	4.4 (0.73)	4.6 (.66)	$p < 0.006$	0.22

[a]Estimate of the magnitude of the effect.

e.g., “If two different groups of scientists study the same question, they will come to similar conclusions.” (R)

“Scientists usually know what the outcome of their experiments will be.” (R)

My view of C.R.E.A.T.E.

Most useful:

- paper series from one lab
- focus on a small # of papers
- figure analysis worksheets
- concept mapping/cartooning

Less useful:

- paper series from one lab
- hiding parts of papers
- complexity of figure worksheets

Figure Facts

- Figure Facts: Encouraging Undergraduates to Take a Data-Centered Approach to Reading Primary Literature
  - Jennifer E. Round & A. Malcolm Campbell, *CBE-Life Sciences Education* **12**: 39-46, 2013
  - "To enhance their data interpretation skills, students used a template called 'Figure Facts' to assist them with primary literature–based reading assignments in an advanced cellular neuroscience course. The Figure Facts template encourages students to adopt a data-centric approach, rather than a text-based approach, to understand research articles. Specifically, Figure Facts requires students to focus on the experimental data presented in each figure and identify specific conclusions that may be drawn from those results."

Figure 1. The Figure Facts Template.

Name: **Author/Year:**

Broad Topic:
Specific Topic:
What is Known:
Experimental Question:

	Panel	Technique:	These data show:
Figure 1			
Figure 2			
Figure 3			
Figure 4			
Figure 5			

Name: Sara Student **Author/Year:** Ripley 2011

Broad Topic: Synapse Stability
Specific Topic: Retrograde signaling to axon
What is Known: Postsynaptic side talks to presynaptic side
Experimental Question: Does retrograde AMPA signaling stabilize synapses?

	Panel	Technique:	These data show:
Figure 1	**A**	Transfected neurons w/ GFP	Transfection was successful
	B	Immunostained for PSD95	Synapses were formed
	C	Counted stable vs. transient puncta	80% of synapse were transient
	D	Stained for AMPA receptors	Stable synapses are AMPAR+
Figure 2	**A**	Transfected dominant-neg form of AMPARs	Transfection was successful
	B	Stained for DN-AMPARS and PSD95	DN-APMARs localize to the postsynaptic membrane
Figure 3	**A**	Counted stable puncta in DN-AMPAR+ neurons	Neurons with DN construct had fewerstable puncta. AMPAR contributes to synaptic stability.
	B	Overexpressed STG in wild-type neurons and counted stable puncta	More stable puncta observed. STG contributes to synapse stability

Round J E , and Campbell A M CBE Life Sci Educ 2013;12:39-46

Figure Facts: findings

- Increased time spent on figures
- Improvement in data interpretation (see Fig. 3)
- Positive opinion of template

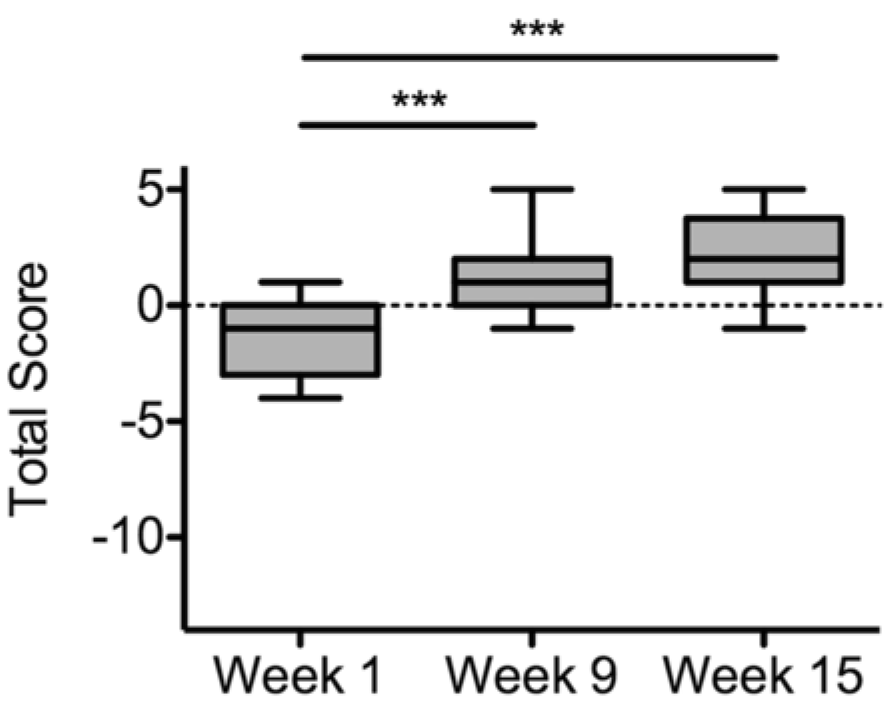

Figure 3.
Students interpreted novel data sets more accurately at weeks 9 and 15.
***, $p < 0.001$ by paired t test; $n = 16$.

My view of Figure Facts

Most useful:

- focus on figures
- simplicity of template

Less useful:

- focus on figures to the exclusion of everything else

My worksheets

- Like Figure Facts template, but also . . .
  - More general conceptual questions
  - Student cartooning
  - Data tables (treated like figures)
  - Varied format from paper to paper