

# Comparing post-course retention of conceptual and procedural knowledge in genetics

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# Project Outline

**Goal:** To assess retention of conceptual knowledge versus procedural knowledge after students completed the second year Fundamentals of Genetics course (BIOL 234).

- Former 234 students were recruited to write the conceptual test<sup>1,2</sup> as well as open-ended questions typical of the problem solving questions on midterms and the course final exam (procedural test).
- Students had completed the course 2.5 to 3 months prior to retention testing.
- The 44 students who volunteered for retention testing were self-selected from 441 students that completed Biology 234 in December 2012.

# Testing Schedule

Sept 2012

- Concept Inventory **Pre-Test**, first day of class
- Midterm 1
- Midterm 2

Dec 2012

- Concept Inventory **Post-Test**, last day of class
- Final Exam

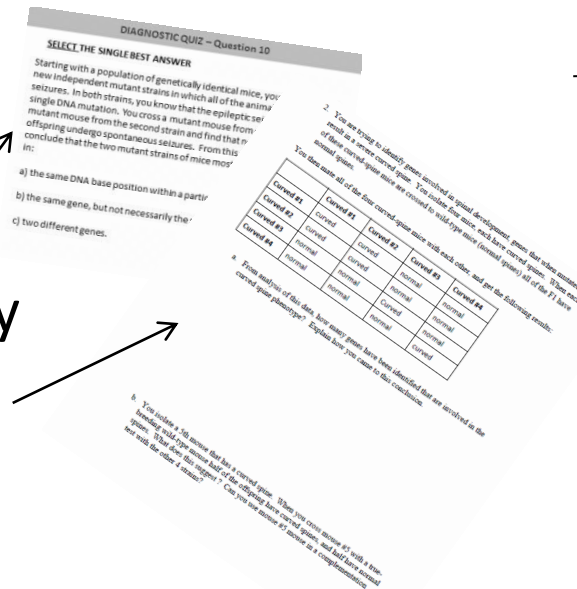
Feb/Mar 2012

## Retention Test

- Concept Inventory
- Procedural Exam

Entire Class  
(n=441)

44 self-selected students



# Results – Concept Inventory Test

**Table 1.** Summary of student performance on the concept inventory test (CI). Average scores were calculated for the whole class (n=406 pre-test, n=400 post-test) and for the self-selected volunteers who participated in retention testing (n=44). Standard deviations are in parentheses.

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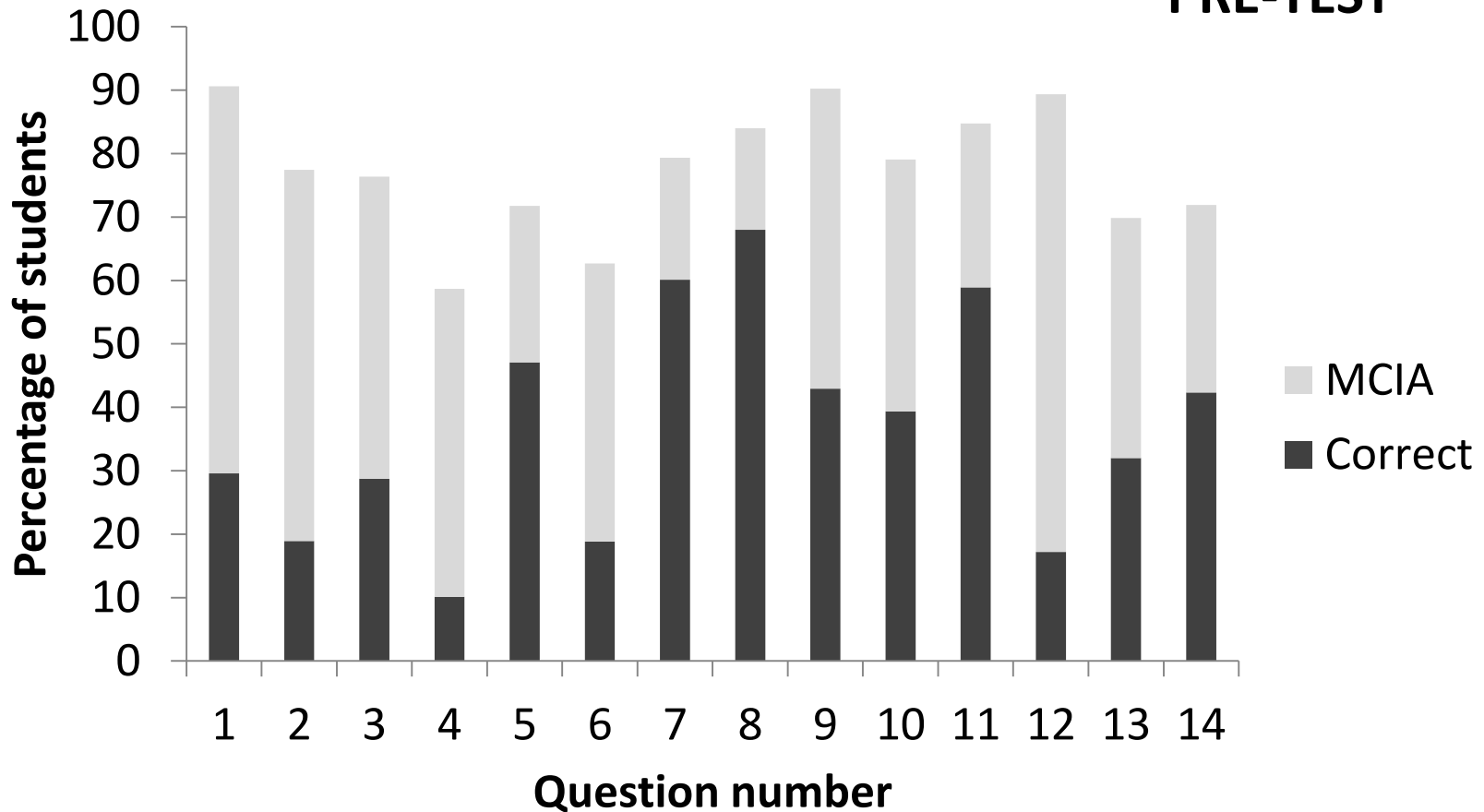
	234 Class	Retention Volunteers
CI Pre-Test	36 % (17)	36% (17)
CI Post-Test	71% (17)	73% (22)
CI Retention Test		72% (20)

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# Results – Concept Inventory Test

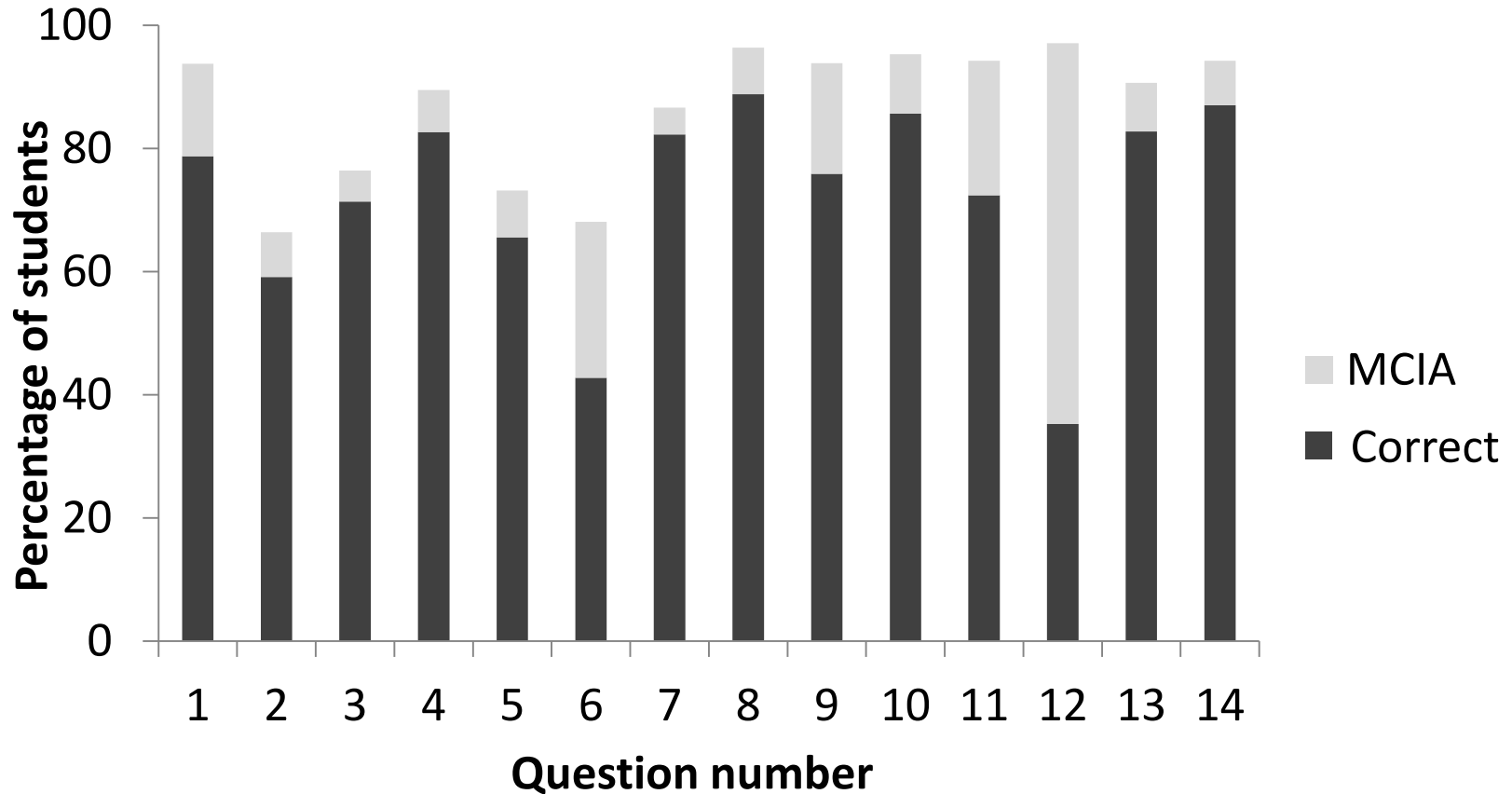
- The matched students (wrote both the pre- and post- test, n=257) made significant gains on the concept inventory with an average normalized change of 46%.
- Comparing pre-test and post-test student responses patterns shows movement away from the most commonly chosen incorrect answer (MCIA) (**Figure 1 & 2**).
- The self-selected volunteer group had a higher normalized change (55%) compared to the class population and performed better on all other assessments. This group showed significant retention of conceptual knowledge based on CI scores (**Figure 3**).

## Concept Inventory PRE-TEST

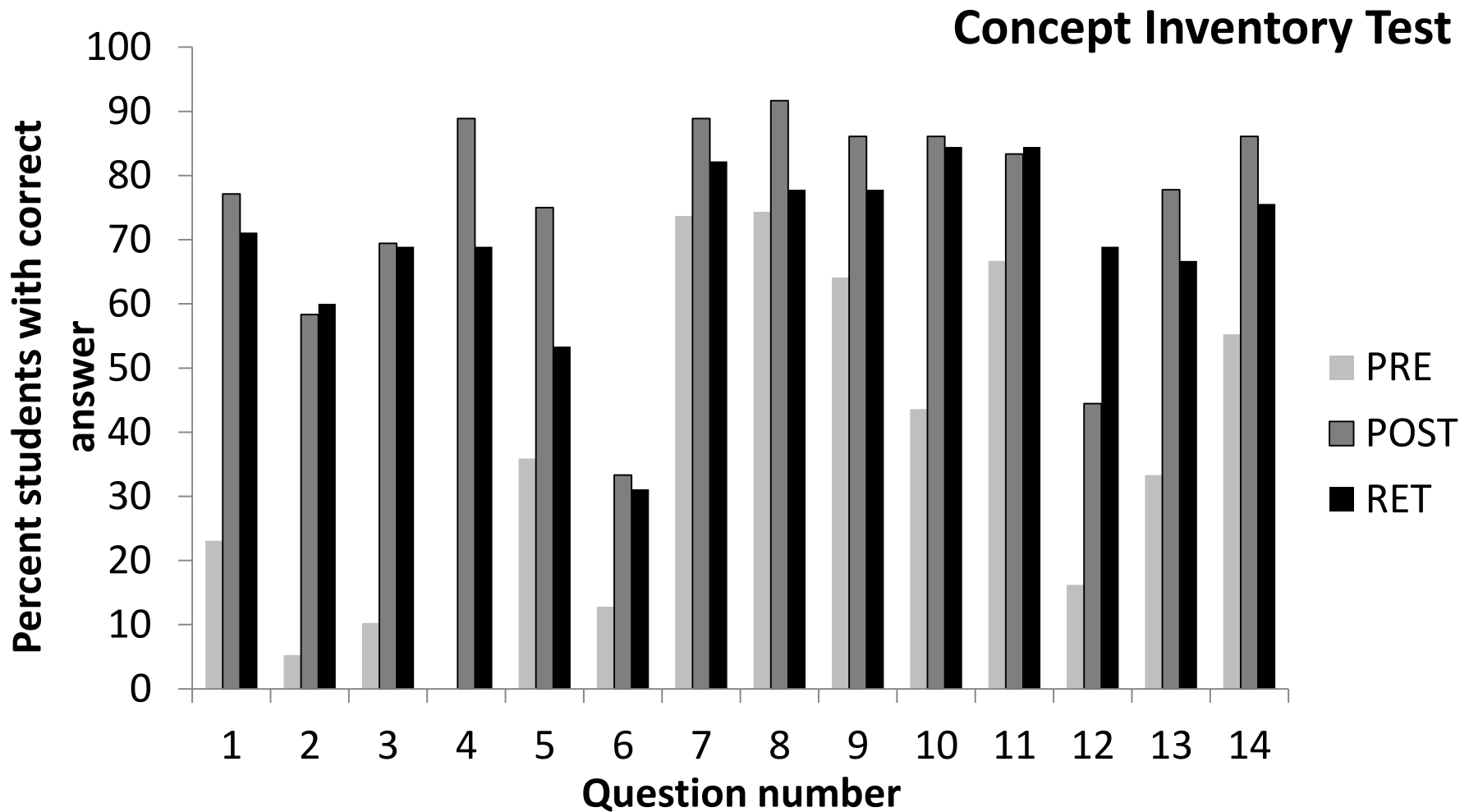


**Figure 1.** Percentage of students who selected the correct answer (dark bars), and the most common incorrect answer (MCIA, light bars) for each question of the concept inventory (CI) pre-test in BIOL234 Fall 2012 (N=270, matched students only).

## Concept Inventory POST-TEST



**Figure 2.** Percentage of students who selected the correct answer (dark bars), and the most common incorrect answer (MCIA, light bars) for each question of the post-test in BIOL234 Fall 2012 (N=270, matched students only).



**Figure 3.** Percentage of students selecting the correct answer for each question in the pre-test (PRE), post-test (POST), and during the retention test (RET) concept inventory test. The students who participated in this study were self-selected volunteers (N=44, retention group only).

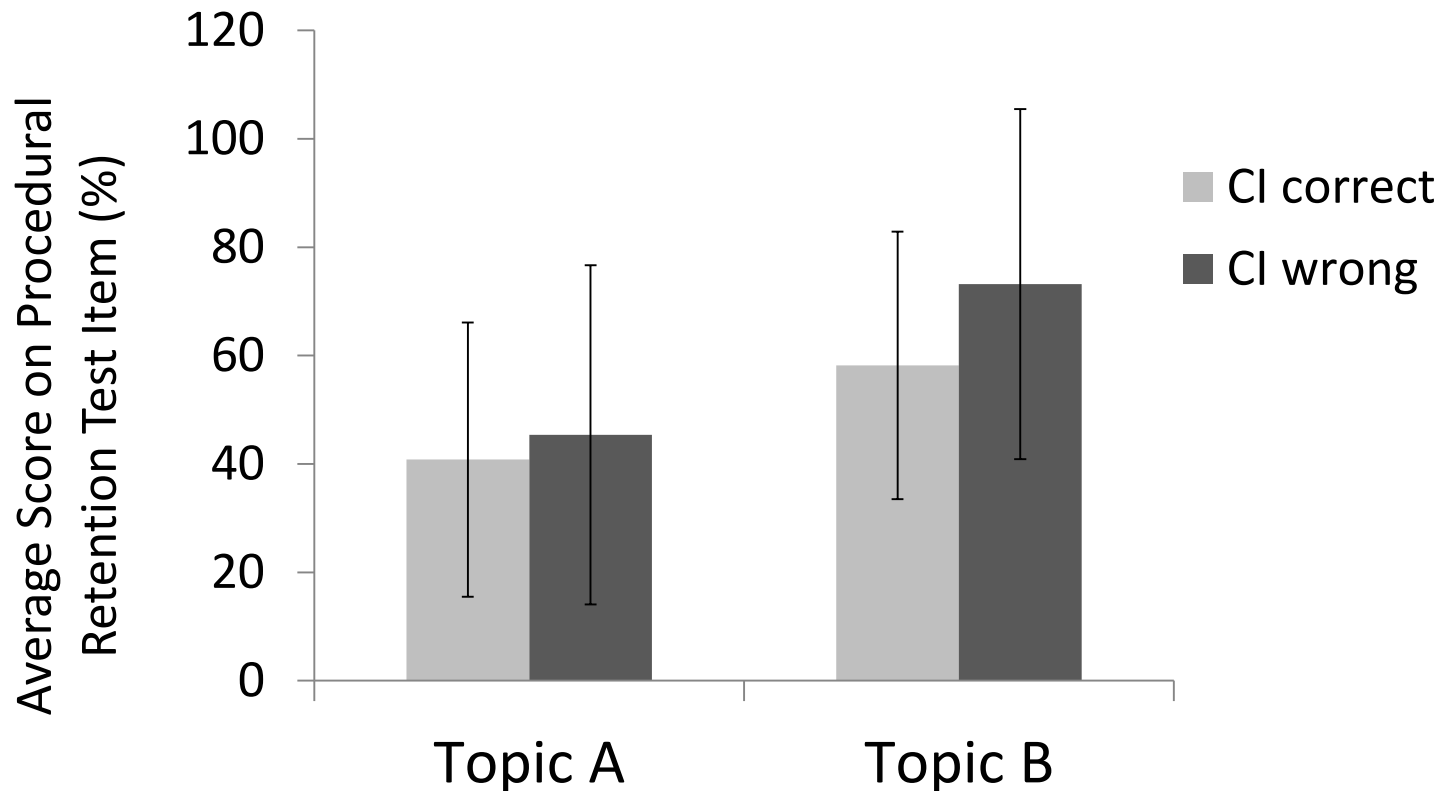


# Results – Retention Testing

- The average score on the CI retention test was not statistically different from the average core on the CI post test written during the 2012 term.
- CI retention scores were significantly higher than the average score on the retention procedural test (t-test  $P < 0.01$ ). Average final exam scores are presented for comparison (n=44 for all values).

	Average Score (SD)
CI Post-Test	73.1 % (22.5)
CI Retention	72.1% (17.4)
Final Exam	76.5 % (10.5)
Procedural Retention	50.5 % (15.6)

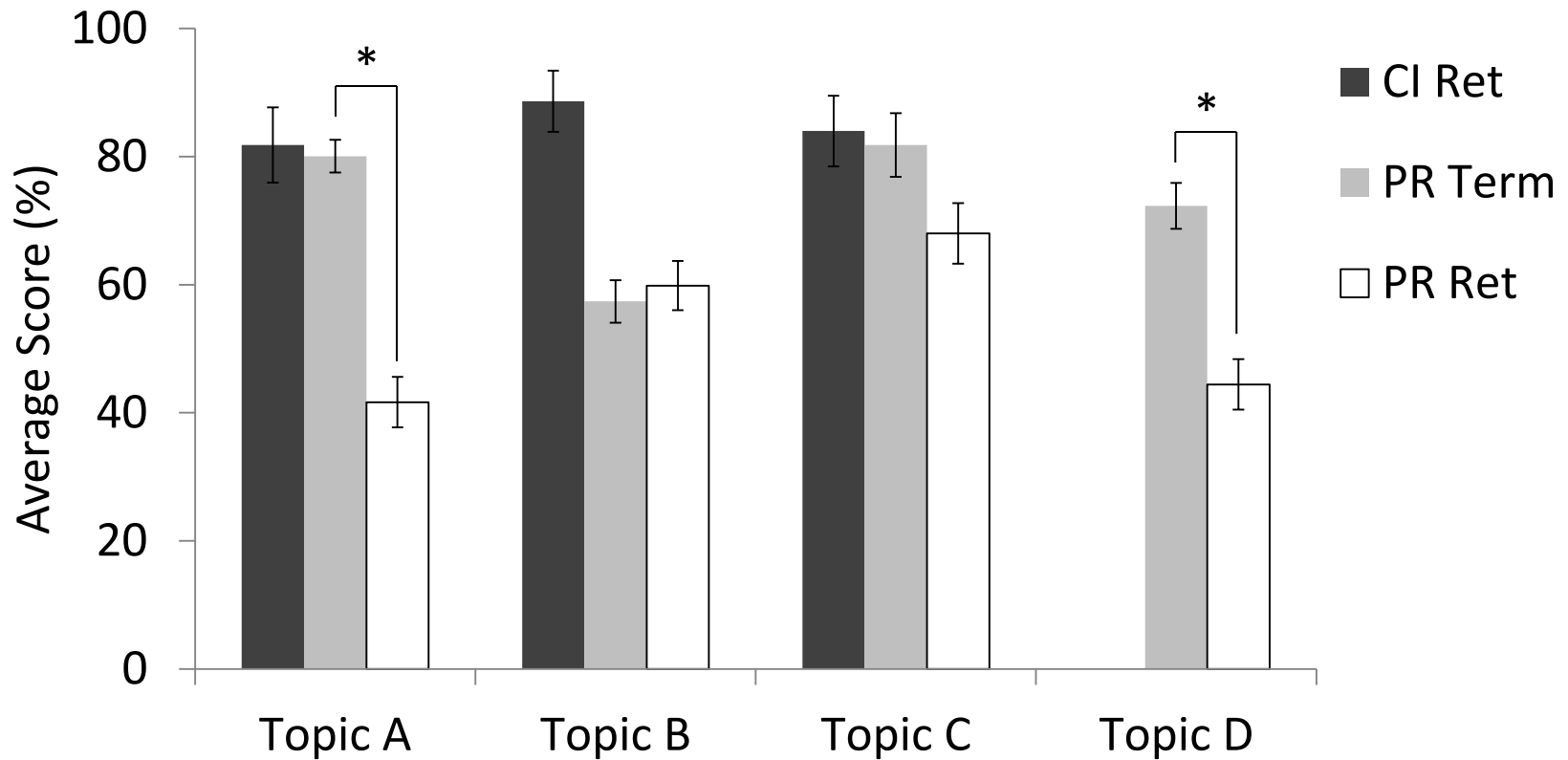
- Student scores on the conceptual test were not correlated to performance on the procedural test (**Figure 4**).



**Figure 4.** Selecting the correct response on the concept inventory test is not correlated with performance on the associated procedural test item. The average score for two procedural items are shown here: Topic A (genetic linkage) and Topic B (genetic complementation). Students were sorted based on selecting the correct answer on the associated inventory question (CI correct) or the incorrect answer (CI wrong). Error bars are standard deviation (CI correct  $n=36$  (Topic A) or  $39$  (B), CI wrong  $n=8$  (A) or  $5$  (B). Independent T-test  $p > 0.05$ .

# Results – Conceptual vs. Procedural

- Four topics were tested on the procedural retention test which could be matched to at least three questions on the concept inventory test.
  - Retention of procedural knowledge was significantly lower than that of conceptual knowledge when comparing scores on the matched CI and procedural retention test questions.
- Performance on procedural test items was significantly reduced for some topics when comparing scores on matched test items from midterms/final exams and the procedural retention test (**Figure 5**).



**Figure 5.** Comparison of average student performance on test items from the concept inventory, midterms/final exams and procedural retention test. Test items are matched based on the concept being tested and required to solve a problem. CI Ret – Concept Inventory Retention Test Item; PR-Term – Procedural Test Item from midterms or final exam; PR-Ret – Procedural Retention Test Item. Topic A – Genetic Linkage; Topic B – Genetic Complementation; Topic C- Gene Interaction; Topic D – Inheritance (Pedigree Analysis). Error bars are standard deviation. \*Indicates t-test  $p < 0.01$ .

# Conceptual Understanding vs. Problem Solving

## DIAGNOSTIC QUIZ – Question 10

### SELECT THE SINGLE BEST ANSWER

Starting with a population of genetically identical mice, you discover two new independent mutant strains in which all of the animals have epileptic seizures. In both strains, you know that the epileptic seizures are due to a single DNA mutation. You cross a mutant mouse from one strain to a mutant mouse from the second strain and find that none of their many offspring undergo spontaneous seizures. From this experiment you would conclude that the two mutant strains of mice most likely have mutations in:

- a) the same DNA base position within a particular gene.
- b) the same gene, but not necessarily the same.
- c) two different genes.

2. You are trying to identify genes involved in spinal development. Genes that when mutated result in a severe curved spine. You isolate four mice, each have curved spines. When each of these curved-spine mice are crossed to wild-type mice (normal spines) all of the F1 have normal spines.

You then mate all of the four curved-spine mice with each other, and get the following results:

	Curved #1	Curved #2	Curved #3	Curved #4
Curved #1	curved	curved	normal	normal
Curved #2	curved	curved	normal	normal
Curved #3	normal	normal	Curved	normal
Curved #4	normal	normal	normal	curved

a. From analysis of this data, how many genes have been identified that are involved in the curved spine phenotype? Explain how you came to this conclusion.

b. You isolate a 5th mouse that has a curved spine. When you cross mouse #5 with a true-breeding wild-type mouse half of the offspring have curved spines, and half have normal spines. What does this suggest? Can you use mouse #5 mouse in a complementation test with the other 4 strains?

## Testing Conceptual Understanding

Concept Inventory - 89%

Part a of Final Exam - 92%

Part a of Procedural Test - 73%

## Testing Problem Solving

Part b of Final Exam – 57%

Part b of Procedural Test – 47%

Student test scores indicate conceptual understanding but reduced success at applying the concept to solve a problem.

# Summary

- The students tested had greater retention of conceptual knowledge compared to procedural knowledge.
- Conceptual understanding does not necessarily correlate with procedural or problem solving performance.
- Focusing class time to encourage a deep conceptual understanding may promote longer term retention.
- Necessary procedural knowledge may require more spread-out practice (or remedial work).

Thank you to all the 234 student volunteers for your time. To Carl Wieman, Sarah Gilbert, Trish Schulte and the Life Sciences CWSEI group for helpful feedback. To Jennifer Klenz and George Haughn for providing class time for the concept inventory test.

Questions about this work? Please contact:

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Cited work:

1 Smith, M., Knight, J, and Wood, W. 2008. The Genetics Concept Assessment: A New Concept Inventory for Gauging Student Understanding of Genetics. CBE-Life Sciences Education 7(4): 422-430.

2 Kalas, P., O'Neill, A., Pollock, C., and Birol, G. 2012. Development and Application of a Meiosis Concept Inventory. Submitted for review to Cell Biology Education, Oct 2012.