Strengthening and Reinforcing Quantitative Reasoning Skills in Biology Courses at a Large Urban Community College

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Bronx Community College

- Urban Campus
  - Part of the City University of New York
  - Open enrollment policy
  - Aging campus
- Approximately 11,000 students
  - Predominantly low-income and minority
  - Most require remedial coursework in math, reading, and writing

Project Rationale

- QL skills are essential for understanding biology
- The transfer of skills from one discipline to another by students is a separate skill and is actually less common than educators expect
- Faculty members had made the assumption that students had learned the necessary QL skills prior to taking biology classes and would be able to apply them in a biology setting, but observations proved otherwise
- *Therefore*: Biology faculty members needed to take a more active role in teaching & reinforcing QL skills

Project Overview

- Goal: Integrating and reinforcing quantitative reasoning skills
- Courses: Introductory courses taught by multiple professors in multiple sections
- Method:
  - Identify the 1 or 2 of the most important QL skills in each course
  - Integrate several modules into the course that reinforce the same QL skill over the semester
- Assessment: Student learning assessed through cognitive and analytical pre- & post-tests

Project Schedule & Participation

Course	First Semester	2nd Semester (revised modules)
Introductory General Biology I	8 out of 13 sections	10 out of 13 sections
Introductory General Biology II	3 out of 5 sections	2 out of 4 sections
Anatomy & Physiology II	10 out of 17 sections	16 out of 19 Sections

Introductory General Biology I & II

GRAPH CREATION

GRAPH INTERPRETATION

PROBABILITY

Introductory General Biology I & II

- Introductory General Biology, 2-course sequence
- General Biology I is a requirement for Ornamental Horticulture, Animal Care, Liberal Arts-Biology
- ~16 sections/semester with ~450 total students per semester
- Students must have completed all remedial requirements prior to enrolling in this sequence
- Skills emphasized:
  - Graph interpretation (I & II)
  - Graph creation (I only)
  - Probability (II only)

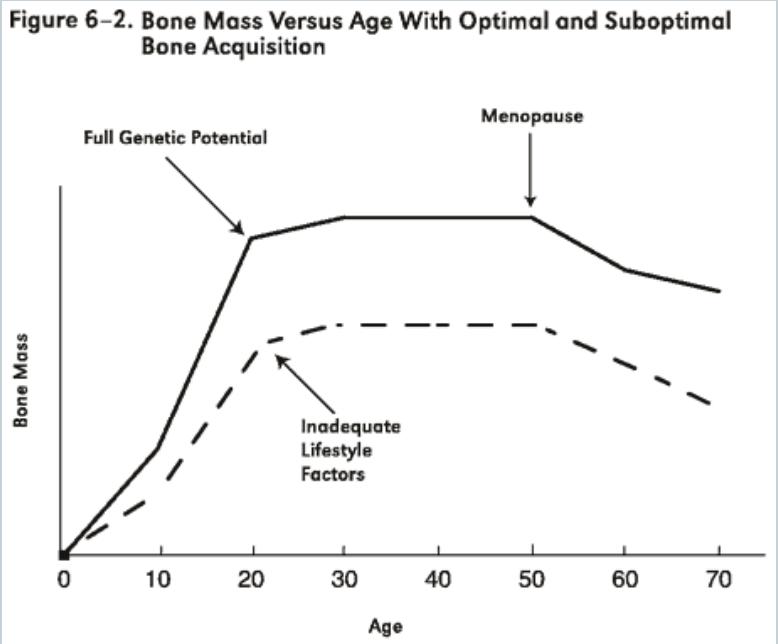
Introductory General Biology - Modules

- Measurement and the Metric System (distance, mass, volume)
- The pH Scale and Hydrogen Ion Concentration (graph interpretation)
- The Protein Concentration Curve (graph creation)
- Osmosis (graph creation and calculating the rate of osmosis)
- Enzymes (graph creation)
- The Photosynthesis Lab (graph creation)
- The Skeletal System – Bone Health (graph interpretation)
- The Fetal Pig (graph creation)
- Meiosis (graph interpretation)
- Simple Genetics Problems (probability)
- The Hyperfly Lab (probability)
- Difficult Genetics Problems (probability)
- DNA Fingerprinting – Determining DNA Fragment Size (graph interpretation)
- Bacterial Transformation (calculating transformation efficiency)
- Human Evolution and Adaptation (measuring skull features using calipers, averaging)

Example module – Graph Interpretation

1) What is the UNIT of the independent variable?
   a) 10
   b) Mass
   c) Time
   d) grams
   e) years

2) What is the dependent variable?
   a) Factors
   b) Age
   c) Bone mass
   d) Potential
   e) Menopause



3) Which of the following statements BEST summarizes the main conclusion that you can draw from this graph?
   a) Bone mass increases with age
   b) Bone mass decreases with age
   c) Inadequate lifestyle factors (not enough calcium, not enough weight-bearing exercise) reduce bone mass
   d) Men have higher bone density than women
   e) The onset of menopause increases bone mass

Example module – Graph Creation

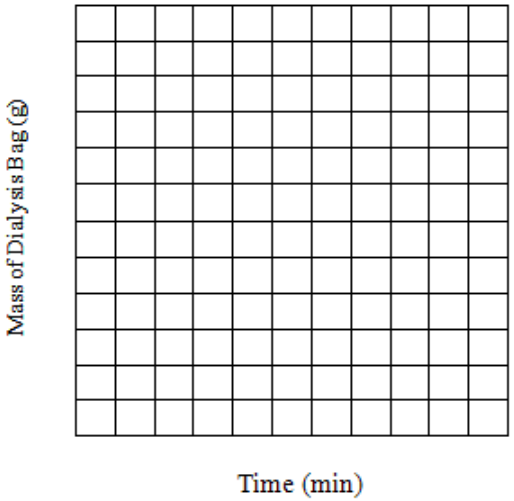
During the Osmosis lab, students:

- Set up the experiment
- Measure mass & record in table
- Calculate the rate of osmosis
- Graph data
- Answer questions interpreting the data/graphs

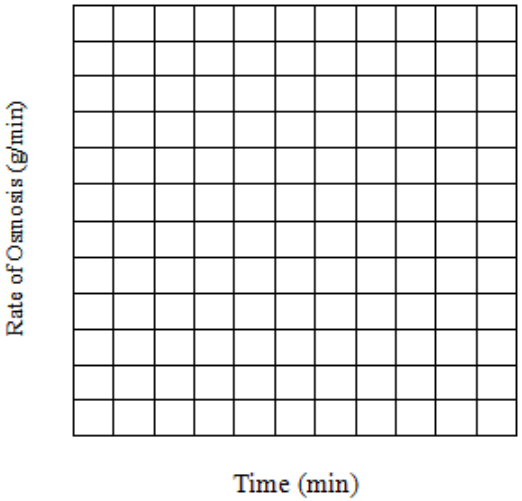
Table 9.3C: Change in Mass for Artificial Cells in Isotonic, Hypotonic, and Hypertonic Solutions

	Bag #1		Bag #2		Bag #3	
Time (min)	Mass (g)	Rate of Osmosis (g/min)	Mass (g)	Rate of Osmosis (g/min)	Mass (g)	Rate of Osmosis (g/min)
0		N/A		N/A		N/A
15		(Bag #1 mass at 15 min – Bag #1 mass at 0 min) / 15 min		(Bag #2 mass at 15 min – Bag #2 mass at 0 min) / 15 min		(Bag #3 mass at 15 min – Bag #3 mass at 0 min) / 15 min
30		(Bag #1 mass at 30 min – Bag #1 mass at 0 min) / 30 min		(Bag #2 mass at 30 min – Bag #2 mass at 0 min) / 30 min		(Bag #3 mass at 30 min – Bag #3 mass at 0 min) / 30 min
45		(Bag #1 mass at 45 min – Bag #1 mass at 0 min) / 45 min		(Bag #2 mass at 45 min – Bag #2 mass at 0 min) / 45 min		(Bag #3 mass at 45 min – Bag #3 mass at 0 min) / 45 min
60		(Bag #1 mass at 60 min – Bag #1 mass at 0 min) / 60 min		(Bag #2 mass at 60 min – Bag #2 mass at 0 min) / 60 min		(Bag #3 mass at 60 min – Bag #3 mass at 0 min) / 60 min

Graph 9.4A.



Graph 9.4B.



Introductory General Biology Assessment

- Oral evaluation during class based on whether the students can answer questions related to graph interpretation

- Administration of pre- and post- tests to evaluate:
  - a) Students' self-confidence (3 to 4 cognitive questions)
  - b) Student's skill levels (4 to 5 analytical questions)

Assessment: self-confidence

A- **Pre-Self-Perception Survey** – *Select the description that best fits your comfort level with the math skill.*

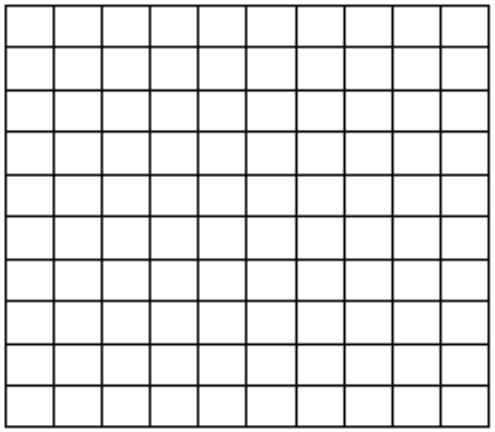
		Feel very confident	Feel confident	Am not sure	Feel insecure	Feel very insecure	Have no clue
1	I _____ that I can understand and explain a line graph. At right is an example line graph: 	O	O	O	O	O	O
2	I _____ that I can make a line graph correctly (which includes appropriately assigning a title to the graph, labeling the axes properly, deciding the right units and scale, and drawing the graph from given data).	O	O	O	O	O	O
3	I _____ that I can use arithmetic (addition, subtraction, multiplication, and division) to determine answers to real-world questions (like which grocery store has the best prices).	O	O	O	O	O	O
4	I _____ that I understand and can determine the probability of events occurring (like the probability of two parents having a blond child).	O	O	O	O	O	O

Assessment: QL Skills (Gen Bio I only)

4. You run to the store to pick up soda on the way to a friend's party. The 12-packs are on sale for $4.29 each. Assume there's no tax on beverages. You want to get as many different types of soda as possible - and there are 6 types at the store. You have one $20 bill, one $5 bill and two $1 bills. Can you get all 6 types of soda? If you can, which of the bills do you need to use? If you can't, how many types can you get?
    a. No, you can only buy 5 of the 6 types of soda
    b. Yes, you can buy all 6 types using the $20 bill and two $1 bills
    c. Yes, you can buy all 6 types using the $20 bill and the $5 bill
    d. Yes, you can buy all 6 types using the $20 bill, the $5 bill, and one $1 bill
    e. Yes, you can buy all 6 types using all of the bills

5. You run a series of standards on the spectro-photometer & get the following data. **Graph** the protein concentration curve. Be sure to **label** the axes appropriately. In addition, **identify** the independent and dependent variables.

standard	Protein conc (mg/l)	Absorbance
1	0	0
2	100	0.1
3	200	0.4
4	300	0.5
5	400	0.8
6	500	0.9



Assessment: QL Skills (Gen Bio II only)

5. The DNA molecule only has four nitrogenous bases (A, C, T, & G). A and T are always present in equal amounts and C & G are always present in equal amounts. If a DNA molecule has 10% G, then what percentage of A does it have?

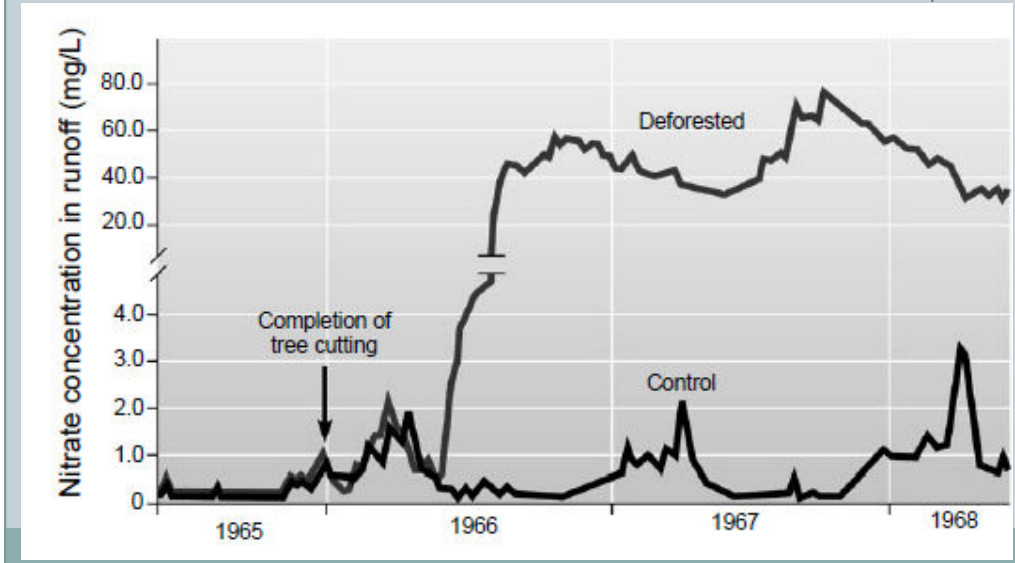
a. 10 %
b. 20 %
c. 30 %
d. 40 %
e. 50 %
f. 60 %
g. 70 %
h. 80 %
i. 90 %

6. Every human has two copies of each gene - one from his mother & one from his father. So a blue-eyed man would have his genes for eye color symbolized as "bb" and a brown-eyed woman would be symbolized by "BB" or "Bb". If the bb man had a child with a Bb woman, what is the probability that the child will have blue eyes (bb)?

a. 0 % b. 25 % c. 50 % d. 75 % e. 100 %

Assessment: QL Skills (Gen Bio I & II)

- This graph shows the results of a study in which the amount of nitrate in the water at the bottom of a deforested slope (deforested watershed) was compared to the amount of nitrate in the water at the bottom of a slope in which the trees were left alone (control watershed).



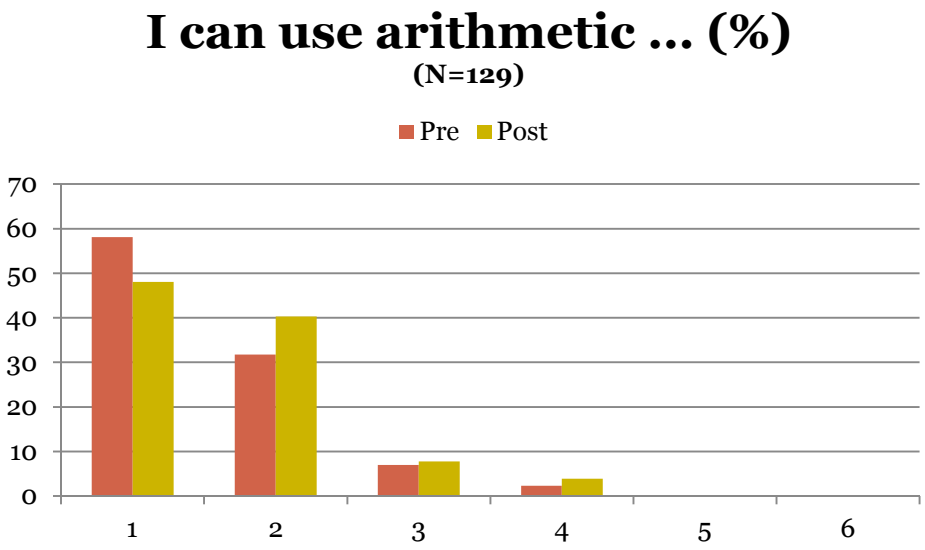
- Which is the independent variable in this graph?
  - Control
  - Deforested
  - Nitrate concentration
  - Time
  - Tree cutting
- What is the **UNIT** of the dependent variable in this graph?
  - Concentration
  - Control
  - Deforested
  - Liters
  - Milligrams
  - Milligrams/Liter
  - Year

What conclusion does this graph **BEST** illustrate?

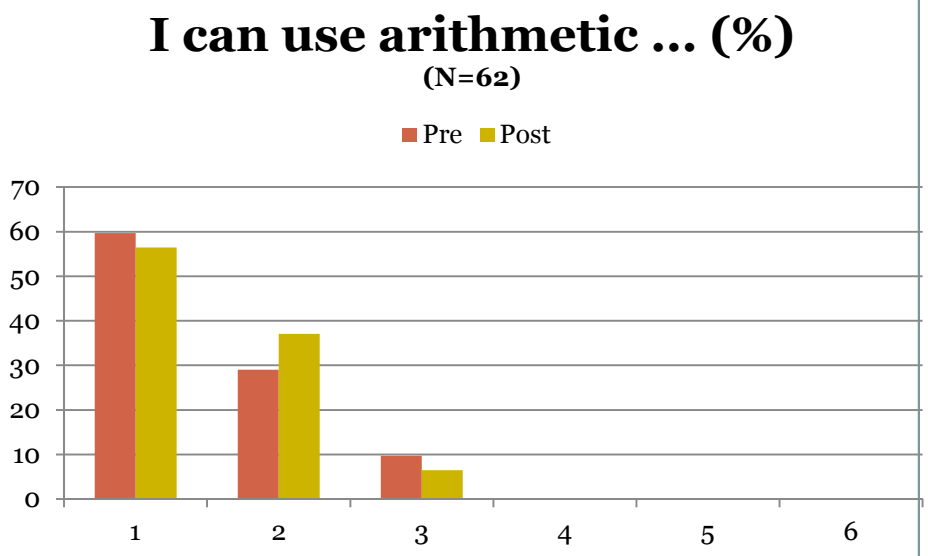
- Nitrate is an important limiting nutrient for trees.
- Carbon is more important than Nitrogen.
- Cutting trees causes deforestation.
- Cutting trees increases the amount of Nitrogen lost from a watershed.
- More rain increases the loss of Nitrate from a watershed.

Gen Bio I: Student Self-Perception

Spring 2009



Spring 2010

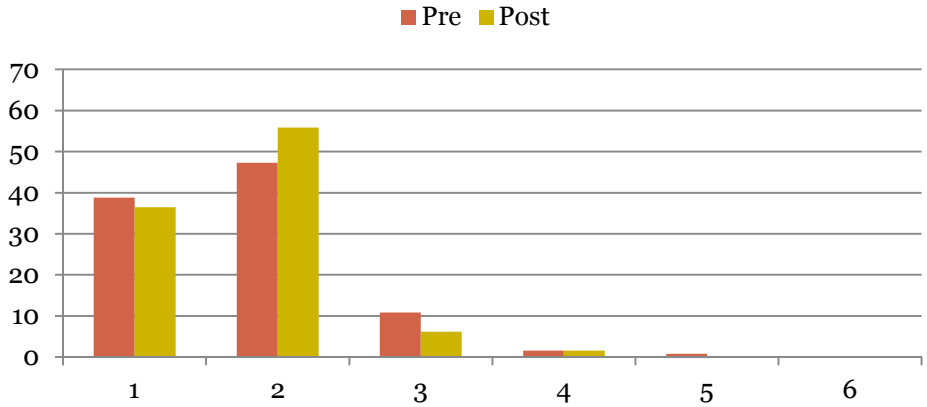


Level of Confidence:
1-feel very confident
2-feel confident
3-am not sure
4-feel insecure
5-feel very insecure
6-have no clue

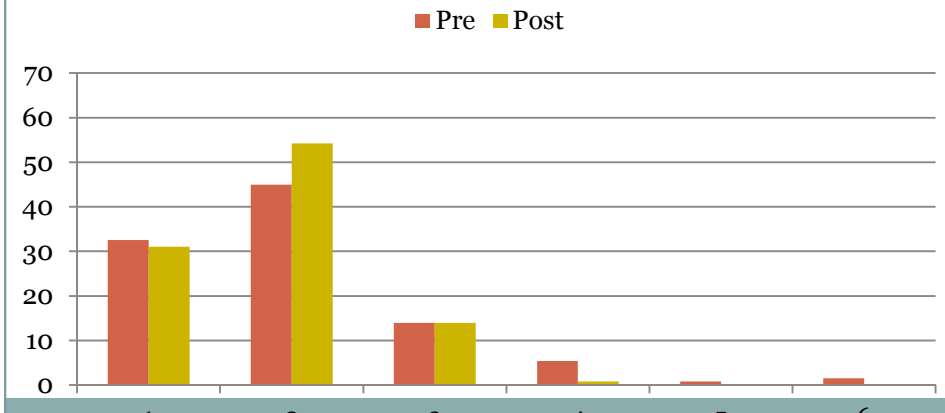
Gen Bio I: Student Self-Perception

Spring 2009

I can understand a line graph ... (%) (N=129)

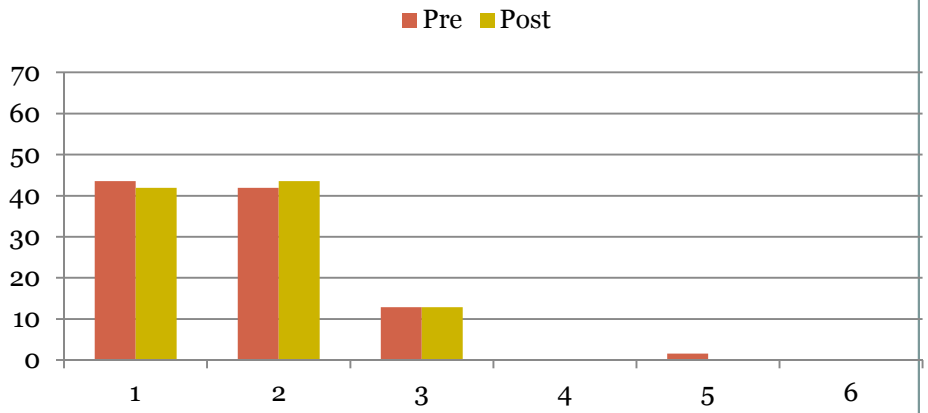


I can make a line graph ... (%) (N=129)

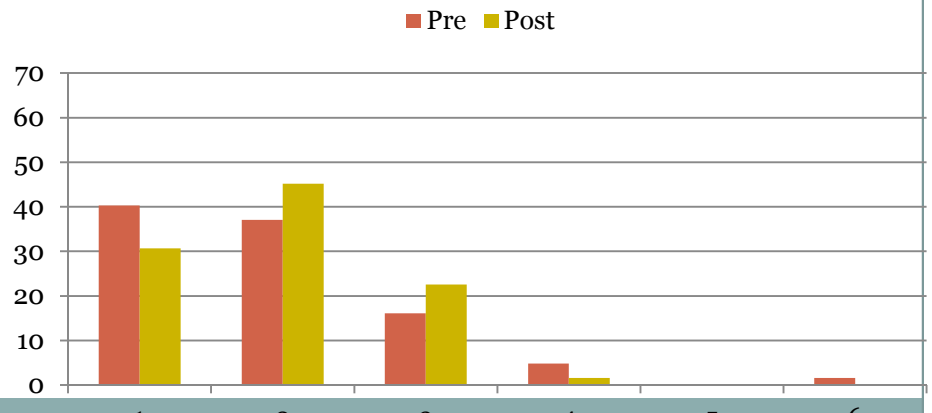


Spring 2010

I can understand a line graph ... (%) (N=62)

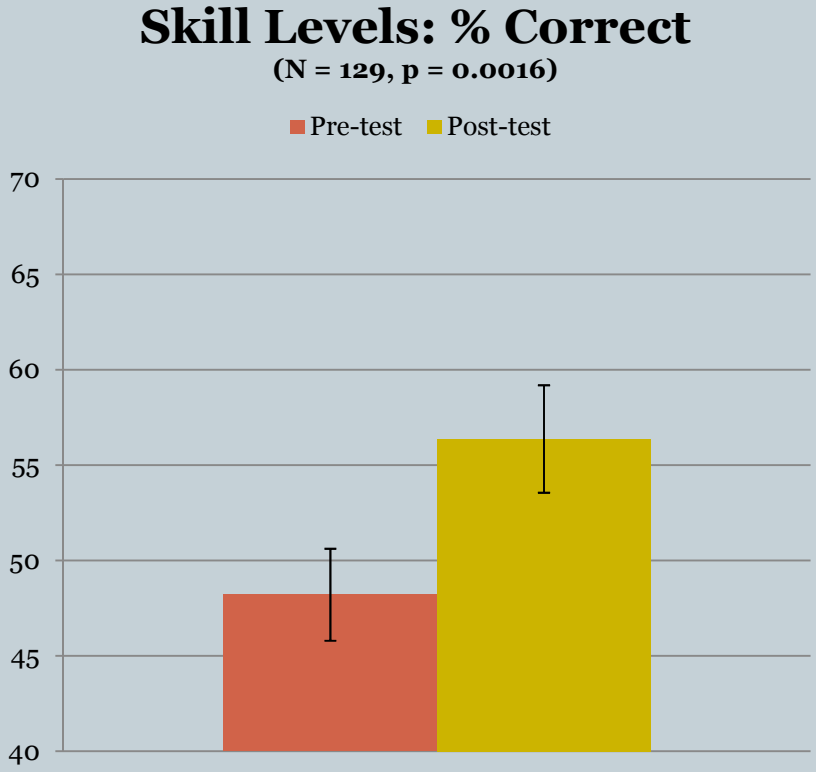


I can make a line graph ... (%) (N=62)

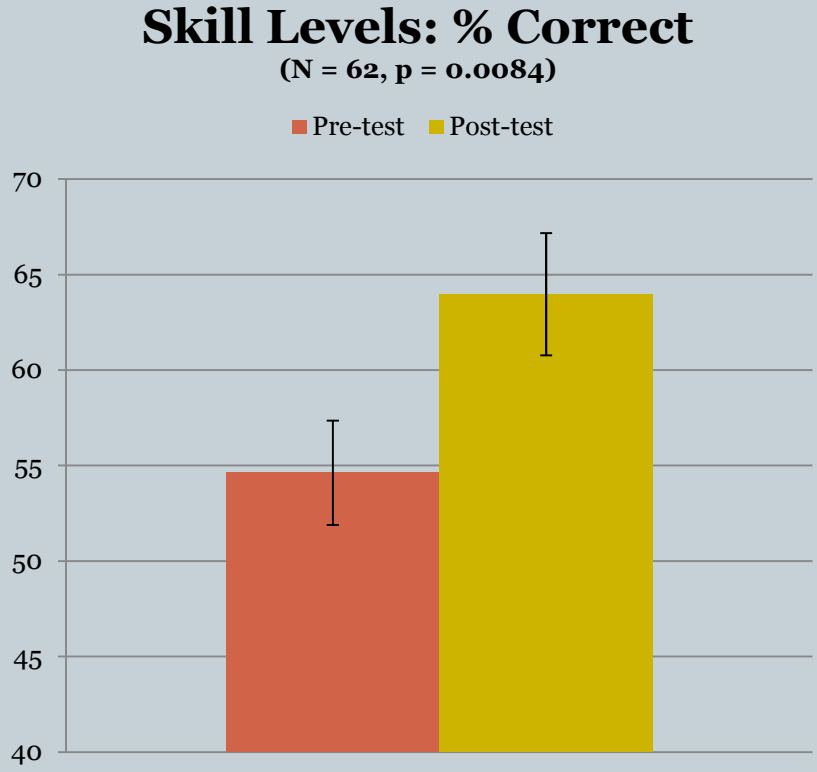


Gen Bio I: Student Skill Levels

Spring 2009

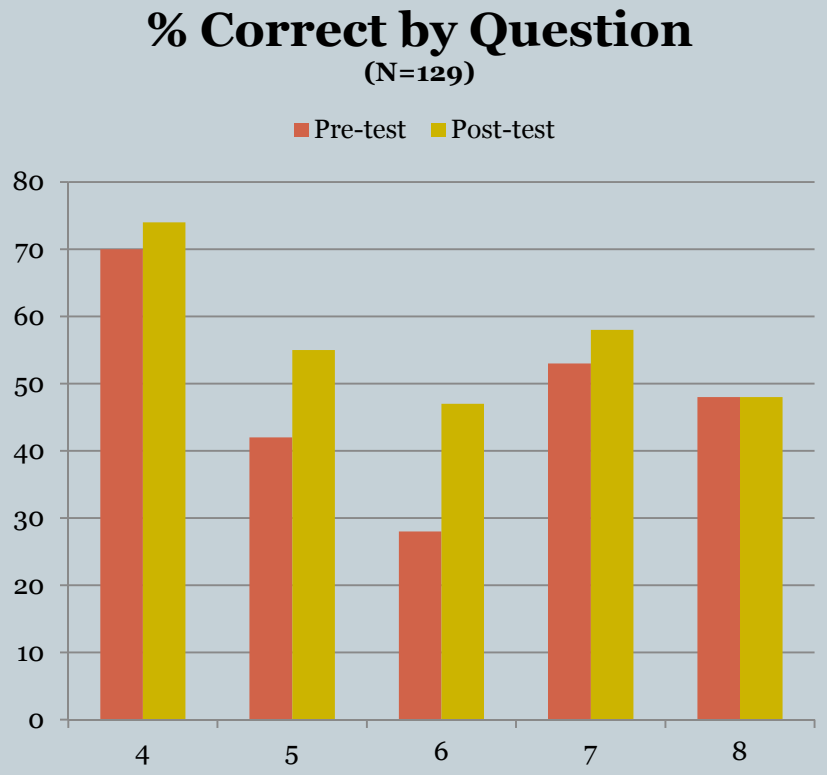


Spring 2010

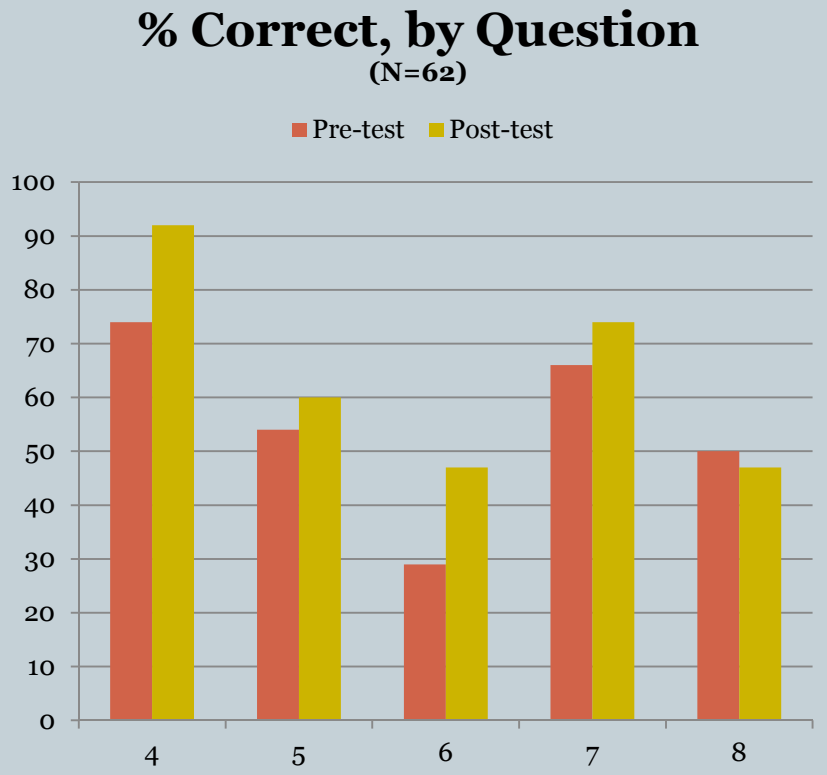


Gen Bio I: Student Skill Levels, by Question

Spring 2009



Spring 2010



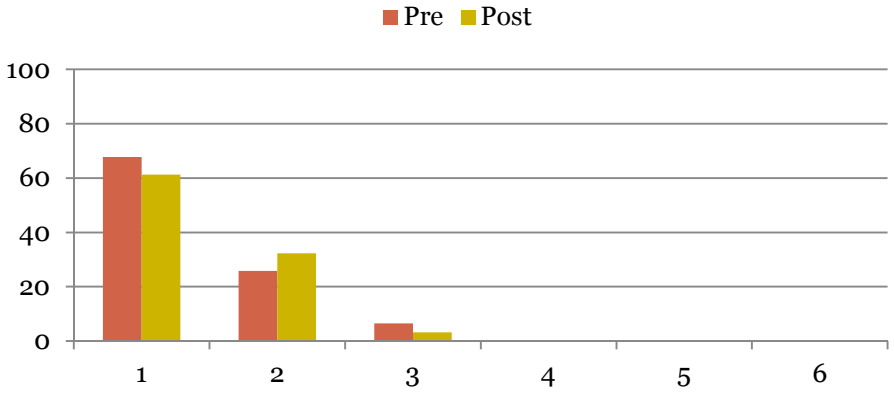
Gen Bio I: Results

- All students overestimated skill level, no changes in confidence levels over semester
- Student scores on the post-test were significantly higher than the pre-test scores both semesters
- Improved ability to determine which variable was the dependent variable
- Increased graph creation skills
- Increased arithmetic skills

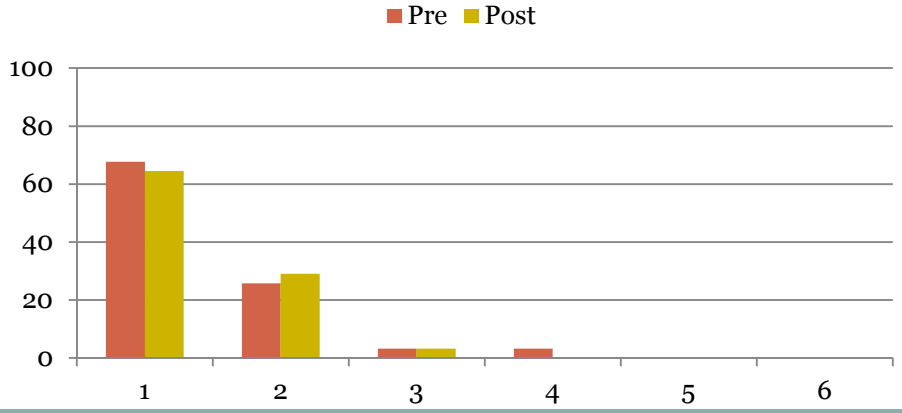
Gen Bio II: Student Self-Perception

Spring 2009

I can understand a line graph . . . (%) (N=31)

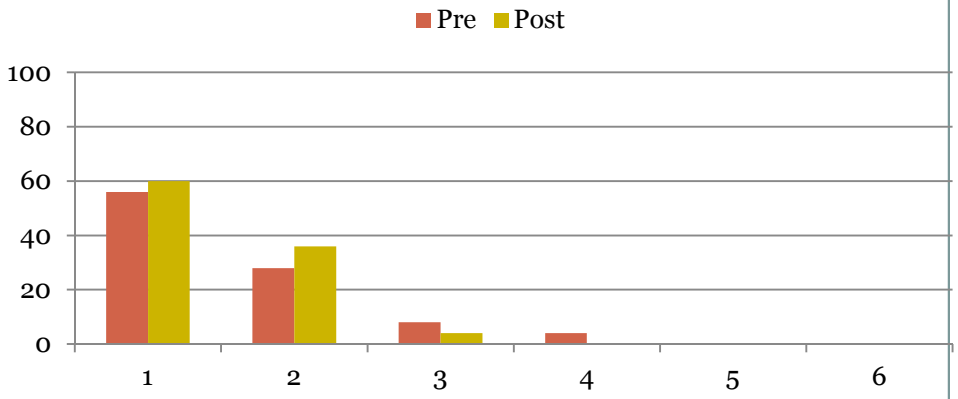


I can make line graph . . . (%) (N=31)

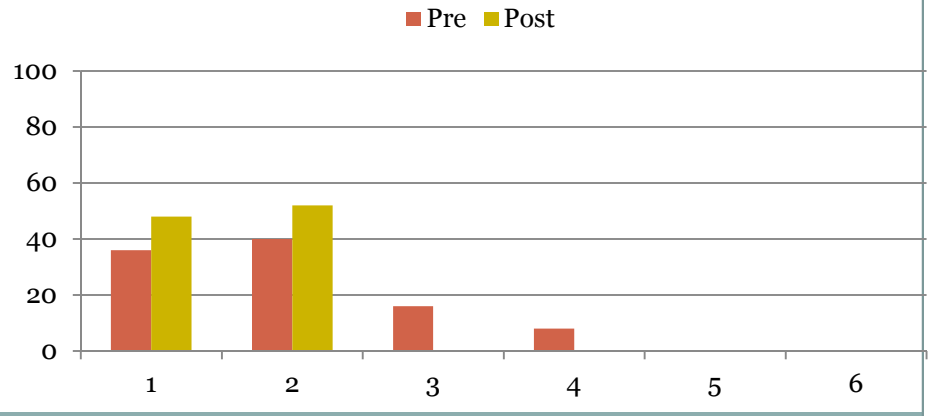


Spring 2010

I can understand a line graph … (%) (N=25)



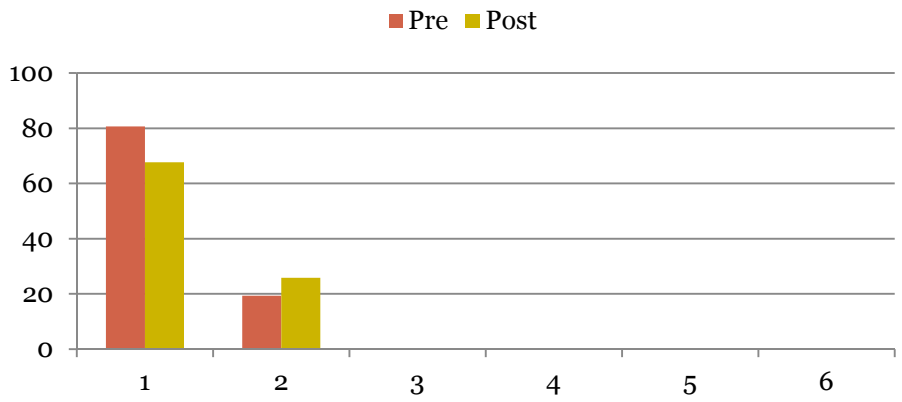
I can make a line graph … (%) (N=25)



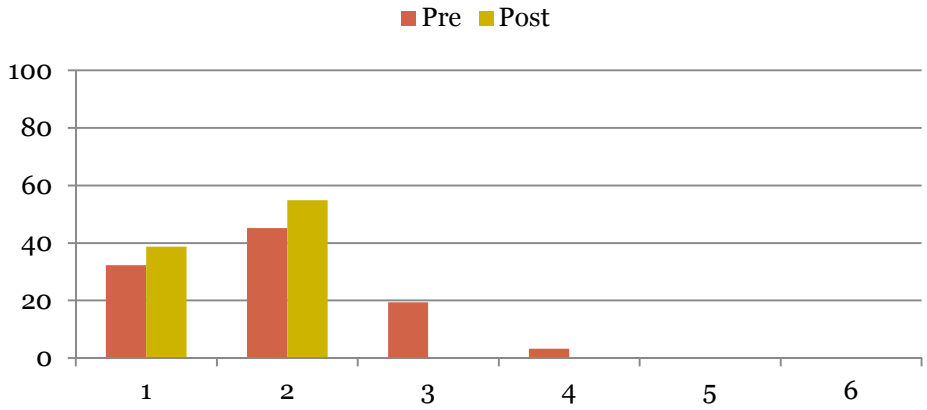
Gen Bio II: Student Self-Perception

Spring 2009

I can use arithmetic … (%)
(N=31)

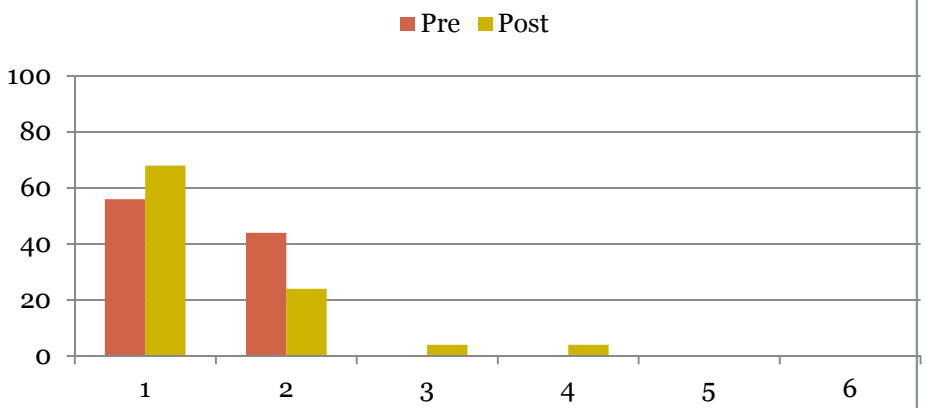


I understand … probability … (%) (N=31)

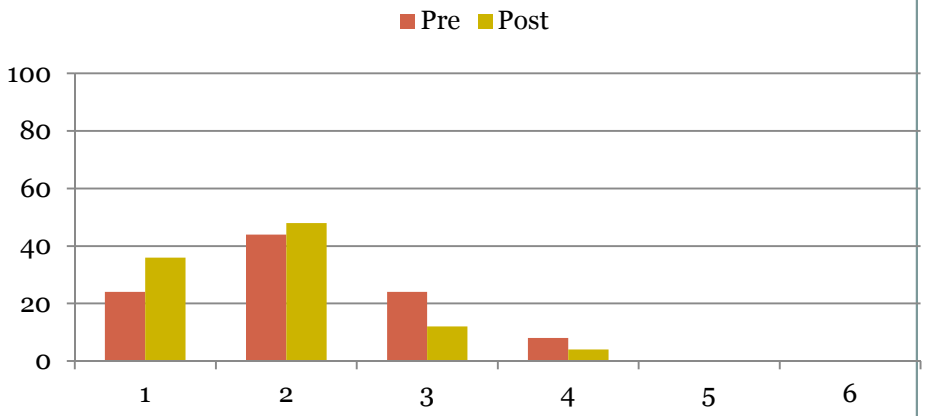


Spring 2010

I can use arithmetic … (%)
(N=25)

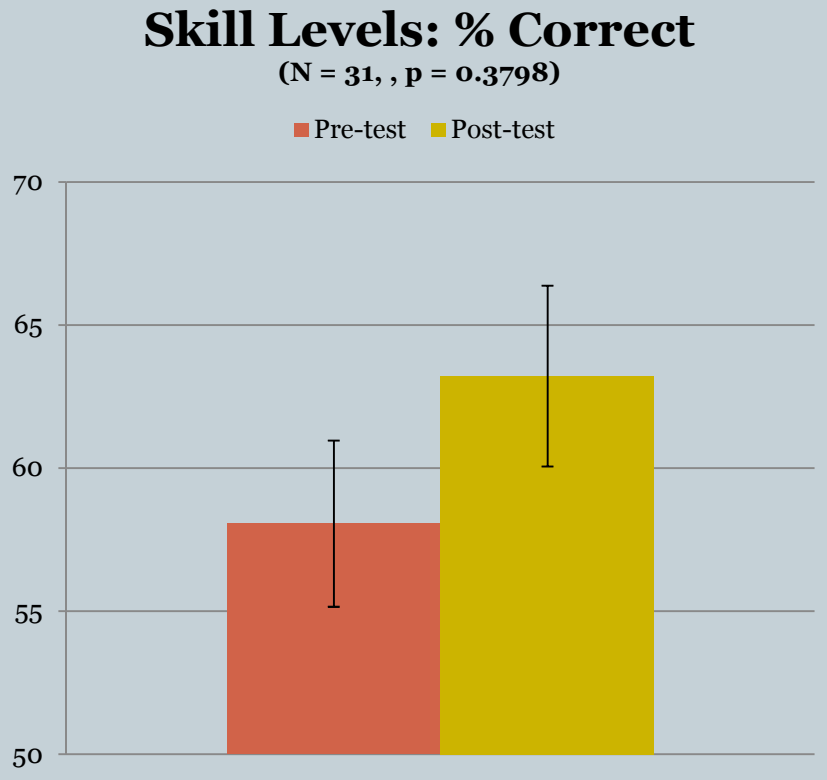


I understand … probability … (%) (N=25)

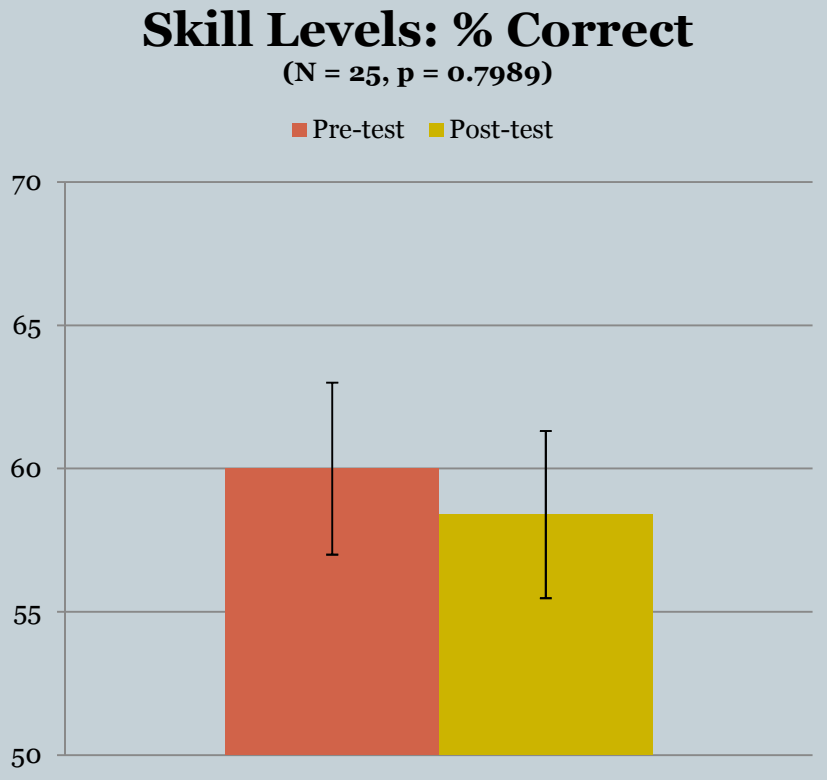


Gen Bio II: Student Skill Levels

Spring 2009

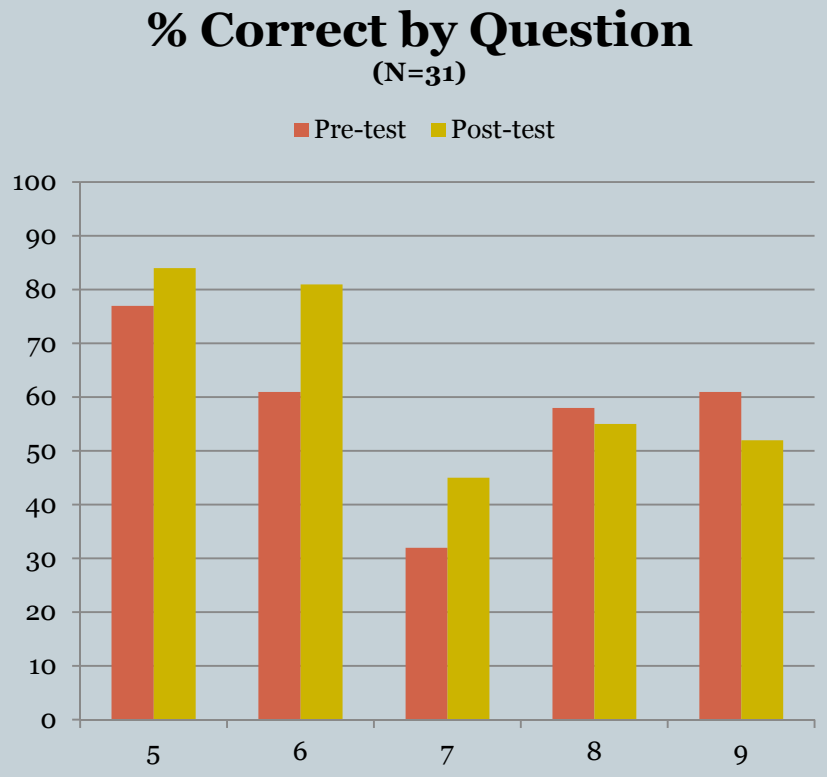


Spring 2010

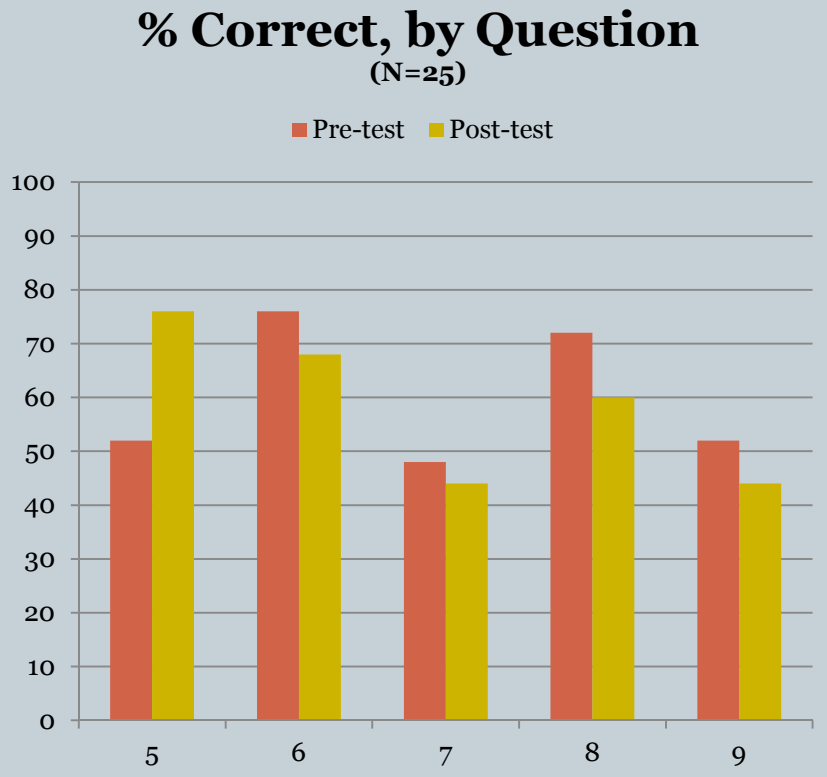


Gen Bio II: Student Skill Levels, by Question

Spring 2009



Spring 2010



Gen Bio II: Results

- No changes in confidence levels over semester for graph interpretation or arithmetic skills
- Increase confidence in probability skills both semesters, probably insignificant
- Post-test scores were not significantly different from pre-test scores
- The only skills improvements were for arithmetic skills (second semester) and probability skills (first semester)

Anatomy & Physiology I

GRAPH INTERPRETATION

Human Anatomy and Physiology I

- A & P I is a requirement for Licensed Practical Nursing, Nursing, Nuclear Medicine Technology, and Radiologic Technology. Other programs: Therapeutic Recreation, Nutrition, Medical Lab Technology, and Liberal Arts-Biology.
- ~25 sections/semester with ~600 total students per semester
- Students must have completed all remedial requirements prior to enrolling in this course

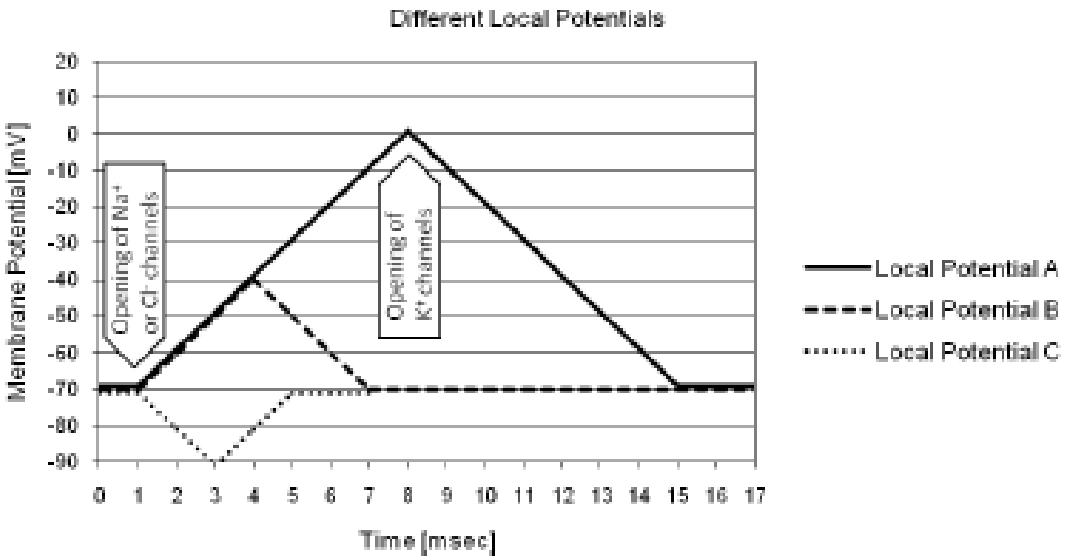
A&P I: Quantitative Literacy Modules

- Skills Emphasized:
  - Graph interpretation
- Modules Implemented:
  - QL Lab Module 1. Osmosis
  - QL Lecture Module 1. pH and buffers
  - QL Lecture Module 2. Membrane Potential
  - QL Lecture Module 3. Muscle Contraction

Example: Lecture Module 2 Membrane Potential (Graph Interpretation)

1) What is the value of the membrane potential when the membrane is at its resting membrane potential (RMP) at 0 msec?
   i. Is the membrane polarized?
   ii. Explain your answer to i.

2) What is the value of local potential A at 3 msec?
   i. Is the value of the membran potential closer to zero?
   i. Is it more or less polarized?
   ii. How do you call this change in membrane potential?
   i. What made the membrane potential change?



Anatomy & Physiology I: Assessment

- Oral evaluation during class based on whether the students can answer questions related with graph interpretation

- Administration of pre- and post- tests to evaluate:
  - a) Students' self-confidence in graph interpretation
  - b) Accuracy in the actual interpretation of a graph.

A&P I: Initial Results

Fall 2008

(N_i= 51; N_f=17)

Fig 1. Comparison of Correct Responses Between Pre and Post-Tests - Fall 2008 [%]

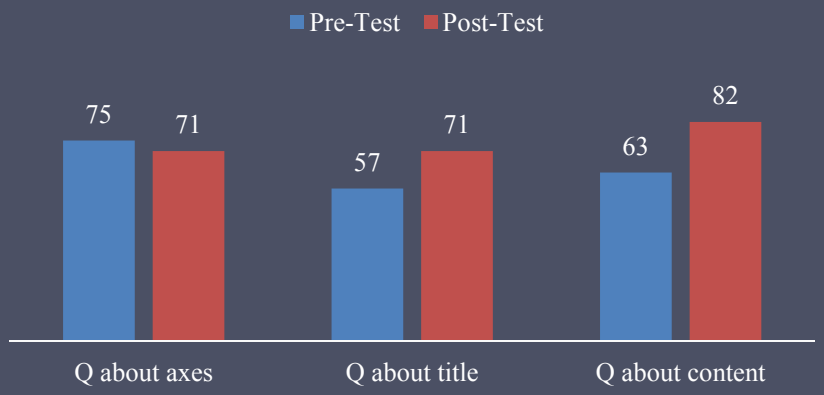
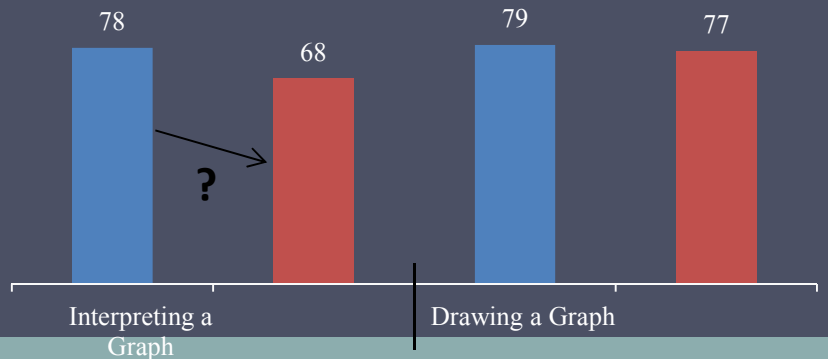


Fig 2. Comparison of Self-Confidence Surveys between Pre- and Post-Survey Fall 2008 [%]

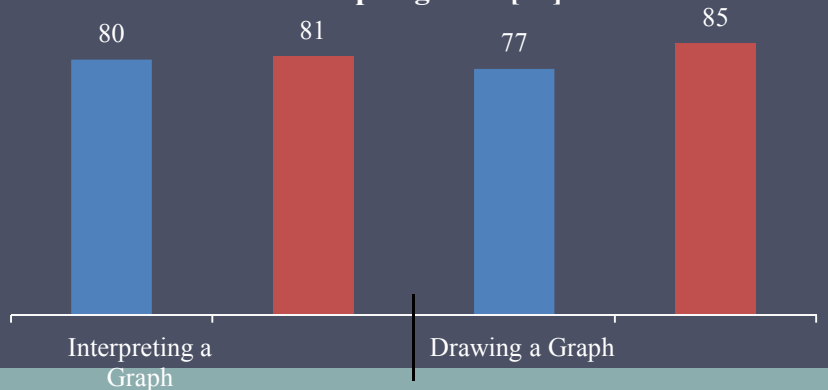


Spring 2009

(N_i=N_f=99)

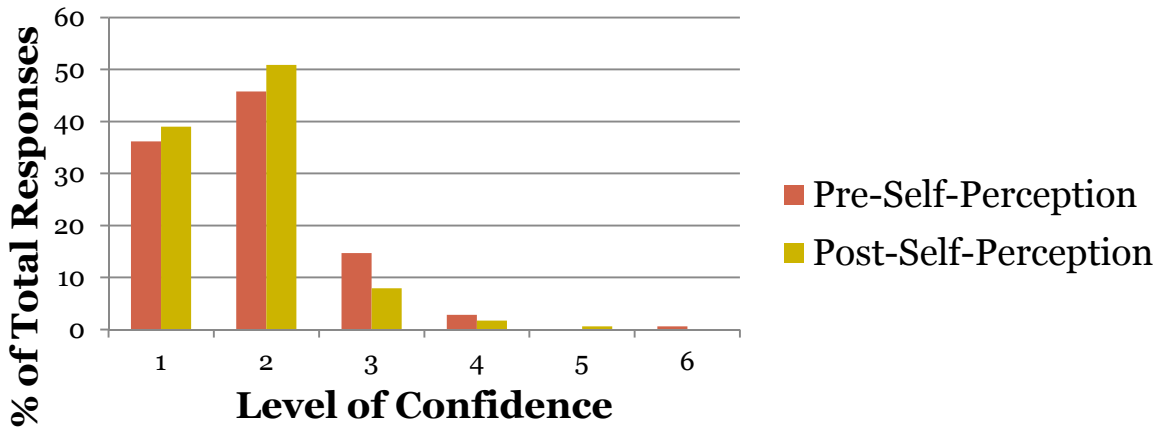
Fig 3. Comparison of Correct Responses Between Pre and Post-Tests - Spring 2009 [%]

Fig 4. Comparison of Self-Confidence Surveys between Pre- and Post-Survey Spring 2009 [%]



A&P I: Revised Assessment: Self-Perception

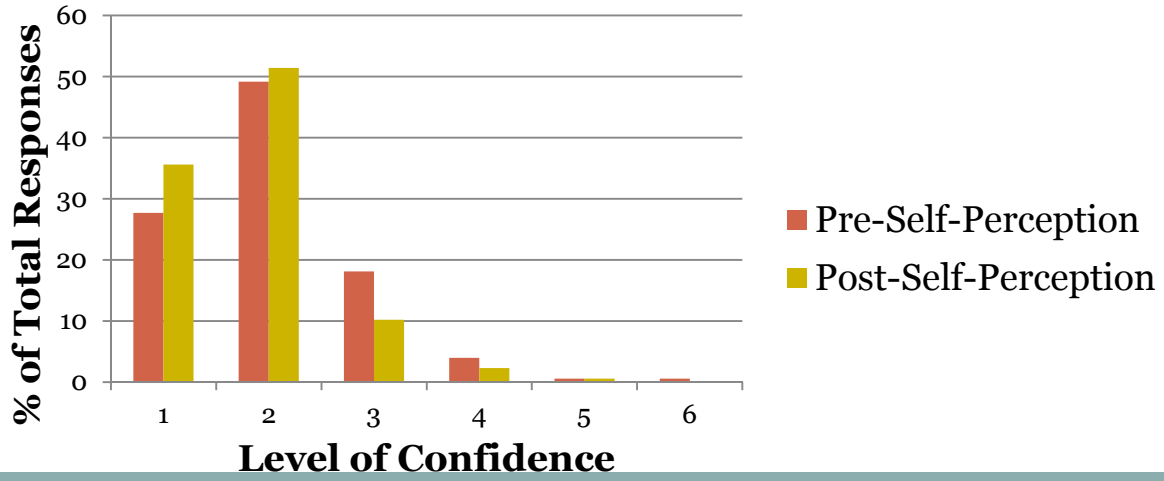
I can understand a line graph correctly



Fall 2009

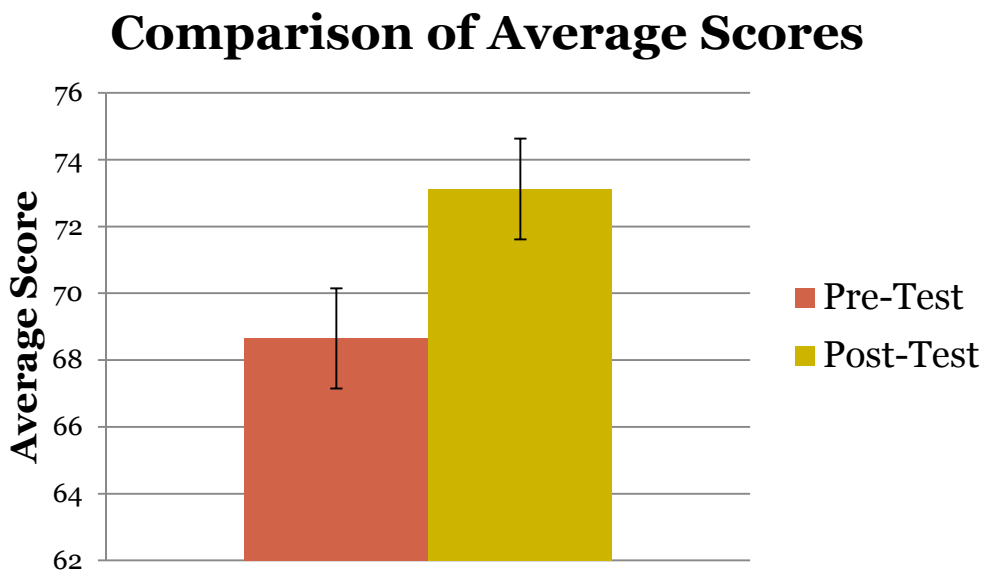
(N = 177)

I can make a line graph correctly



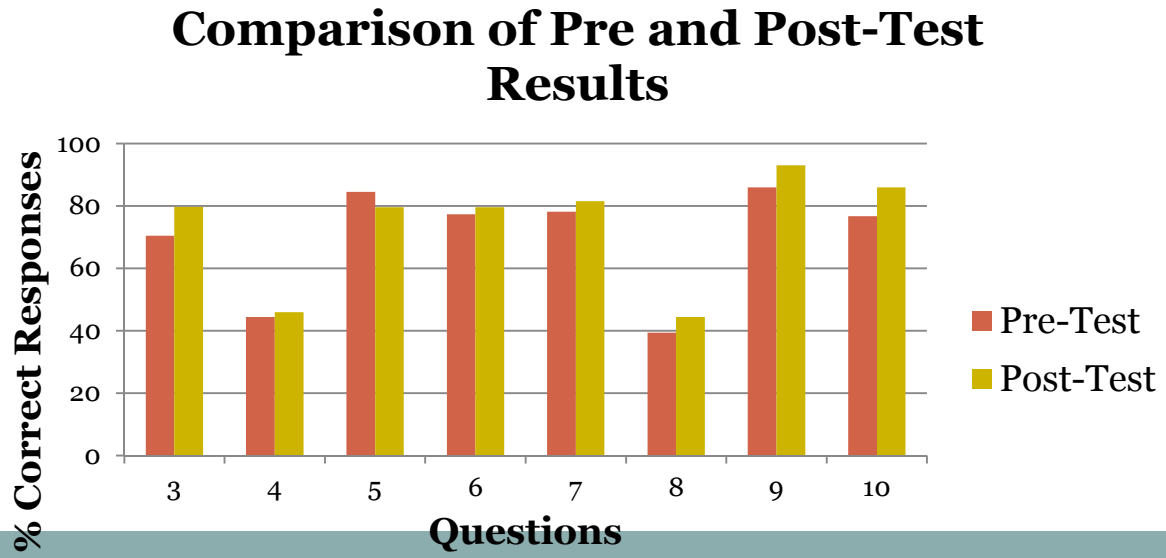
Level of Confidence:
1-feel very confident
2-feel confident
3-am not sure
4-feel insecure
5-feel very insecure
6-have no clue

A&P I: Revised Assessment: QL Skills



Fall 2009

(N = 187, p = 0.002), Bars=SEM



Question Types:
Q3: Axes
Q4: Title
Q5: Inference
Q6-Q10: Details

A & P I: Results

- After small initial trials, the pre-test/post-test was redesigned
- There were small improvements in confidence levels during both semesters for graph interpretation and graph creation skills
- Student scores on the post-test were significantly higher than the pre-test scores in the final semester with a large sample size

Results Summary & Conclusions

- We've seen minor improvements in probability skills (Gen Bio II) and graph interpretation skills (Gen Bio I, A&P I) with the implementation of QL modules.
- We did not achieve 100% participation by faculty, although participation improved in A&P I.
- The key to getting faculty to participate is integration of QL activities and assessments into the overall course structure, and maximizing the ease of implementation of both activities and assessment tools.
- The key to getting students to participate is integration of QL activities and assessments into the overall course structure & attaching a grade of some sort to the activities.

Steps Taken Since the Conclusion of this Project

- Full integration of these activities into the course activities, assessments, and revision procedures
  - Some activities have been modified or replaced as a result of student & faculty feedback
  - Assessment is now conducted as part of the overall department assessment effort, using common final questions
- Implementation of new PowerLab activities in Introductory General Biology I and Anatomy & Physiology II. These new activities are hands-on, data-driven, experimental activities in which students collect data and interpret graphs.

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- Student participants in 2008-2009 biology courses
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