I Taught My Dog to Whistle, and Other Lessons from Student Research

A. Malcolm Campbell
Biology Department and GCAT

North Georgia College & State University
March 29, 2012
Outline of Presentation

Why did you come to college?

What is the value of an education?

Why is research important?

Give examples of student research

New approach to intro bio as a model for other courses.

What does it take to become educated?
Guess what, I taught my dog to whistle!

http://thegoodpeople.se/blog/?p=208
Teaching vs Learning

Really?!
Teaching vs Learning

Whistle! C’mon boy, whistle!
Teaching vs Learning

???????????????
I thought you said you taught your dog to whistle.
I did, but I didn’t say that he learned to whistle.
Why did you come to college?
Are you training for one job?

“Number of Jobs Held, Labor Market Activity, and Earnings Growth among the Youngest Baby Boomers: Results from a Longitudinal Survey”

http://www.officefurniturepics.com/tag/used-office-cubicles/
Are you training for one job?


- born in the years 1957 to 1964
- jobs from age 18 to age 42
- average of 10.8 jobs
- more jobs ages 18 - 24 than 36 - 42
- 23% held at least 15 jobs
- 14% held zero to four jobs

“Number of Jobs Held, Labor Market Activity, and Earnings Growth among the Youngest Baby Boomers: Results from a Longitudinal Survey”
No one gives you an education.

If you want one, you have to take it.

John Taylor Gotto
Describe the best learning experience you’ve had outside of schools.
List jobs that pay you to memorize information that you don’t use....
Who thinks they can remember more factoids than a computer?

http://yourwallpaper.com/abstract/circuitboard01-1024.phpml
Why try to compete with computers by memorizing?
What can humans do that computers cannot?
Describe the best educational experience you’ve had in school.
Education is the only industry where customers never complain when they get less product for their money.
Percent Americans 25+ with Bachelor’s Degree

30.4% overall

14.1% Hispanics

19.9% African Americans

34.0% Caucasians

Average Annual Earnings Workers 18+

advanced degree $74,602
bachelors degrees $51,206
high school diploma $27,915
no high school diploma $18,734.

http://usgovinfo.about.com/od/censusandstatistics/a/collegepays.htm
Who is John Taylor Gotto?

(prize for first correct answer)
Why is it that you can look up this, but if you hit a word in class, you ask the teacher what it means?
Take charge of your own education.
Raise your hand if you learned a lot by doing your research.
Raise your hand if you learned a lot by doing your research.

How many tests did you take on your research?

How many times did you have to memorize factoids?

Why should course work be any different than research?
Synthetic Biology Research at Davidson College
Synthetic Biology: Win-Win

Win #1: your design functions as expected.
Synthetic Biology: Win-Win Research

Win #1: your design functions as expected.

Win #2: your design fails but you uncover basic biology
Real World Applications of Synthetic Biology
Land Mine Detection
Land Mine Detection
New weed may flag land mines

By John K. Borchardt | Contributor to The Christian Science Monitor
Production of Medicines

$1 per pill
Production of Medicines

10¢ per pill
Biofuels from Algae

CO$_2$-neutral

1,000,000 gallons in 2008
Laurie Heyer, Todd Eckdahl & Jeff Poet

Building Bacterial Computers
Can we build a bacterial cryptographic hash function?
What is a hash function?
Can Bacteria Perform a Hash Function?
Use XOR Logic Gate for Hash Function

<table>
<thead>
<tr>
<th>Input 1</th>
<th>Input 2</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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Use XOR Logic Gate for Hash Function

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\[ Y = A \oplus B \]
Use XOR Logic Gate for Hash Function

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XOR Logic Gate Diagram:

```
A
\[\rightarrow\]
B
\[\rightarrow\]
Y
```
Design Linear Bacterial Hash Function

\[ \text{CAB} = 010000001 \]

\[ \text{HASH VALUE} = 0 \]
Time-Delayed Bacterial Growth

3 hours

15 hours

40 hours

Amp

β-lactamase

β-lactamase

β-lactamase

Monday, March 26, 2012
Time-Delayed Bacterial Growth

0 hours

1mm
DNA-based XOR Logic Gate

RFP \rightarrow pOmpC \rightarrow pLux \rightarrow GFP

RBS

Monday, March 26, 2012
DNA-based XOR Logic Gate

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RFP → RBS → pOmpC → pLux

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Testing Bacterial XOR Logic Gate

Relative Fluorescence

XOR +LuxR

\[ \text{RFP} \quad \text{GFP} \]

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<tr>
<th></th>
<th>LB</th>
<th>-</th>
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Monday, March 26, 2012
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Relative Fluorescence

XOR +LuxR

RFP

GFP

- RFP
- GFP

High Osmolarity (Input A)
3OC6 (Input B)

Monday, March 26, 2012
Testing Bacterial XOR Logic Gate

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Relative Fluorescence

RFP

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Testing Bacterial XOR Logic Gate

Relative Fluorescence

XOR +LuxR

RFP
GFP

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High Osmolarity (Input A)
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pOmpC
pLux

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Relative Fluorescence

XOR +LuxR

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<tr>
<td>0</td>
<td>1.00</td>
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<td>RFP</td>
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<td>GFP</td>
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High Osmolarity (Input A) → pOmpC → 3OC6 (Input B) → pLux → RBS → GFP
pLux + LuxR Promotes Backwards

Relative Fluorescence

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Monday, March 26, 2012
Why build bacterial computers?
Evolution of Computers

1943
Evolution of Computers

iPhone in 2012
Evolution of Bacterial Computers

E. coli in 2012

Living Hardware in 2022
Without basic research, there can be no applications....

After all, electricity and the lightbulb were not invented by incremental improvements to the candle.

French President Nicholas Sarkozy
Skills Most Sought After by Employers

1) Communications Skills
2) Analytical/Research Skills
3) Computer Literacy
4) Flexibility
5) Interpersonal Abilities
6) Leadership Skills
7) Multicultural Sensitivity
8) Organizational Skills
9) Problem-Solving/Creativity
10) Teamwork

http://www.quintcareers.com/job_skills_values.html
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Personal Values Employers Seek in Employees

1) Honesty/Integrity
2) Adaptability
3) Dedication/Tenacity
4) Dependability
5) Loyalty
6) Positive Attitude
7) Professionalism
8) Self-Confidence
9) Self-Motivated
10) Willingness to Learn

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http://www.quintcareers.com/job_skills_values.html
Your College Education Put Into Focus
Would you rather settle for a blue collar B
or try for an A and risk failure?
“Would you like me to give you a formula for success? It's quite simple, really. **Double your rate of failure.** You are thinking of failure as the enemy of success. But it isn’t at all. You can be discouraged by failure or you can learn from it, so go ahead and make mistakes. Make all you can. Because remember that’s where you will find success.”

Thomas J. Watson
The scenery only changes for the lead dog.
The scenery only changes for the lead dog.
Our Current Challenge:
Introductory Biology

Integrating Concepts in Biology

by
A. Malcolm Campbell, Laurie J. Heyer
and Christopher J. Paradise
What’s Wrong with Biology Education Now?

• Vocabulary is emphasized
• Experimental approaches are minimized
• Math is absent
• Memorization is rewarded
• Critical thinking is discouraged
• Information is irrelevant to students

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If we currently cover all the important stuff.....

...how can we add more content?
Too much content for the containers
Too much content for the containers
Start with the literature...
Present information and data...
... in the context of the big picture.
Artificial Divide within Biology

Small Biology

Big Biology
Five Levels of Organization

- Molecular
- Cellular
- Organismal
- Population
- Ecological System
Five Big Ideas of Biology

- Information
- Homeostasis
- Emergent Properties
- Evolution
- Cells

Biology
Five by Five Matrix of Biology

- Information
  - Molecular Ecology
  - Organismal Ecology
  - Population Ecology
  - Cellular Ecology

- Biology
  - Homeostasis
  - Evolution
  - Emergent Properties
  - Cells

Monday, March 26, 2012
Five by Five Matrix of Biology

- Cellular
- Organismal
- Population
- Ecological System
- Evolution
- Homeostasis
- Emergent Properties
- Cells
- Information

Biology

Molecular

Ecological System
Five by Five Matrix of Biology

- Molecular
- Ecological System
- Population
- Cellular
- Organismal
- Information
- Evolution
- Emergent Properties
- Homeostasis
- Cells

Biology
Five by Five Matrix of Biology
Five by Five Matrix of Biology
BioMath Explorations

BioMath Exploration 6.3

How can you fit exponential curves to data?
Ethical, Legal and Social Implications

Are religion and evolution compatible?

Is science possible if you are uncertain about what is true?

Does basic biology have any impact on the real world?

Who owns your DNA?
Did my students learn less content?
Student Content Assessment

p = 0.06

p = 0.97

percent correct

Fall 2010

new

traditional

p = 0.97

+/- SEM

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Student Content Assessment

83% response rate (new)
63% response rate (traditional)

$p = 0.97$

$p = 0.06$

Fall 2010
Spring 2011

+/- SEM
Can my students analyze data better?
Student Skills Assessment

% Correct

Traditional  New

$p = 0.043$
Student Skills Assessment

% Correct vs Quiz

- Traditional (quiz averages)
- New (quiz averages)

- New, \( p = 0.015 \)
- Traditional, \( p = 0.320 \)
Why bother changing?
National Recognition of Need to Change

VISION AND CHANGE
A CALL TO ACTION

A SUMMARY OF RECOMMENDATIONS
MADE AT A NATIONAL CONFERENCE ORGANIZED BY THE
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

NSF

Science

AAAS
AP Biology is Changing to Match Our Design
To whom much has been given, much is expected.
Acknowledgements

Faculty: Laurie Heyer, Jeff Poet, Todd Eckdahl, Karmella Haynes, Pat Sellers, Mark Barsoum


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Davidson College James G. Martin Genomics Program
MWSU SGA, Foundation & Summer Research Institute