Learning how students learn: coming full circle

Ido Roll
with Doug Bonn, James Day, & Natasha Holmes (Physics), Jared Taylor (Biology), Jennifer Duis (Chemistry), Bruce Dunham (Statistics), Brett Gilley (EOS)

External collaborators:

Deborah Butler (UBC, Faculty of Education), Dan Schwartz (Stanford), David Yaron (Carnegie Mellon University), Manu Kapur (National Institute of Education, Singapore).

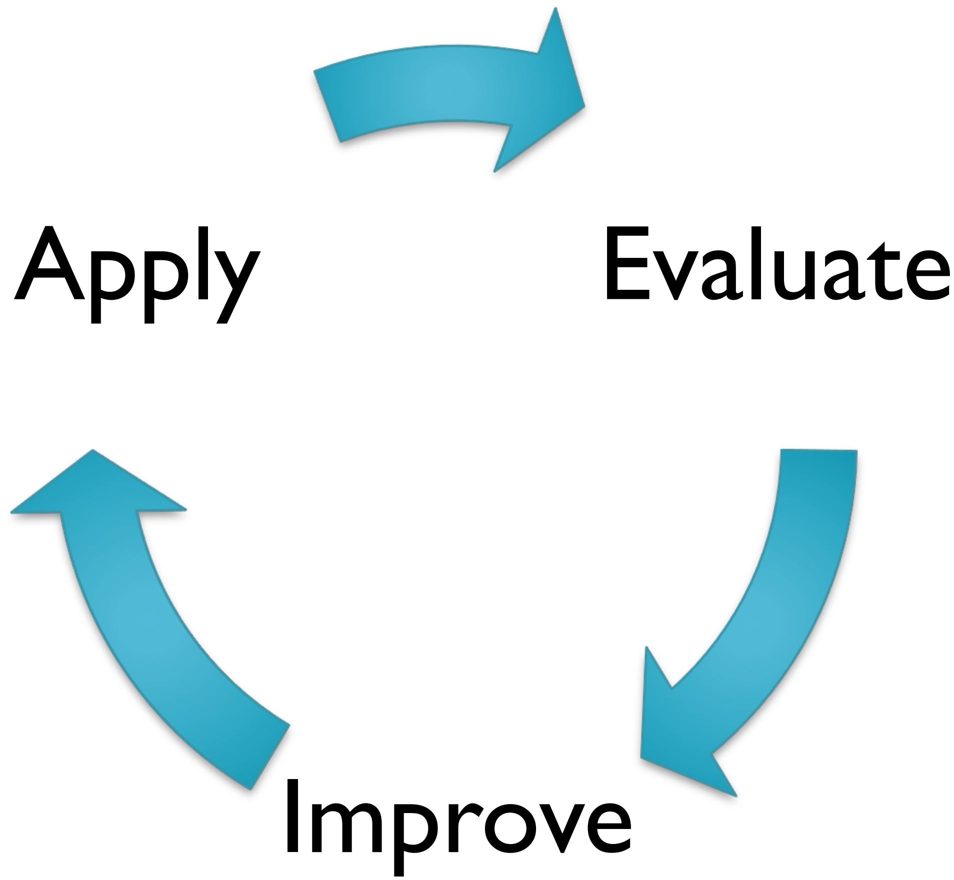
In-vivo Scientific Research in Education

- Evaluating instruction and learning
  - Where it happens
  - Using valid methodology

	Pseudo-scientific	Scientific
In the lab		Proven, but not realistic -Ignores key factors -Often short durations (~minutes) -Small samples
In the field	Realistic, but not "proven" -Hard to generalize -Hard to identify outcomes -Often confounded	?

CWSEI

Coming Full Circle



Example 1: Helping students become better scientists

- What we know: Invention activities help students learn better from subsequent instruction
  - (see posters by *Natasha Holmes*, *James Day*, and *Jared Taylor*)
- What we do not know:
  - How do students learn from invention activities?
  - What are the key elements of invention tasks?
  - How can we help students improve their scientific reasoning skills?

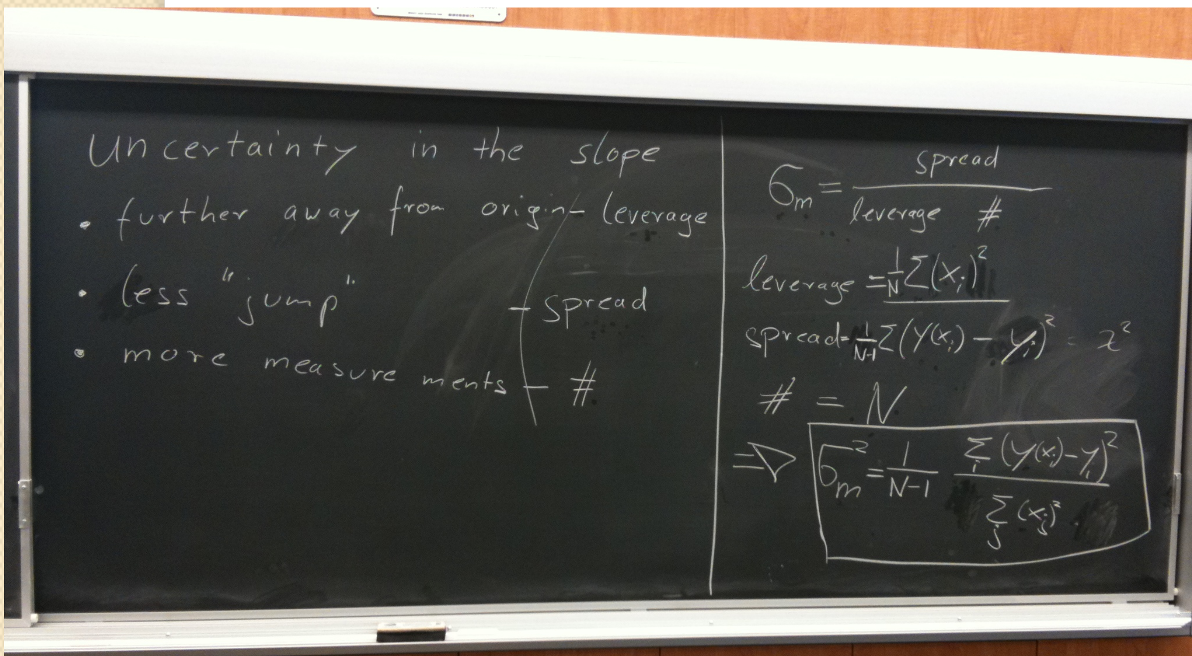
* This work is supported in part by the Pittsburgh Science of Learning Center, which is funded by the National Science Foundation (award #SBE-0354420).

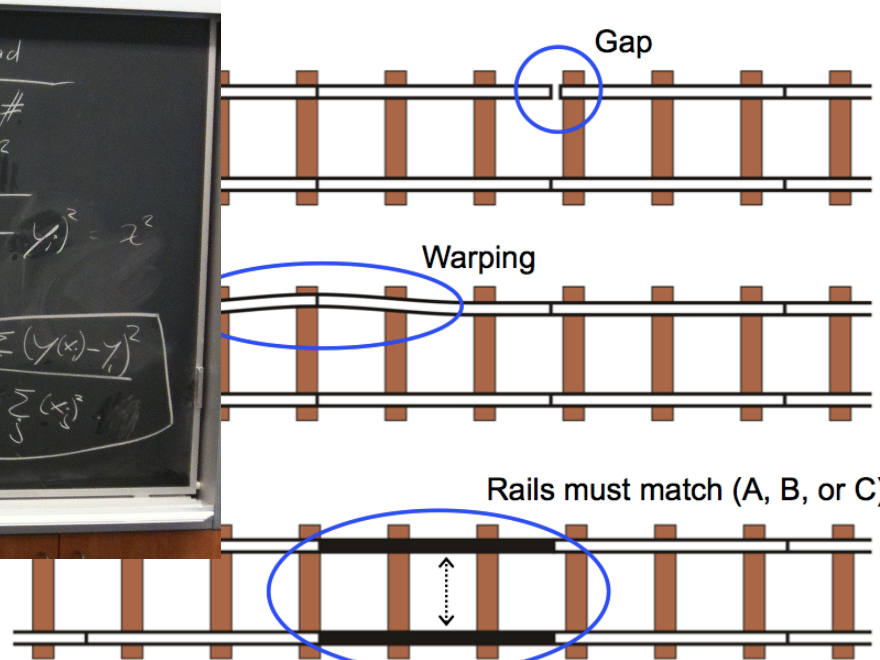
Method

- Observe and record students as they engage in invention tasks
  - Phys 107/109
  - Biol 112
- Analyze students' interactions and artifacts to identify productive and unproductive behaviors, successful task elements, and missed opportunities for learning.

Identifying and embedding key task elements

- Example: map features of task and domain
  - Using contrasting cases
  - In subsequent instruction (add contrasting)





Identifying and promoting productive scientific reasoning skills

- Example: Identifying productive task progression
  - Productive behavior: cyclic improvement

Student 1:	Analyze	Design	Implement	Evaluate	Design	I.	E.	Present
Student 2:								

  - Common error I: dive right in

Student 1:	A.	Implement	Present
Student 2:			

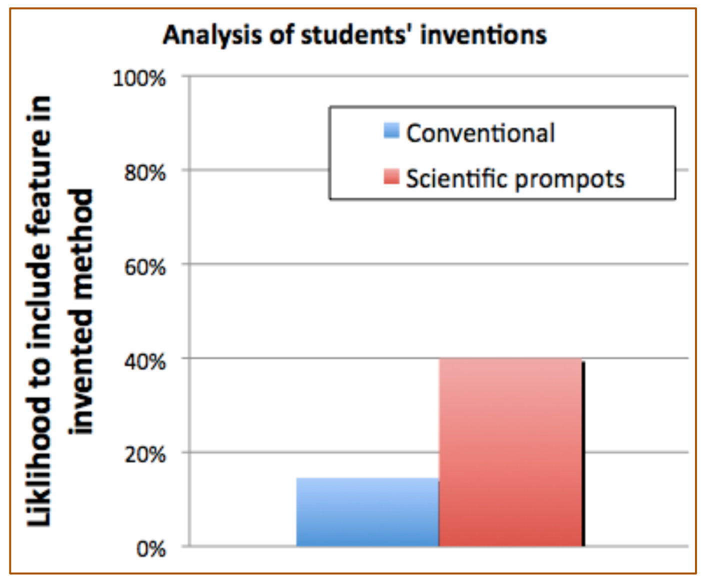
  - Common error II: lack of communication

Student 1:	Analyze	Design	Present

Student 2:	Ana.	Des.	Implement	E	D	Imp.	Present

Identifying and promoting productive scientific reasoning skills

- Improvement: prompt students for desired scientific behaviors
  - Evaluate quality of inventions with and without prompts.
  - Found that prompts help students develop more sophisticated methods.
  - See complete results in poster by Natasha Holmes.



Understand how students learn from invention activities

- Students' inventions are often incomplete, yet, they function as "productive failures".
- Analysis revealed that inventions help students notice and encode deep features of the domain.

slope of origin to each data point $= m_d$
slope of the model $= m$
number of points in data set $= n$

$\cancel{\sum_{i=1}^{n} (m_d - m)}$ $\quad \frac{1}{n^2}\sum_{d=1}^{n}(m_d - m)^2$

n is squared to reflect the fact that a data set with more data points will be more accurate

factors
$\rightarrow \sum_{i=1}^{N}(\text{Data point}_i - SD)$
$\rightarrow \frac{1}{N}$
$\rightarrow (x_{max} - x_{min})$

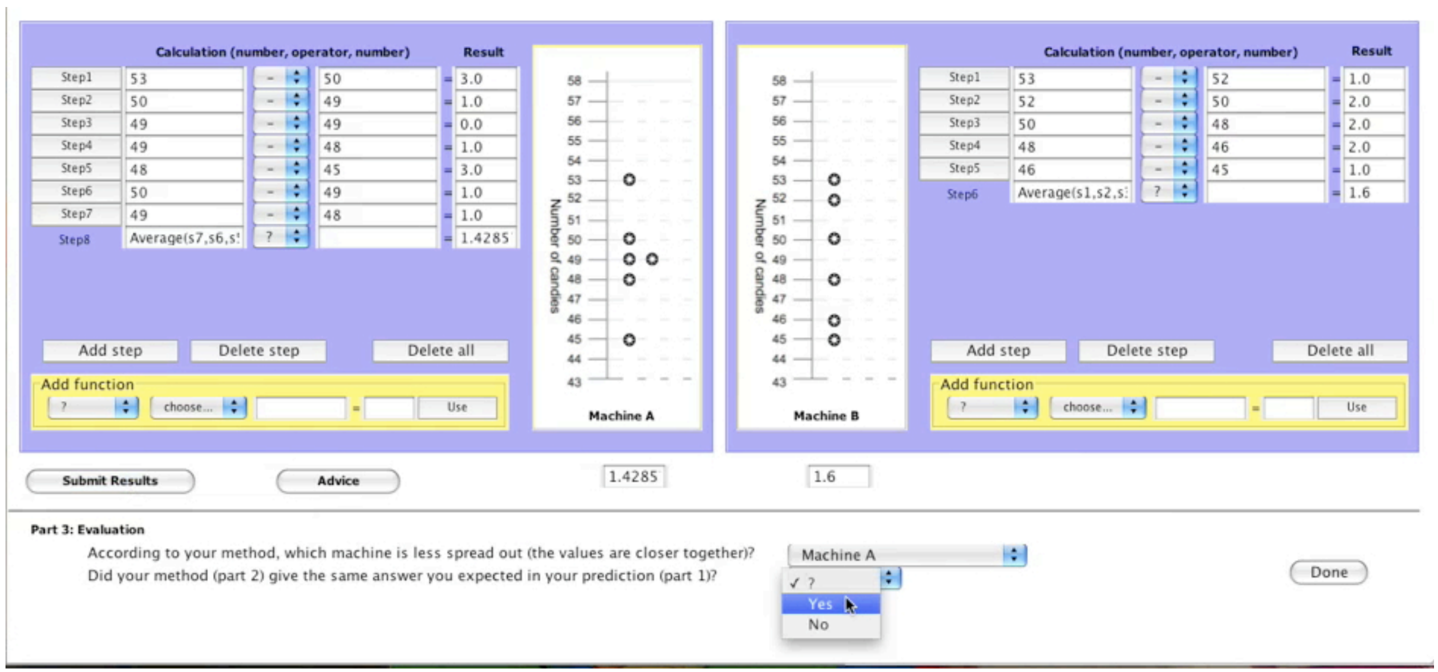
$$= \frac{\sum_{i=1}^{N} y_i - SD}{N(x_{max} - x_{min})}$$

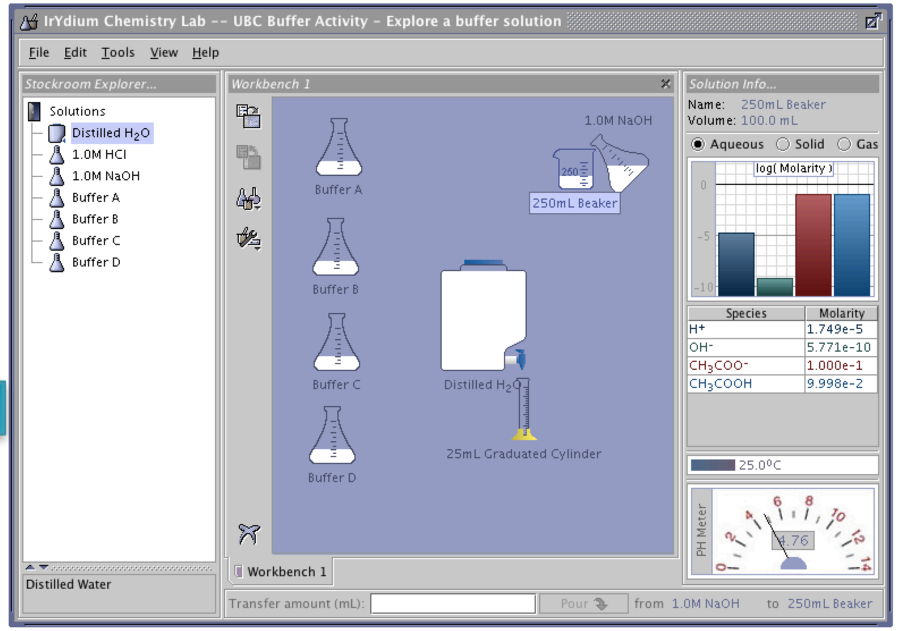
Example II: Can inventions generalize across topics and students?

- EOS – develop an invention activity for turnery diagram
- Statistics – develop a sequence of invention activities for ANOVA

Example III: Can invention activities be facilitated using technology?

- Chemistry (using a virtual lab)
- Statistics (with individualized support)
- Physics (with a sequence of inventions, see poster by Natasha Holmes)





Invention

Invent a method to calculate and assign the buffer capacity for each of the buffers. That is, invent a method to assign a number (or more) that captures the ability of the buffer to absorb strong acid or base without changing its pH drastically.

Your method should yield the correct ranking for the 5 solutions described in the table. That is, a solution with lower buffer capacity should be more sensitive to acids and bases than a solution with higher buffer capacity.

Your method should be able to assign a value based solely on the composition of the solution. Your method should not involve the result of mixing it with other solutions. (You can mix solutions to test whether your method works, but your method should not involves steps that involve making mixtures.)

Direct instruction

1. Fill three Erlenmeyer flasks with 25 mL of the buffer solution and two Erlenmeyer flasks with 25 ml of water. Record the initial concentrations of the ions in the solutions.
2. Add 5.0 mL of the strong acid to a flask containing the buffer. Record the new pH and concentration changes.
3. Now add 5.0 mL of strong acid to 25 mL of water and record the pH.
4. Repeat steps 2 and 3 with the strong base.
5. Add 25 mL of distilled water to a flask containing the buffer. Record the new pH and concentration changes.

	Buffer Solution			Water
	$[CH_3COOH]$	$[CH_3COO^-]$	pH	pH
Reaction with strong acid				
Initial				
After addition of 5.0 mL HCl				
Reaction with strong base				
Initial				
After addition of 5.0 ml NaOH				
Addition of distilled water				
Initial				
After addition of 25ml H_2O				

The acetate buffer can be described by the following equilibrium equation:

$$\underset{\text{weak acid}}{CH_3COOH} + H_2O \rightleftharpoons H_3O^+ + \underset{\text{conjugate base}}{CH_3COO^-} \qquad K_a = 1.78 \times 10^{5}$$

What happens to the concentrations when we add HCl to the buffer? Notice that when you added acid to the buffer, the amount of A^- went down and the amount of HA went up. This is because the added acid (H^+) reacted with conjugate base (A^-) to form HA:

$$H^+ + A^- \rightarrow HA$$

Since A^- reacts with (or absorbs) any added acid, the amount of A^- sets the buffer capacity for addition of acid (i.e. the amount of acid that can be absorbed).

What happens to the concentrations when we add NaOH to the buffer? When you added base to the buffer, the amount of HA went down and the amount of A^- went up. This is because the added base (OH^-) reacted with weak acid (HA) to form A^-:

$$OH^- + HA \rightarrow A^-$$

Since HA reacts with (or absorbs) any added base, the amount of HA sets the buffer capacity for addition of base (i.e. the amount of base that can be absorbed).

Summary

- *In-vivo* scientific research in education can tell us
  - Whether our ideas work
  - Whether they generalize
  - How to improve them
  - What and how students learn
- The rare combination of resources and expertise in the Faculty of Science and CWSEI make it happen here.