Learning how students learn: coming full circle

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In-vivo Scientific Research in Education

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

<table>
<thead>
<tr>
<th>Pseudo-scientific</th>
<th>Scientific</th>
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| **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 | ? |
Coming Full Circle

Apply

Evaluate

Improve
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?

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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**
  - **Common error I: dive right in**
  - **Common error II: lack of communication**

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<tr>
<th>Student 1:</th>
<th>Analyze</th>
<th>Design</th>
<th>Implement</th>
<th>Evaluate</th>
<th>Design</th>
<th>I.</th>
<th>E.</th>
<th>Present</th>
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<td>Student 2:</td>
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<th>Student 1:</th>
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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.
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.

\[ \text{slope of origin to each data point} = m_d \]
\[ \text{slope of the model} = m \]
\[ \text{number of points in data set} = n \]
\[ n \mid m_d = \frac{1}{n^2} \sum_{i=1}^{n} (m_d - m)^2 \]

\[ n \text{ is squared to reflect the fact that a data set with more data points will be more accurate} \]
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)
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 involve steps that involve making mixtures.)
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.