Chemistry in the field and chemistry in the classroom: A disconnect?

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18th BCCE - Iowa State University
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Pedagogical Organization of Academic Chemistry: Established Content and Process
- Analytical chemistry
- Biochemistry
- Inorganic chemistry
- Organic chemistry
- Physical chemistry
- Theoretical chemistry

But “frontier science,” which reflects the creativity and progress in academic and industrial research and development, occurs across such boundaries:

“…its [chemistry’s] methods, concepts, and practitioners are penetrating virtually every nook and cranny of science and technology.”
----I. Amato (Science, 1991)
Two Centuries of Chemistry: From Discrete Field to Ubiquitous Presence

- What are the current valued activities of chemistry?
- Is the fundamental organization of the textbook based vision of chemistry up to date?

A Conceptual Framework for Chemistry

Conceptual Framework: “Upper Levels”
Testing the Framework

- Are some activities missing from the framework?
- Are some activities present in the framework but not in the domain of chemistry?

Evidence for the Domain of Chemistry Represented in the Conceptual Framework

- Nobel Prizes (1952-2002)
- 2002 New York Times Science Times (54 reports)
- 2002 Scientific American News Scan (32 reports)
Evidence from Textbooks

- Aligned with National Science Education Standards
  - Modern Chemistry (2002)
  - Merrill Chemistry (1998)
  - ChemCom (2002)
- Objectives reflect focus of classroom chemistry

Textbook Coverage during a First High School Chemistry Course

<table>
<thead>
<tr>
<th>Measure</th>
<th>Modern</th>
<th>Merrill</th>
<th>Chem Com</th>
</tr>
</thead>
<tbody>
<tr>
<td># pages</td>
<td>599</td>
<td>648</td>
<td>484</td>
</tr>
<tr>
<td>% of pages covered</td>
<td>66%</td>
<td>58%</td>
<td>100%</td>
</tr>
<tr>
<td># objectives</td>
<td>291</td>
<td>195</td>
<td>120</td>
</tr>
<tr>
<td>% objectives covered</td>
<td>65%</td>
<td>53%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Distribution of ChemCom Objectives

EXPLAIN
- Hypothesis Generation
- Hypothesis Testing

ANALYZE
- Goal (What do you want to know?)
- Method (How to determine what you have)

SYNTHESIZE
- Functional Motifs
- Structural Motifs
- Process Motifs

TOOLBOX
- Representational Systems
- Quantification Systems

Scope of EXPLAIN Objectives

EXPLAIN
- Hypothesis Generation
- Hypothesis Testing

Hypothesis Generation Themes

- Textbook EXPLAIN activity is presented as well-established content skills to be mastered by student
- Authentic EXPLAIN chemistry activity couples hypothesis generation with hypothesis testing
The table below shows the distribution of hypothesis generation themes from News Reports vs. Textbook Objectives:

### Hypothesis Generation Themes: News Reports vs. Textbook Objectives

<table>
<thead>
<tr>
<th>Theme</th>
<th>News Reports</th>
<th>Merrill Chem</th>
<th>Modern Chem</th>
<th>ChemCom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Type</td>
<td>25%</td>
<td>4%</td>
<td>14%</td>
<td>24%</td>
</tr>
<tr>
<td>EM &amp; Prop. of Atoms &amp; Molecules</td>
<td>31%</td>
<td>12%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Stoichiometry</td>
<td>2%</td>
<td>7%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Prop. of Matter</td>
<td>23%</td>
<td>51%</td>
<td>44%</td>
<td>24%</td>
</tr>
</tbody>
</table>

### Hypothesis Generation Themes: News Reports vs. Textbook Objectives, cont.'

<table>
<thead>
<tr>
<th>Theme</th>
<th>News Reports</th>
<th>Merrill Chem</th>
<th>Modern Chem</th>
<th>ChemCom</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodicity</td>
<td>1%</td>
<td>18%</td>
<td>15%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Equilibrium &amp; Kinetics &amp; Thermo</td>
<td>8%</td>
<td>4%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Struct.-Prop. Relationships</td>
<td>11%</td>
<td>0%</td>
<td>14.5%</td>
<td></td>
</tr>
</tbody>
</table>

The bar chart compares the distribution of themes across different textbooks.
CONCLUSION

There is a disconnect between the focus of high school chemistry and what chemists do

Effects of the Disconnect

- Educational goal of a coherent knowledge base not met since a “skills-first” agenda yields inert knowledge that is rarely usable or memorable.
- Educational goal of basic scientific literacy not met since current instruction ignores 2/3 of the domain of chemistry.
- Beginning students are not engaged in the wonder and excitement of the discovery and creativity at the heart of chemistry.

“Repairing” the disconnect: Use evidence in deciding what to teach

- Realize that most students do not study any chemistry after high school.
- Introduce tools and skills on a need-to-know basis
- Emulate the domain’s valued activities in instruction by providing scaffolded problem-solving scenarios situated within the context of frontier science storylines*

* Using and Authoring Virtual Lab Activities for Introductory Chemistry. A workshop presented Wednesday at 2 PM by David Yaron and Michael Karabinos, Carnegie Mellon University (http://ir.chem.cmu.edu)