Chemistry in Context: A Citizen-First Approach to Foster Student Engagement and Motivation

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How Do We Typically Teach Chemistry? “The Mold”

We teach general chemistry as if we must first build the foundation of content for our students …

Mostly non-contextualized
How Do We Typically Teach Chemistry? “The Mold”

… so that later down the road, our students get to apply their knowledge to examine the larger issues in our world.
The Chemistry in Context Approach

Contextualized Content

Foundational Contexts

Molecular Structure & Bonding
Equilibria
Atomic Structure
States of Matter
Kinetics
Thermodynamics
Stoichiometry
Redox

The Ozone Hole
Air Quality
Energy
Climate Change
Nuclear Fission
Electronics
Water
Genetic Engineering
Food
Chemistry in Context:
The Book That “Broke the Mold”

• Geared toward non-science/liberal arts majors

• Majority of textbooks are 'watered-down' versions of traditional CHM-majors textbooks w/ spattering of applications

• CiC's approach: start with the 'big picture' & bring in the chemistry content on a need-to-know basis

• Applications are relevant to society: “citizens-first” approach (cf. “atoms first”)

• The only meaningful way to reach non-science majors is to personalize the content via contextualization (‘how does this relate to my everyday life?’)
1. Portable Electronics: The Periodic Table in the Palm of Your Hand
2. The Air We Breathe
3. Radiation from the Sun
4. Climate Change
5. Water Everywhere: A Most Precious Resource
6. Energy from Combustion
7. Energy from Alternative Sources
8. Energy Storage
9. The World of Polymers & Plastics
10. Brewing & Chewing
11. Nutrition
12. Health & Medicine
13. Genes & Life
14. Who Killed Dr. Thompson? A Forensic Mystery
A Challenging Audience: The Non-Science/Liberal Arts Major

- Their entire exposure to chemistry is represented by a single course
- Many did not take chemistry in high school
- Not particularly interested in the “why” underlying the concepts
- Need to know how the chemistry concepts influence their everyday lives
- Can especially benefit from group activities, demos, videos, games, student response systems (SRS), and other interactive & online activities
Chemistry Instruction: The ‘Citizen-First’ Approach

I. Create connections between contexts and chemistry content
Contextualized Connections

Redox reactions, states & properties of matter, stoichiometry, thermodynamics, etc.
Chapter 14: A Forensic Mystery!

• Capstone chapter connecting the content covered in other chapters

• Different narrative style than rest of text

• Part mystery novel … … part textbook

Back in the Crime Lab

Dr. Littleton was taken into custody on the evening of August 27 and remained in jail overnight. Fingerprints were taken, as well as a cheek swab to retrieve a sample of his DNA. DNA analysis was performed on the cigarette butts found near the hit-and-run scene and was compared with that of Dr. Littleton.

As discussed in Chapter 13, DNA is located in the nucleus of cells throughout the body. However, DNA must first be extracted from other cellular material, as well as debris such as clothing or cigarette butts. Commonly, a mixture with equal parts water, phenol (C₆H₅OH), and chloroform (CHCl₃) is used to extract DNA from its host matrix.

The DNA that has been extracted into the aqueous phase is then amplified using a technique known as the polymerase chain reaction (PCR). As illustrated in Figure 14.18, the double-stranded DNA is denatured into individual strands by heating to high temperatures (about 94 °C). Once the single strands are obtained, the solution is cooled to 72 °C, and an enzyme known as Taq polymerase is added. This catalyst serves to add complementary nucleotides to the single strands of DNA, giving rise to two identical DNA molecules. This process is repeated many times, to yield billions of copies of the original DNA extracted from a sample. The PCR technique has made it possible to produce significant quantities of DNA from extremely small samples, which is essential in properly identifying suspects.

NOTE: Spiraling is essential so students realize that chemistry content is relevant to a variety of contexts!
Chemistry Instruction: The ‘Citizen-First’ Approach

I. Create connections between contexts and chemistry content

II. Focus on student engagement
Textbooks: The Student Perspective

- “Do we *really* need to buy the textbook? It’s so expensive!”
- “What sections will be on the exam?”
- “I can’t understand what they are talking about!”
- “There aren’t enough examples provided.”
- “It is so long and boring!”
- “I don’t see how it relates to what we are talking about in lecture.”
- “I don’t see how it relates to the real world.”
Textbooks: The Faculty Perspective

- Students don’t appreciate how textbooks are organized.

- Students are poor readers and can’t extract key information from textbooks—even if written in a user-friendly manner.

- Students are used to getting snippets of information from social media and lack the discipline (or attention span!) to read textbooks.

- Textbook costs are becoming a burden for students; should I just adopt an online HW system (e.g., ALEKS/“ALEKSPedia”)?

- Students are overwhelmed by the pace of the course & choose to spend their time completing assignments rather than reading the textbook, doing practice problems, etc.

- How do we get students to read their books?!
“Smartbook” format (McGraw Hill) offers embedded assessment with reading to ensure students “interact” with the e-textbook.

- Embedded videos and simulations
- Margin notes (*Did You Know?*) - further exploration, historical info., section/chapter spirals
- In-chapter activities (*Emphasizing Essentials, Concentrating on Concepts, Exploring Extensions*) – to practice fundamentals or go beyond the content; used to foster student-instructor engagement

Let’s check it out …
Student Engagement: Embedded Visualizations, Simulations & Videos

Cholesterol (Ch. 12)

Many others woven throughout all chapters …
Student Engagement:
The “Hook” Opening Video
REFLECTION

Forensic Evidence Collection

A number of techniques are required to analyze evidence in a forensics investigation. However, the most crucial component of the investigation is related to the crime scene itself. With emotions running high, those among the first to respond to a crime must take steps to ensure that the crime scene is not contaminated. Furthermore, forensic investigators must collect and record all relevant evidence in an appropriate manner. For each of the following personnel, list three important operating protocols that you think would help protect the integrity of the crime scene:

a. Initial responder (police officer, firefighter, or emergency medical technician (EMT))
b. Detectives
c. Forensic scientists
Chemistry Instruction: The ‘Citizen-First’ Approach

I. Create connections between contexts and chemistry content
II. Focus on student engagement
III. Create pathways for active, student-centered instruction
Student-Centered Instruction: Connections to Personal Interests

• Explore further, apply concepts from the textbook, draw connections with the real world, or look for more recent material

  ➢ News & Views from scientific journals, scientific reporting from NY Times, sciencedaily.com, C&E News, www.acs.org, ChemMatters (ACS), Reactions videos and infographics (ACS), etc.

  ➢ *Behind the Scenes at MIT* (http://chemvideos.mit.edu/)

  ➢ *A Short History of Nearly Everything* by Bill Bryson (older, but a good starting point)

  ➢ *Unstoppable: Harnessing Science to Change the World* (Bill Nye)

  ➢ *Best American Science and Nature Writing* series

  ➢ *Other suggestions?*
Student-Centered Instruction: Connections to Personal Interests

- Alter chapter selection or order to match group interest
- Supplement chapter with relevant information
  - National or local news (opioids, Covid-19 treatment, etc.), climate change (e.g., climate.nasa.gov, climatechangenews.com, etc.)
- Use opportunities for reflection & short essays
Electron Configurations and Periodic Properties: Atomic Radii

Atomic radii increases down a column because successively larger valence-shell orbitals are occupied. Atomic radii decreases from left-to-right because the effective nuclear charge increases.
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IV. Never assume a lack of prior assumptions
Prior Knowledge & Assumptions

Students walk in with already-formed conceptions about the world—often deeply held.

Facts alone rarely dislodge misconceptions.

*How People Learn*, National Academies Press, 1999
What Americans know and don’t know about science

% of U.S. adults who answer each question correctly

<table>
<thead>
<tr>
<th>Life science</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Antibiotic resistance is a major concern of antibiotics overuse</td>
<td>79</td>
</tr>
<tr>
<td>Identify the definition of an incubation period</td>
<td>76</td>
</tr>
<tr>
<td>Inserting a gene into a plant is an example of genetic engineering</td>
<td>56</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Earth and other physical science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil, natural gas and coal are fossil fuels</td>
<td>68</td>
</tr>
<tr>
<td>Tilt of Earth's axis in relation to sun determines seasons</td>
<td>63</td>
</tr>
<tr>
<td>Deforestation on land leads to increased erosion</td>
<td>60</td>
</tr>
<tr>
<td>The main components of antacids are bases</td>
<td>39</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Numeracy and chart reading</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Chicago, Illinois, has the greatest annual range of temperatures (with charts)</td>
<td>59</td>
</tr>
<tr>
<td>A car traveling 40 mph travels 30 miles in 45 minutes</td>
<td>57</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scientific processes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify the need for a control group to determine effectiveness of a new drug</td>
<td>60</td>
</tr>
<tr>
<td>Identify a hypothesis about a computer slowing down</td>
<td>52</td>
</tr>
</tbody>
</table>

Notes: All questions are multiple choice. For full question wording, see topline.
Source: Survey conducted Jan. 7-21, 2019.
“What Americans Know About Science”

PEW RESEARCH CENTER
When Science & Politics Mix ...

Role of science knowledge in public perceptions that climate research reflects the best evidence depends on one’s political point of view

% of Republicans or Democrats who say climate research findings are influenced by the best available scientific evidence most of the time

<table>
<thead>
<tr>
<th></th>
<th>Republican</th>
<th>Democrat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>17</td>
<td>27</td>
</tr>
<tr>
<td>Medium</td>
<td>16</td>
<td>42</td>
</tr>
<tr>
<td>High</td>
<td>21</td>
<td>73</td>
</tr>
</tbody>
</table>

Note: Respondents who gave other responses or who did not give an answer are not shown. Republicans and Democrats include independents and other non-partisans who “lean” toward the parties. Respondents who do not lean to a political party are not shown.

Source: Survey conducted May 10-June 6, 2016.
“Politics of Climate”

PEW RESEARCH CENTER
Facts are Becoming Increasingly Harder to Discern ...

Climate confusion among US teachers

“When I do teach about climate change, I emphasize ...”

... the scientific consensus that recent global warming is primarily being caused by human release of greenhouse gases from fossil fuels.

... that many scientists believe that recent increases in temperature are likely due to natural causes.

Agree or strongly agree

- Mixed messages 31%

Disagree or strongly disagree

- Scientific consensus 54%
- Denial 10%
- Avoidance 5%

Survey of 1,500 middle and high school teachers (Science 2016, 351, 665)
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V. Teach students to examine multiple sources, ask questions, and look for biases
“Fake News”?! Always Consider the Source!

- Always require citations on reports
- Use library databases for news & articles
- Evaluate author or funding agency biases
- Consider the publishing or media source; discuss the peer review process
An Interesting Case Study!

Claims of a ‘scientific consensus’ on climate change rest on two college student papers, the writings of a wacky Australian blogger, and a non-peer-reviewed essay by a socialist historian ...

BUT: 97% consensus among climate scientists!

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VI. Present the ebb and flow in science
The ‘Real’ Scientific Method

• When presenting the scientific method
  ➢ Include history and current examples
  ➢ Discuss (qualitatively) sample size
  ➢ Present the process of revision and consensus in science

• When turning to policy or contentious issues
  ➢ What is a fact versus an opinion
  ➢ What is known
  ➢ What is interpretation
  ➢ What is up for debate as action or policy response
Real-World Examples ...

• Assignment idea: Compare popular press video to more scientific sources
  ➢ Covid-19 vs. influenza
  ➢ Opioid addictions
  ➢ Anything on red wine, coffee, chocolate!
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VI. Present the ebb and flow in science
VII. Include debates
Class Debates

• Can be done both in-person & online (WebEx, etc.)
• Identify contrasting opinion pieces or media sources and expand
• *Exploring Extensions* prompts in textbook
  - Text directly identifies and explores common misconceptions

For example …

• Present common arguments:
  - GMOs cause health problems such as allergies and cancer
  - GMOs create “super insects” and “super weeds”
  - Farmers can’t replant genetically modified seeds

• Follow with a specific counterpoint
• Include relevant peer-reviewed research references
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