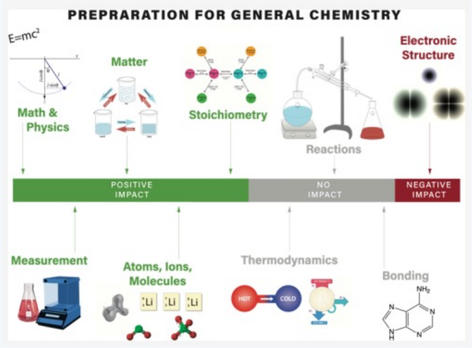
A systemic evaluation of atomic representations in general chemistry textbooks

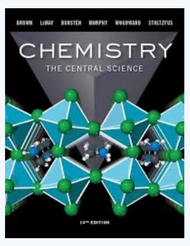
Siddharth Siravara,[1,3] Aiden Choi,[2,3] Binyomin Abrams[3]

Mercer Island High school, Mercer Island, WA[1]; Seoul Preparatory, Seoul, South Korea[2]; Boston University , Boston, MA[3]

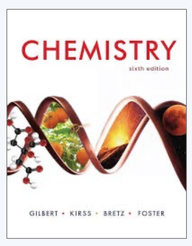
The Refinement of curriculum and knowledge

- ***Challenges***:
  (1) Previous work in the Abrams group has shown that **Chemistry students struggle to grasp quantum chemistry concepts.**[1]
  (2) Student struggles are amplified by **naïve conceptions** that stem from previous exposure to the subject
- ***Goals***:
  (1) Identify how the presentation of information in textbooks encourages the development of naïve conceptions.
  (2) Better understand how chemistry curriculum needs to be refined to **increase student understanding**

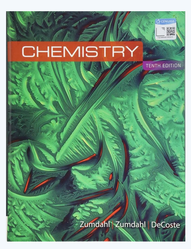




Brown and LeMay, *Chemistry: The Central Science* (14e), 2017



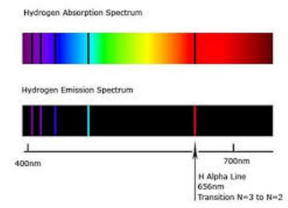
Gilbert, et. al., *Chemistry: The Science in Context* (6e), 2020



Zumdahl and Zumdahl, *Chemistry* (10e), 2017

Textbook Coding System

- To collect sufficient data for each text a coding key was developed that readers to order their images, as well as significant features.
- Two coders generated a list of **22 common atomic representations**. These representations included graphs, models, and equations.
- Each representation was **associated with its own set of questions** meant to discern if the diagram and text around it referenced the concepts needed to understand the model being discussed.
- The two readers analyzed each text separately, filling out the coding templates as they read. Once finished the two coding documents were **compared with an 89% agreement rate.**

Page #	**Atomic Emission Spectra - Hydrogen**
	Are lines labeled with wavelength or frequency? Answer
	Is the connection to energy transitions made? Answer
	Are these shown as experimental evidence for quantization? Answer
	Do they note Paschen and Lyman spectra? Answer
Notes Answer	

A Sample coding template used to classify textbook figures.

Inconsistencies in use of atomic-theory representations in General Chemistry textbooks

Key preliminary findings:

Within each text Atomic representations were used inconsistently

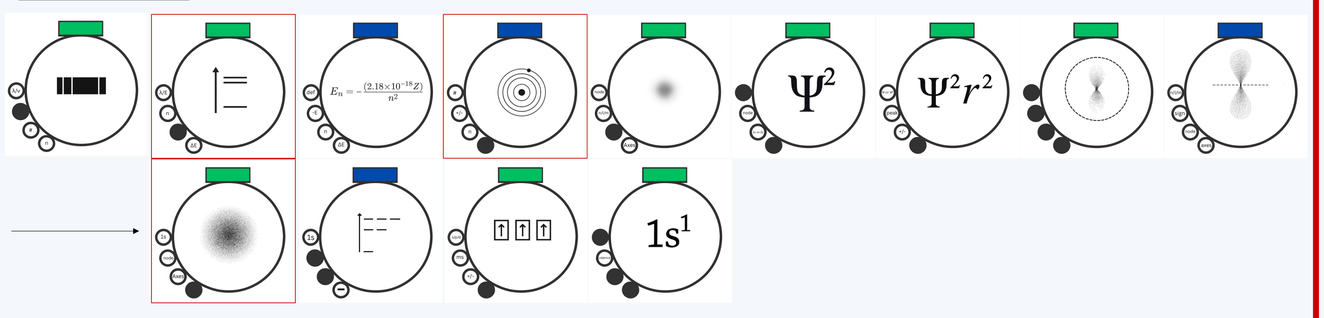
- Certain representations like the nodal model were often introduced and not referenced again.
- The textbooks contained **mislabeled diagrams.**
- Terms associated with the Bohr model and classical chemistry like" jump" , "orbit", and "fall" were used to describe representations of the modern atomic model.

Along with differences within the text each textbook approached atomic chemistry through a different lens.

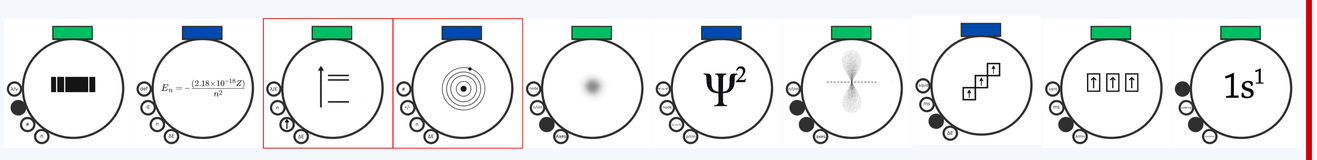
- *Chemistry* **lacked in information about wave functions** and reenforced Bohr conceptions through the text
- *Chemistry: The Central Science* **lacked information on wave functions and periodic trends.** It also reenforced Bohr conceptions through the text.
- *Chemistry: The Science in Context* explained the history of atomic chemistry's development and often alternated between wave and particle descriptions of an electron.

To the right are pictorial representation of the presentation of atomic information in the analyzed textbooks

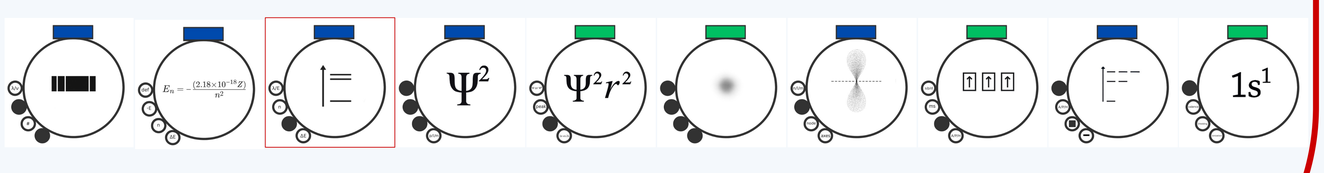
Zumdahl:



Brown and LeMay



Gilbert, et. al.



A Key for the Pictorial representations:

n/l/m: The representation is labeled with quantum numbers.
n: The representation is connected to the quantum number n.
A/P/H: The representation is connected to Hund's rule and the Aufbau and Pauli principles.
#: The representation is used to explain quantization.
Axes: The representation is labeled with Axes.
Nodes: The representation is labeled with nodes.
Symmetry: The representation is labeled with symmetry.
Peak: The peak of the graph is interpreted.
Ψ vs Ψ²: Ψ is compared with Ψ².
Ψ or Ψ²: The graph is compared with Ψ or Ψ².
1s: The diagram is labeled with orbitals.
1s vs 2s: The diagram compares two orbitals.
-E: negative energies are interpreted.
ΔE: The diagram is related to energy transitions.
-: The energy level diagram has lines.
MS: Spin is discussed in relation to the diagram.
λ/v: Frequency and wavelength are related to the diagram.
λ/E: Energy and wavelength are related to the diagram.
def: The equations terms are defined.
Radius: The diagram is used to explain the radius trend of the periodic table.
Shielding: The diagram is used to explain shielding.
Ionization: The diagram is used to explain ionization.
Valence: The diagram is used to explain valence electrons.
The representation is mentioned and explained:
The representation is repeatedly used :
Particle like representation:

Future Directions

- Create interviews to see if **teacher understanding** of quantum chemistry reflects inconsistencies in chemistry textbooks.
- Broaden the analyzed texts to include introductory high school and high level general chemistry textbooks.
- Understand **how the textbooks relate different representations to each other** through the creation of detailed diagrams.

References

1. Ed debts
2. Physical chemistry textbooks
3. Nordic Textbooks
4. Climate in textbooks
5. Junior high school chemistry