# How loud is this page? The noise in, and of, representations

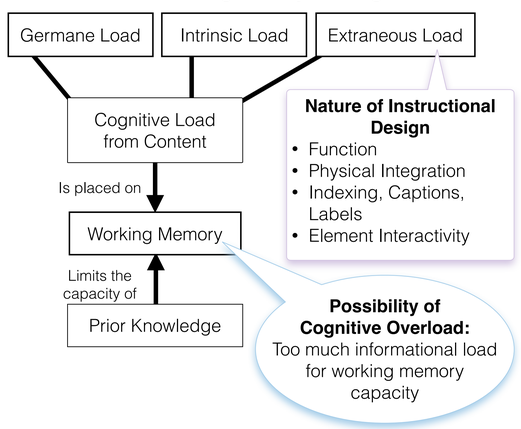
Merry Gillaspie[1] and James Nyachwaya[2]

[1]Wartburg College, [2]North Dakota State University

## Background

Chemistry content is generally represented using four types of representations: text, symbolic, submicroscopic, and macroscopic (Johnstone, 1991; Corrdi et al., 2012). It is often necessary for a student to integrate at least two of these representational types in order to understand phenomena. The active process of learning science also requires students to assimilate new information from representations with their prior knowledge of a topic using their working memory (Cook, 2006).

**Schematic of Working Memory and Cognitive Load**




Textbooks are important instructional materials in the general chemistry curriculum. While intended for a range of student readers, the variety of prior knowledge levels present at the start of the course means that cognitive overload is likely for some learners. We were interested in the extent that the use of representations in general chemistry texts promotes or hinders learning due to extraneous cognitive load, or "noise." Specifically, we were guided by the following questions, which can be divided into four categories suggested by cognitive load theory.

## Research Questions

**Number, Type, and Purpose of Representations**

1. What is the per-page distribution of different representation types and representations overall?
2. What function do representations serve in General Chemistry texts?

**Spatial Contiguity Principle**

3. To what extent are representations physically integrated with the running text?

**Instructional Guidance Principle**

4. To what extent are representations and math equations indexed within the running text?
5. To what extent do representations have captions or labels?

**Split Attention Principle**

6. To what extent do representations require conceptual integration with the text and/or each other?

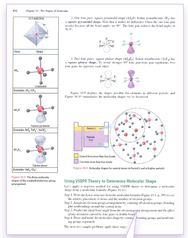
## Acknowledgments


- Thank you to NDSU for facilities and housing.
- Thank you to all of the Growing Up STEM REU undergraduates and faculty mentors for their guidance.
- This material is based upon work supported by the National Science Foundation under NSF DUE-1156974. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.


NDSU

## Methodology

**1. Textbook Selection**
- Five general chemistry textbooks
- Four from the top five distributed texts in 2012 (Pyburn & Pazicni, 2014)
- Fifth chosen based on convenience



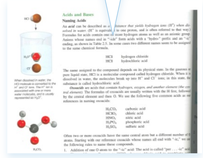
**2. Number and Type of Representations Counted**

| Page | Total # | Text | Symbolic | Submicro. | Macro. |
|---|---|---|---|---|---|
| 412 | 12 | 1 | 4 | 7 | |
| 413 | 7 | 1 | 6 | | |

**3. Detailed Coding**: We used a modified form of the GAP Protocol (Slough et al., 2010).

| Page # | Function | | | | Static/Dynamic | | Physical Integration | | | | Figure Indexing | | | Math Eqn. Indexing | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Represent. | Decor. | Interpret. | Organize | Static | Dynamic | Distal | Facing | Proximal | Direct | Same pg. | Diff. pg. | Unindexed | Yes | No |
| 62 | 2 | 2 | 1 | 1 | 6 | | | | 1 | 5 | 1 | 0 | 3 | | |

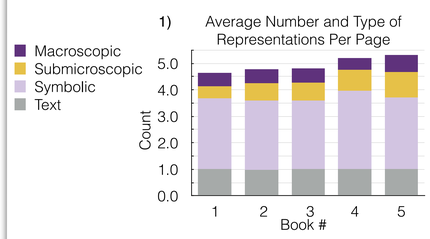
| Caption | | | | | | Labels | | Element Interactivity | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yes | No | Identify | Describe | ID & Describe | Engage | Yes | No | Yes | No | Group 1 | Group 2 | Group 3 |
| 2 | 2 | | | 2 | | 4 | | 3 | 3 | 2 | 2 | 2 |



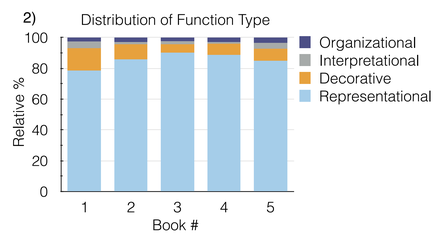
**4. Analysis**
- Counting verifications across both rubrics and categories
- Excel statistics

## Results

### Number, Type, and Purpose of Representations

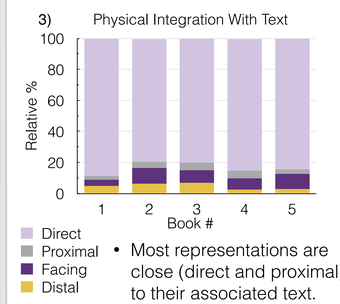



- On average, a page has text plus 3 or 4 representations.
- Symbolic representations are the most common.
- The most variation occurs with submicroscopic representations.



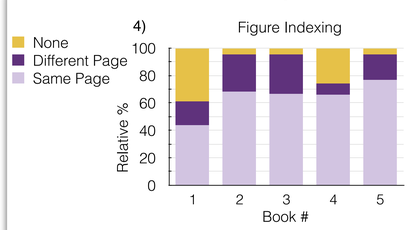

- Texts have more decorative representations than organizational and interpretational ones combined.

### Spatial Contiguity Principle

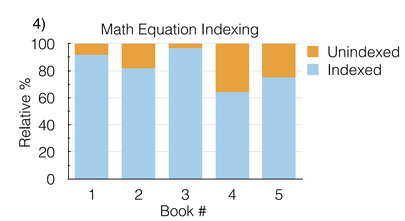



- Most representations are close (direct and proximal) to their associated text.
- At least 10% are further away from their text (facing or distal).

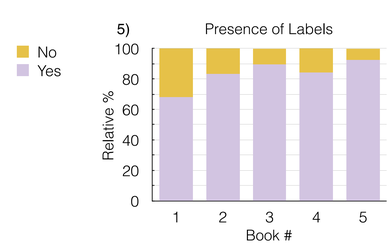
### Instructional Guidance Principle



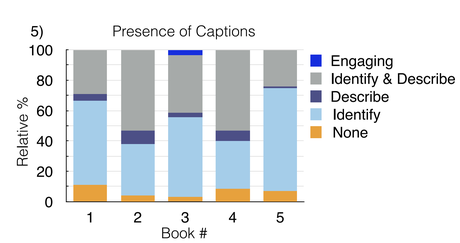

- At least 60% were indexed.
- 10% or more were indexed on a different page.




- Unindexed equations often are not referenced in later text.

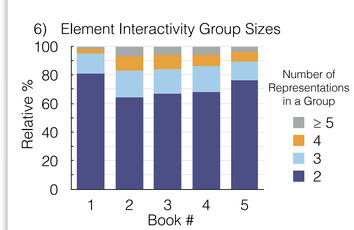


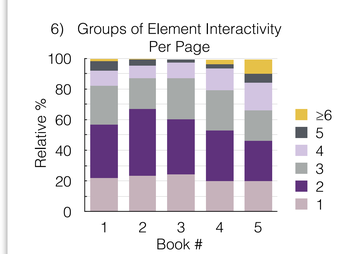

- 30% or less did not have labels.




- 90% or more are captioned.

### Split Attention Principle




- Most pages have 1, 2, or 3, groups of interactivity.

## Discussion

**Number, Type, and Purpose of Representations**
- On average, the sampled texts contain at least three representations plus text. Corradi et al. found that two representations plus text was high for low prior knowledge level students.
- Symbolic representations were the most prevalent. These representations tend to promote rote memorization (Nakhleh, 1993).
- The second most common function of representations was decorative. Decorative representations take away cognitive resources meant for learning, likely leading to unnecessary cognitive overload (Slough et al., 2010).

**Spatial Contiguity Principle**
- Representations that are facing or distal to the text (at least 10% in our study) make text-representation association more difficult (Wu & Shah, 2004).

**Instructional Guidance Principle**
- Lack of indexing makes it harder to associate representations with the associated text.
- The absence of captions and labels makes it harder to "read" a representation (Sweller, 2004).

**Split Attention Principle**
- Larger element interactivity group sizes and more groups of element interactivity per page increase the cognitive load present in a page of text (Plass et al., 2009).

## Future Studies

- Determine the extent to which our coding categories impact cognitive load using eye tracking and other techniques.
- Conduct readability studies on general chemistry textbooks.
- Based on a recent study on representations using learners with low prior knowledge (Corradi et al., 2014), replicate that study with learners possessing high prior knowledge or experts.

## References


- Chang, R., Goldsby, K.A. (2013). *Chemistry.* 11th ed. McGrawHill, New York, NY.
- Gilbert, T., R., Kriss, R. V., Foster, N. & Davies, G. (2015). *Chemistry.* 4th Ed. W.W Norton & Company, New York, NY.
- Brown T.L, LeMay, H.E., Bursten, B.E., Murphy, C.J., Woodward, P.M., & Stoltzfus, M.W. (2015). *Chemistry: The Central Science.* 13th ed. Pearson, Upper Saddle River, NJ.
- Tro, N. J. (2015). *Chemistry: Structure and Properties.* Pearson, Upper Saddle River, NJ.
- Silberberg, M. and Amateis, M. (2015). *Chemistry: The Molecular Nature of Matter and Change*, 7th Ed. McGrawHill, New York, NY.

- Cook, M.P. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education, 90*(6),1073-1091.
- Corradi, D.M.J., Elen, J., Schraepen, B., & Clarebout, G. (2014). Understanding possibilities and limitation of abstract chemical representations for achieving conceptual understanding. *International Journal of Science Education, 36*(5), 715-734.
- Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem, *Journal Computer Assisted Learning, 7*, 75-83.
- Nakhleh M.B. (1993). Are our students conceptual thinkers or algorithmic problem solvers? *Journal of Chemical Education, 70*, 52-55.
- Plass, J.L., Homer, B.D., & Hayward, E.O. (2009). Design factors for educationally effective animations and simulations. *Journal of Computing in Higher Education, 21*(1), 31-61.
- Pyburn, D.T. & Pazicni, S. (2014). Applying the multilevel framework of discourse comprehension to evaluate the text characteristics of general chemistry textbooks. *Journal of Chemical Education, 91*, 778-783.
- Slough, S.W., McTigue, E.M., Kim, S., & Jennings, S.K. (2010). Science textbooks' use of graphical representation: A descriptive analysis of four sixth grade science texts. *Reading Psychology, 31*, 301-325.
- Sweller, J. (2004). Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture. *Instructional Science, 32*, 9 - 31.
- Wu, H.-K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education, 88*, 465- 492.