Methods: Context

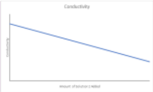
- Data came from a general chemistry (I) class in the spring semester of 2020
- Based on: reactions in aqueous mediums and the concept of precipitation

Methods: Activity

- Students were shown a 12 second video of precipitation and assigned a set of questions to respond to regarding the reaction in the video
- Students were asked to write their answers down and record their conversations

Handout Instructions:

1. Watch the 12 second video in the link below. In the space below, describe what you observed.
2. Based on the ions in the two solutions, what are the formulas of the compounds in each solution?
3. Based on the formulas you determined above, predict the products and write a complete molecular equation of the reaction.
4. Write a complete ionic equation for the reaction.
5. Write the net ionic equation.
6. Suppose we initially measure the conductivity of one of the solutions, and then slowly add the second solution to it, how would you expect the conductivity of the mixture to change? Assume you have equal amounts of solution.
7. (a)In the space below, sketch a graph of current conducted against amount of solution 2 added.
(b) Explain your sketch.

Question	Translation or Representation	Expected Answer/ Answer Components	Sample Response	No. of groups with correct responses (n = 79)
1	Macroscopic Observation	Initial solutions clear, solutions mixed/ touched, yellow precipitate/solid was formed,	When mixed the substances made a yellow color	**1**
2	Submicroscopic to Symbolic	$Pb(NO_3)_2$ and KI	Pb^{2+}, NO_3^-, K^+, I^-	**56**
3	Symbolic	$Pb(NO_3)_2$ (aq) + 2KI (aq)→PbI_2 (s) + $2KNO_3$ (aq)	$Pb(NO_3)_2$ + 2KI →PbI_2 + $2KNO_3$	**11**
4	Symbolic/ Submicroscopic	Pb^{2+} (aq) + $2NO_3^-$ (aq) + $2K^+$ (aq) + $2I^-$ (aq) → PbI_2 (s) + $2K^+$ (aq)+ NO_3^- (aq)	Pb^{2+} + $2NO_3^-$ + $2K^+$ + $2I^-$ → PbI_2 (s) + $2K^+$ (aq)+ NO_3^-	**6**
5	Symbolic/ Submicroscopic	Pb^{2+} (aq) + $2I^-$ (aq) → PbI_2 (s)	Pb^{2+} + $2I^-$ → PbI_2 (s)	**16**
6	Conceptual Understanding	Conductivity will decrease	More ions means more conductivity	**35**
7a	Symbolic			**32**
7b	Conceptual Application	The conductivity decreases because there are fewer free ions in solution	No explanation, students don't understand what conductivity is	**10**

General Chemistry Students' Representational Fluency and Conceptual Understanding of a Precipitation Reaction

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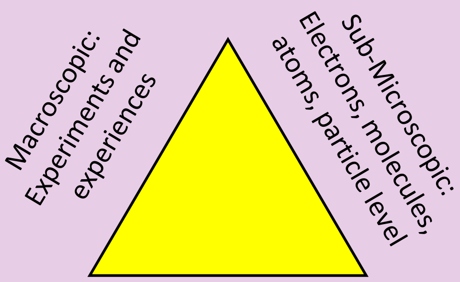
Johnstone's Triangle



The framework for this research was based in Johnstone's Triangle (Johnstone, 1991). Johnstone's Triangle claims there are 3 levels of representation in chemistry, Macroscopic, Symbolic, and Submicroscopic. We collected data to look for students' fluency translating between these three areas. In the methods section above, the specific questions and their place on Johnstone's Triangle are shown.

Goals:

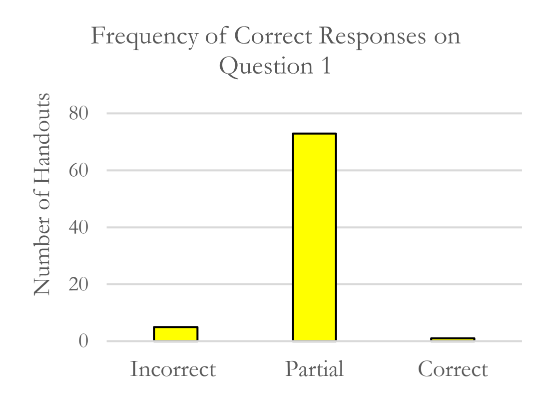
Uncover college general chemistry students'

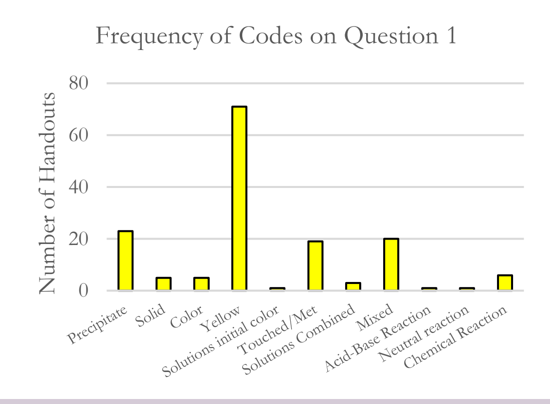
- Ability to translate between different levels of representation in the context of a precipitation reaction
- Conceptual understanding of the process of precipitation

Relevance:

- Many other studies have also examined student's fluency and found that even up to the 3rd level of undergrad, students are still not translating at a satisfactory level (Gkizia, Salta, Tzougraki, 2020)
- The misconceptions about precipitation and other chemical events can be tracked back to students' misconceptions regarding language use, for example terms like solute, solvent, and solution (Çalık, Ayas, 2005)

The reaction the students observed in this precipitate forming.





These three graphics are all different representations of the data we collected from question 1. Top left is based on how the coders graded each handout. Bottom left is a graph of codes. Codes that were rare or irrelevant were left off. The representation below is a Word Cloud of the relevant language used by the students.

The size of each word is dictated by its frequency in the responses.

Results:

Overall, our study shows mixed results:

- Many students struggled to navigate the different levels of representation.
- We were surprised by how many provided partial observations (macroscopic level).
- Students also struggled with the conceptual aspects of precipitation, which is linked to their understanding of the submicroscopic (particle) level.

References:

Çalık, M., & Ayas, A. (2005). A Cross-Age Study on the Understanding of Chemical Solutions and Their Components. *International Education Journal*, *6*(1), 30-41.

Gkitzia, V., Salta, K., & Tzougraki, C. (2020). Students' competence in translating between different types of chemical representations. *Chemistry Education Research and Practice*, *21*(1), 307-330.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of computer assisted learning*, *7*(2), 75-83.

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