General chemistry students' conceptual understanding of dissolving and associated phenomena

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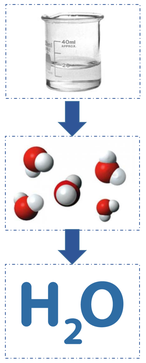
Background

Student Schemas

- Assimilation – incorporating new information into an existing schema.
- Accommodation – modifying existing schemas to be inclusive of new information or revisions in knowledge.[3]
- More-Knowledgeable Other – a peer or superior who helps to alter schemas.

- This study is grounded in the framework that chemistry is represented at three levels: macroscopic, microscopic/particulate, and symbolic levels.[1]
- Understanding chemistry requires that students understand, represent and translate between the three levels of representation, making them critical to understanding chemistry concepts.[4]
- Additionally, constructivism supports that students learn best from concrete to abstract experiences.[2]



Methodology

- This study took place in a second semester General Chemistry (II) class at a Mid-western United States institution (n=160).
- Students completed a worksheet in groups of 3-4, with a total of 46 groups.
- Students were asked to discuss in their groups, come to a consensus, and write their answers to the questions in the worksheet.
- Audio transcripts of deliberations in the groups were also collected.
- The activity took place immediately after the chapter on intermolecular forces.
- Open-ended, free-response questions were used in the activity.

Coding

- Responses were scored as either correct or incorrect based on an established grading key.
- Responses to A (Describe…) were examined for the number of correct aspects.
- Drawings of interactions were examined and coded
- Initial categories informed by previous research. New categories for drawings were created as necessary.
- All existing categories were reviewed iteratively.
- Responses to C (Conservation…) and D (Entropy…) were examined for correct reasoning.
- Analysis of the data was constructed through a grounded-theory approach.

Research Questions

What is general chemistry students' conceptual understanding of dissolving and associated phenomena?

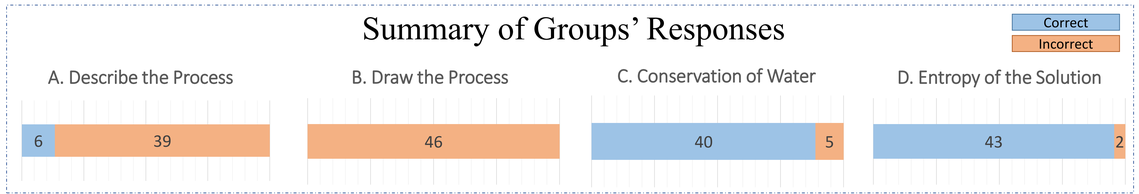
A. To what extent can students describe what happens when sodium chloride dissolves in water?

B. To what extent can students draw a diagram to depict the interactions in the solution?

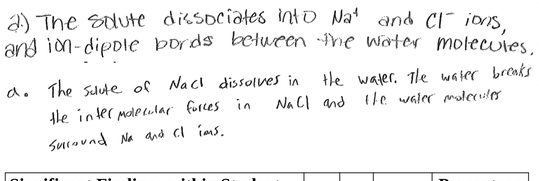
C. To what extent can students explain how much water is left after dissolving has occurred?

D. To what extent can students explain how the 'total' entropy of the solution compares to the pure solvent?

Results

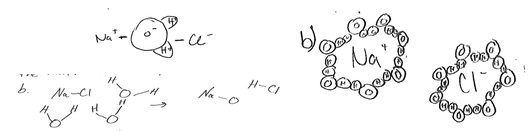


A. Describe the Process



Significant Findings within Student Reasoning and Misconceptions	Yes	No	Bonds	Percentage Correct
Mentions the positive and negative charge on the sodium and chloride ions	22	23	N/A	**49%**
Uses the terminology 'dissolve' or 'dissociate' in the response	21	24	N/A	**47%**
Mentions the water molecules will surround the ions	7	38	N/A	**16%**

B. Draw the Process



Traits of Drawings	Yes	No	Partial	Percent Accurate
Draws Na and Cl with charges (ions) not NaCl nor Na and Cl	25	20	1	**54%**
Draws water with a bent structure	29	16	1	**63%**
Shows bonds and intermolecular forces and distinguishes between the two	5	41	N/A	**11%**
Water molecules surround the Na^+ and Cl^- ions	8	34	4	**17%**

C. Conservation of Water

Grouping (Same amount of water because…)	Number of Groups	Percent of Groups
The amount of water decreases	5	**10%**
There is no heat provided to the solution	3	**6%**
Water is attracted to the positive and negative ends of sodium chloride	2	**4%**
Water doesn't break; remains intact	4	**8%**
Dissolving occurs	8	**16%**
There is no reaction that occurs	8	**16%**
There is no evaporation	5	**10%**
Other Responses	7	**14%**
No response provided from students	7	**14%**

D. Entropy of the Solution

Groupings	Number of Groups	Percent of Groups
Increases due to dissolving	7	**15%**
Disorder increases so entropy increases	7	**15%**
Total entropy of the solution is greater than pure solvent (increases)	11	**23%**
Increases due to splitting of solvent NaCl	4	**9%**
Entropy decreases	3	**6%**
Other Responses	8	**17%**
No response provided from group	7	**15%**

Mentions the following term:	Yes	No	Percent Correct
Disorder/Order	12	33	26%
Dissolving	6	39	13%
Solvent	22	23	48%
Solute	5	40	11%

Discussion

- None of the groups provided correct answers on all four prompts. Four groups (9%) articulated a correct answer on three of the four questions. Seven groups (15%) articulated a correct answer on one or fewer questions.
- In listening to the audio files, there was little to no discourse between most groups, even though time and opportunity was provided to discuss answers to reach a group consensus.
- In response to question **A**. groups articulated the splitting of the sodium chloride; however, few discussed the surrounding of the ions by water molecules.
- Less than half the groups responses' to question **B**. drew the O with the Na and the H with the Cl ion. Furthermore, 17% drew the water molecules surrounding the sodium and chloride ions.
- While 89% of groups' responses were coded as correct for question **C.**, only 16% of groups attributed the amount of water remaining the same because there is no reaction so water is not created, nor destroyed.
- 96% of groups in **D**. were coded as a correct response; however 4 groups (9%) explained were scientifically accurate and detailed.

Future Research

- The use of a conceptual change activity or a MORSE (Model-Observe-Reflect-Speak-Explain) thinking frame approach to reform student thinking
- Expansion of the associated phenomena to include: molecular and ionic compounds, conductivity, concentration, molecular geometries, and homogeneous/heterogeneous mixtures.

References

[1] Devetak, Iztok, Janez Vogrinc, and Saša Aleksij Glažar. "Assessing 16-year-old students' understanding of aqueous solution at submicroscopic level." Research in Science Education 39.2 (2009): 157-179.

[2] Çalik, Muammer, Alipaşa Ayas, and Richard Kevin Coll. "Enhancing pre-service elementary teachers' conceptual understanding of solution chemistry with conceptual change text." *International journal of science and mathematics education* 5.1 (2007): 1-28.

[3] Bruck, Laura B., Aaron D. Bruck, and Amy J. Phelps. ""Gone" into Solution: Assessing the Effect of Hands-On Activity on Students' Comprehension of Solubility." *Journal of Chemical Education* 87.1 (2009): 107-112.

[4] Adadan, Emine, and Funda Savasci. "An analysis of 16–17-year-old students' understanding of solution chemistry concepts using a two-tier diagnostic instrument." *International Journal of Science Education* 34.4 (2012): 513-544.

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