

4-2016

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Probing Question Order Effect in Chemistry Concept Inventories

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What is Question Order Effect?

Test PV

1. Question 1
2. Pictorial
3. Question 3
4. Verbal
5. Question 5

Test VP

1. Question 1
2. Verbal
3. Question 3
4. Pictorial
5. Question 5

- Teachers often randomize test questions and create multiple versions of tests to prevent cheating.
- Current literature across various subjects is split on whether or not this gives students taking a certain test version an unfair advantage.^{1,4}
- The goal of this project is to test whether the question order effect is present in a chemistry concept inventory. Many studies have been done regarding content order and difficulty order, but we want to test the effect of pictorial versus verbal question order.^{2,3}
- A similar study was performed at a western institution to compare results between institutions.

Research Question

- How does question order affect student performance on conceptually isomorphic questions when presented with pictorial and verbal versions of the questions?

Methods and Participants

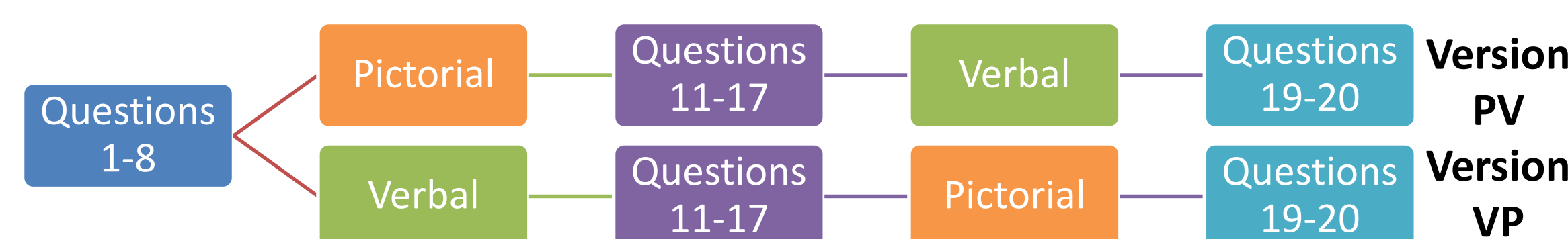
- A 20 question concept inventory about acids and bases was given to all sections of General Chemistry II (GCII) and Organic Chemistry I (OCI) at the beginning and end of the semester for two semesters.
- Data was only kept if students answered with a proper level of effort. We only kept students who self-reported a moderate effort (1, 2, or 3 out of a 4 pt scale) and high effort (1 or 2 out of a 4 pt scale).
- 768 pre and post survey responses were collected from GCII and OCI. After cleaning the data for effort levels and whether or not the students used resources, we were left with the following sample size:

| | Moderate Effort | | | High Effort | | |
|----|-----------------|------|-----|-------------|------|-----|
| | GCII | | OCI | GCII | | OCI |
| | Pre | Post | N/A | Pre | Post | N/A |
| PV | 134 | 101 | 82 | 59 | 70 | 39 |
| VP | 144 | 101 | 81 | 66 | 61 | 40 |

- Selective, semi-structured interviews were conducted at the end of each semester. A total of 19 students were interviewed. (7 from GCII, 12 from OCI)

Instruments

- Two inventory versions:



Verbal Question

V. What characteristic always distinguishes a weak acid from a strong acid?

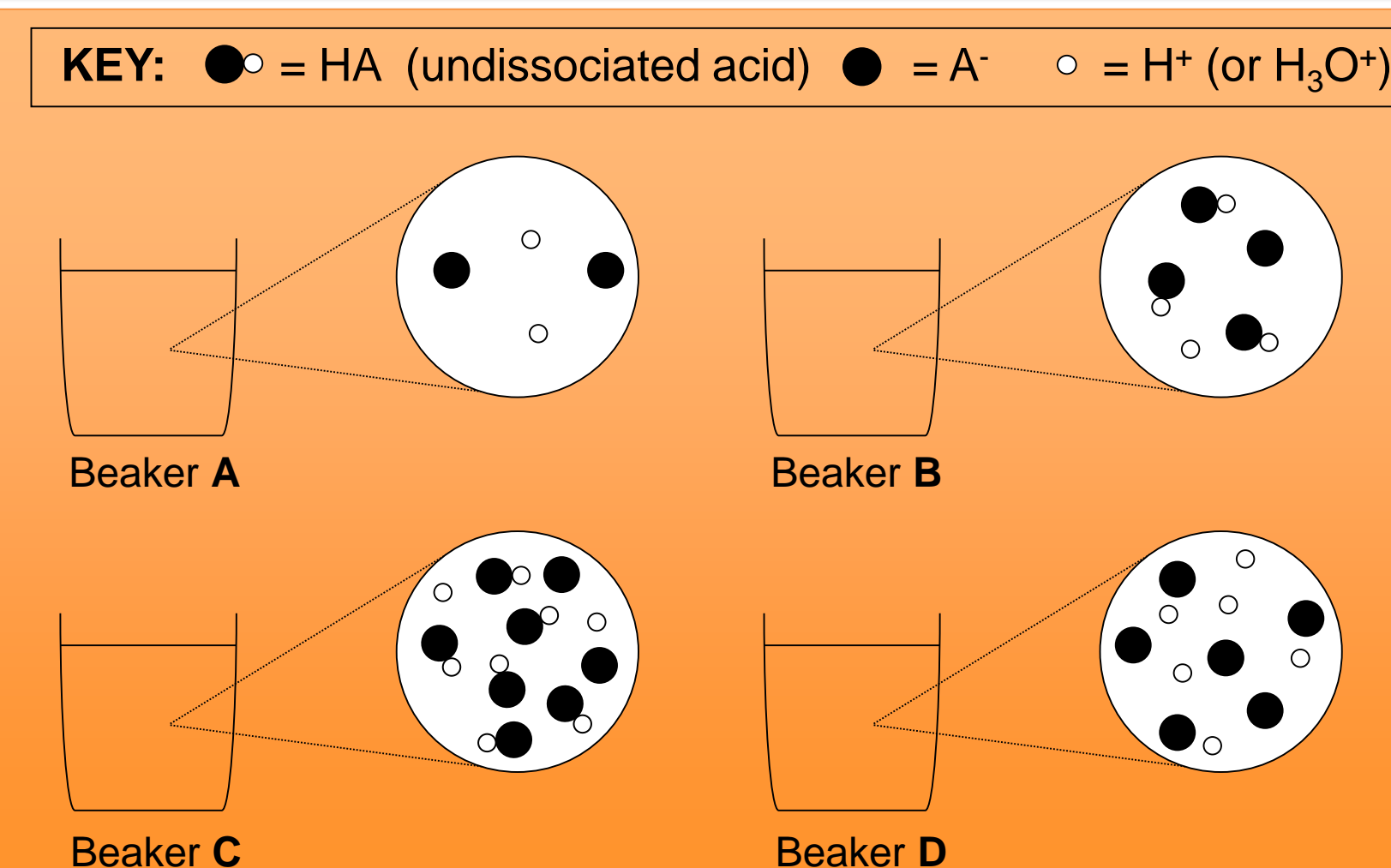
- A weak acid doesn't dissociate much in water; strong acids completely dissociate.
- A weak acid is more dilute than a strong acid.
- A weak acid has a higher pH than a strong acid.
- A weak acid more easily dissociates in water because it has weaker bonds.
- Statements a – c are all characteristics that distinguish weak acids from strong acids.

Pictorial Question

Question P refer to the drawings on the right. Four beakers each contain an acid. Molecular-level drawings in the circles to the right represent the particles in solution. Water molecules are not shown. Each beaker contains the same volume of solution.

P. Which statement is true?

- Beakers A and B contain the weakest acids.
- The acid contained in Beaker C could be HCl (aq), which is a strong acid.
- The most concentrated acid is contained in Beaker D.
- The acid contained in Beaker A could be HNO₃ (aq), which is a strong acid.



Results – Concept Inventory

Moderate Effort % Correct

| Question | GCII Pre | | Significance | | Question | GCII Post | | Significance | | Question | OCI | | Significance | |
|----------|--------------|-------|--------------|-------------|----------|--------------|-------|--------------|-------------|----------|--------------|-------|--------------|-------------|
| | Test Version | | p value | effect size | | Test Version | | p value | effect size | | Test Version | | p value | effect size |
| | PV | VP | | | | PV | VP | | | | PV | VP | | |
| P | 15.7% | 20.8% | 0.267 | .067 | P | 39.6% | 49.5% | 0.157 | .100 | P | 29.3% | 30.9% | 0.824 | .017 |
| V | 30.6% | 32.6% | 0.715 | .022 | V | 43.6% | 53.5% | 0.159 | .099 | V | 35.4% | 38.3% | 0.701 | .030 |

High Effort % Correct

| Question | GCII Pre | | Significance | | Question | GCII Post | | Significance | | Question | OCI | | Significance | |
|----------|--------------|-------|--------------|-------------|----------|--------------|-------|--------------|-------------|----------|--------------|-------|--------------|-------------|
| | Test Version | | p value | effect size | | Test Version | | p value | effect size | | Test Version | | p value | effect size |
| | PV | VP | | | | PV | VP | | | | PV | VP | | |
| P | 16.9% | 19.7% | 0.692 | .035 | P | 47.1% | 57.4% | 0.242 | .102 | P | 35.9% | 40.0% | 0.707 | .042 |
| V | 30.5% | 36.4% | 0.489 | .062 | V | 38.6% | 57.4% | 0.032 | .188 | V | 38.5% | 42.5% | 0.715 | .041 |

- We observed a question order effect only on question V for students with high effort. The western institution found similarly insignificant results. The only question that showed significance was question P in the post populations.
- Due to this both institutions treated the data by separating each of the populations by gender as well as by students' scores on the first 8 homogenous questions to see if any of these factors played a role. No question order effect was observed.

Results – Interviews

| Question | Answer | GCII | | OCI | | Example of quote providing justification for choice |
|---------------------------------------------------------------|---------------|------|----|-----|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| | | PV | VP | PV | VP | |
| Did you prefer seeing the verbal or pictorial question first? | Pictorial | 2 | 0 | 1 | 0 | "I thought it [P1] kind of helped to visualize the dissociated-ness because you can tell the stronger ones and they tell you here that's undissociated and you know it's a weak acid. So yeah that kind of helped me to see [P1] first." |
| | Verbal | 0 | 1 | 0 | 3 | "Yeah because [V] was kind of like a definition almost and that kind of thing and [the diagram] was kind of more applied so it built off of it... [having V first] made me more sure of my answers." |
| | No Preference | 2 | 0 | 4 | 4 | "...they kind of work in a package where like no matter which order you put them in they all kind of influence the other one the ones that follow..." |
| Did the first question help with following questions? | Yes | 2 | 1 | 1 | 3 | "I did think that [V] influenced my answer because I, if I wasn't 100% certain on the behavior of the strong and weak acid, I leaned back on my answer for [V] to answer [P], so by choosing an answer here in [V], I carried that information forward to [P]." |
| | No | 2 | 1 | 4 | 4 | "I just kind of went through them. I didn't really think about the other questions. I guess that's just kind of how I take tests." |
| | Subconscious | 1 | 1 | 1 | 1 | "I guess subconsciously it did [influence my answer], but like I wasn't aware of it." |

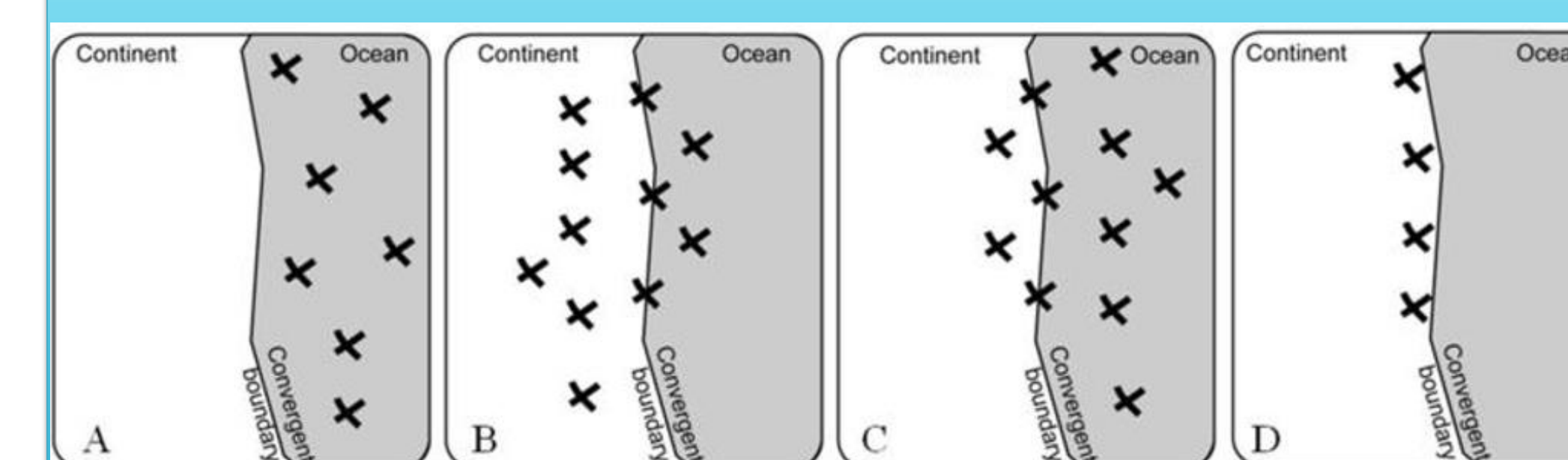
Discussion/Conclusion

- The Concept Inventory data demonstrates that a question order effect does not exist among any of the populations.

Next Step

- We are now probing into question order effect in geoscience concept inventories using the same methods.
- So far, preliminary analysis shows similar results with significance in only one question (V) from the Moderate Effort Pre population.
- Example of pictorial question:

The maps below show the surface of the Earth as viewed from the sky. Which map best illustrates where earthquake epicenters, marked with an X, would be located?



Future Work

- We will analyze students' misconceptions in this inventory through item analysis.
- We also plan to look at how answer choices evolve from pre to post and across expertise level.

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Acknowledgements

- UNL UCARE – Undergraduate Research Grant
- M. Stains Research Group