Using Multiple Disciplinary Lenses to Explore Students' Graphical Interpretation: A Case Study

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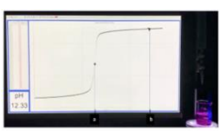
We present a case study of how one student, Aubrey, utilized ideas from biology, mathematics, and chemistry to make sense of a graph common to introductory chemistry: a titration curve. Via multidisciplinary analysis, we found that Aubrey exhibited shape thinking activated by biology resources. However, while she also activated math resources, her interpretation was bound by treating the graph as a static object. Furthermore, Aubrey activated chemistry resources to 'read beyond the data,' but her inferences appeared to be influenced by biology resources. With the current findings, we argue that students may memorize graph features without understanding what is happening conceptually or mathematically and then transfer these learned facts to other disciplinary contexts. Therefore, instructors should be aware of the knowledge and reasoning skills a student may bring from other introductory STEM courses when interpreting graphs.

While previous literature has explored graphical interpretation generally and from specific disciplinary perspectives (e.g., Roth et al., 1999; Rodriguez et al., 2019), there is limited multidisciplinary work. This poster fills that gap by presenting a unique case study of a graphical interpretation task from chemical, biological, and mathematical points of view. Participants (n=15) were recruited from introductory biology and chemistry courses. Data include semi-structured, hour-long interviews involving three tasks. We present only the results of one task: Aubrey's graphical interpretation of a titration curve (Figure 1). A multidisciplinary analysis was conducted using Corbin and Strauss's (2008) constant comparison method.



Task 1: In a titration experiment, a base is added to an acidic solution at a constant rate. The graph (Figure 1) shows how the pH of the solution changes with the amount of base added. Using the graph, explain the relationship between the pH of the solution and the amount of base added to the solution.

Figure 1. The Titration Curve Task.

Aubrey employed resources from each discipline to interpret the titration curve, but her sense-making was bound to her understanding of a biology graph with a similar S-shape. This suggests students may memorize and transfer learned facts about graph features to other disciplinary contexts. However, to engage in authentic interpretation across disciplines, students need to be able to make sense of all curvature and critical points on a graph and understand how they emerge from simultaneous changes in quantities. Therefore, it may be valuable to prompt science students to think through mathematically meaningful critical points or graph features in the context of the physical phenomenon they represent. In conducting a multidisciplinary analysis, we discovered tensions between each discipline's interpretation and expectations. Thus, while this poster presents data and conclusions from a unique case study, it also provides pedagogical insights from adopting a multidisciplinary approach.

Acknowledgments

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Background

Problem Statement

How do students reason about quantities and quantitative relationships as part of interpreting and making inferences about graphs commonly discussed in introductory biology and chemistry courses?

Theoretical Orientation

Quantitative Reasoning ⟷ Covariational Reasoning

Representations ⟷ Graphical Reasoning

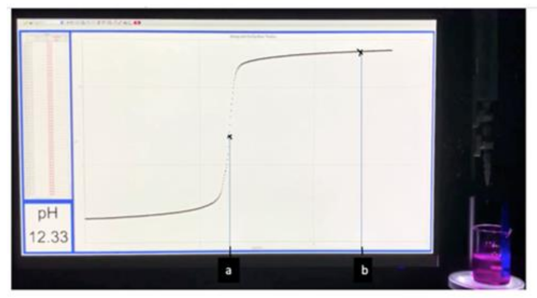
Data Collection

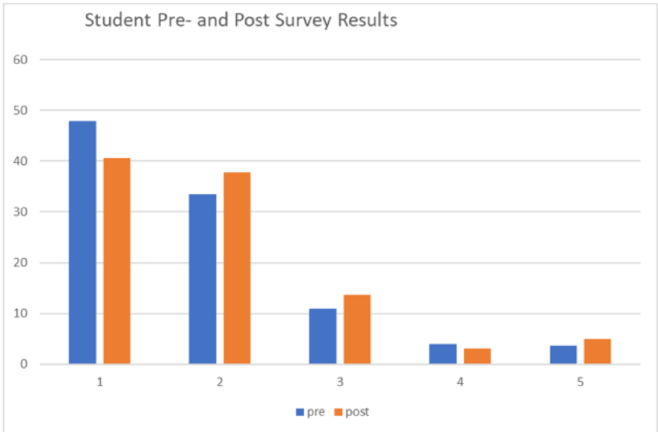
Method
- Surveys
  - Pre-survey (n=660)
  - Post-survey (n=492)
- Interviews
  - Pre-interview (n=16)
  - Post-interview (n=15)

Titration Task

In a titration experiment, a base is added to an acidic solution at a constant rate. The graph below shows how pH of the solution changes with amount of base added. Using simulation video and the graph below, explain the behavior of function f that represents pH on the interval from $x = a$, and $x = b$.

1. pH is increasing at an increasing rate.
2. **pH is increasing at a decreasing rate.**
3. pH is increasing at a constant rate.
4. pH is decreasing at a decreasing rate.
5. pH is decreasing at an increasing rate.





Analytical Method

- Three disciplinary-based education experts (mathematics, biology, and chemistry) analyzed Aubrey's response from their disciplinary perspective
- Knowledge-in-pieces
- Open Coding
- Constant comparison

Findings

Biology

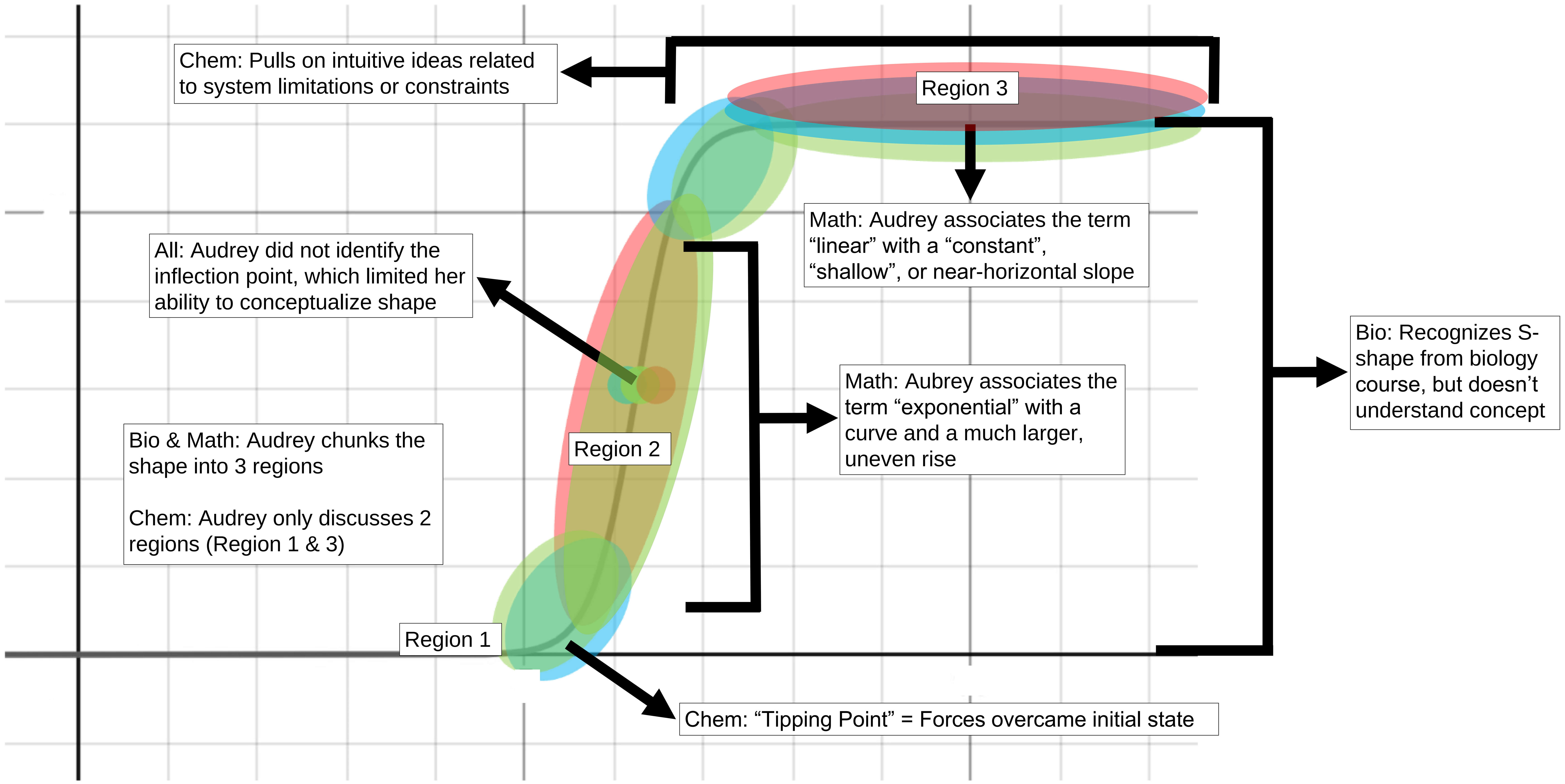
Overall: Aubrey activates biology resources that are rooted in viewing the graph as a static object

Chemistry

Overall: Aubrey activates chemistry resources to 'read beyond the data,' but her inferences appear influenced by biology resources

Mathematics

Overall: Aubrey activates math resources, but her interpretation is bound by treating the graph as a static object



Key Takeaways

- Instructors should be aware of the knowledge and reasoning skills a student may bring from other introductory STEM courses when interpreting graphs
  - Students may be viewing graphs as disconnected chunks, instead of a continuous set of data
  - Students may also be missing important mathematical features of the graph, such as the inflection point
- Graph features matter differently across disciplines, which may impact the type and sophistication of reasoning used
  - In science, it may be sufficient to associate concepts with chunks or shapes as part of focusing on interpretation and "reading beyond the data"
  - However, this may promote students to think of graphs as objects composed of shapes, rather than as emerging through covariation
  - Therefore, it may be valuable for science instructors to prompt students to engage with graphs from a more mathematical perspective