Addressing inequity in student outcomes through interventions to help student preparation for college chemistry: Adaptive question-embedded videos and atomic-level conceptions

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Introduction

- Undergraduates often see general chemistry as a major hurdle to a STEM degree.
- Much of the difficulties students face in this class arise from a lack of preparation in their pre-college education.
- This is ultimately the responsibility of a student's high school chemistry teachers
  - However, for a high school chemistry teacher to be able to teach their students well, they must have a solid grasp of high school chemistry concepts themselves.
  - In addition, they must take these concepts and accurately articulate them to their students.
- We believe that a significant gap could exist in both qualities.
- Specifically, this study was done to investigate if high school chemistry teachers had a correct understanding of two types of dissolution: acid dissolution and ionic solid dissolution.
- The general approach to this study was done through a qualitative lens, with special emphasis being put on teacher representations of chemistry, such as equations, pictures, and observable explanations.
  - These three, together, form the pedagogical framework Johnstone's triangle, a well-regarded framework for chemical education.
- For this study, we have two primary research questions we wish to answer:

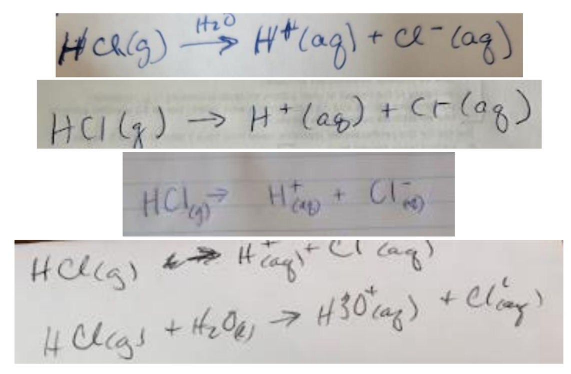
Research Question: How accurate is a high school chemistry teacher's understanding of nanoscopic processes?

Research Question: How close is a high school chemistry teacher's instruction to what really happens in chemistry?

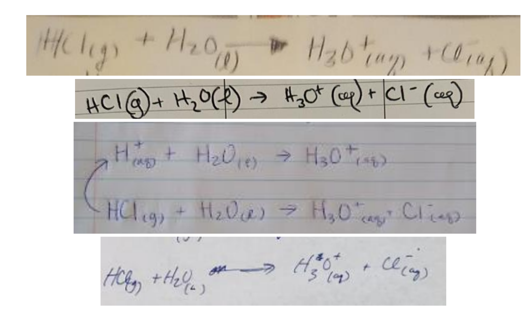
Results

HCl gas dissociates	HCl gas hydrolyzes to form hydronium	HCl gas dissolves, then dissociates/hydrolyzes	Other

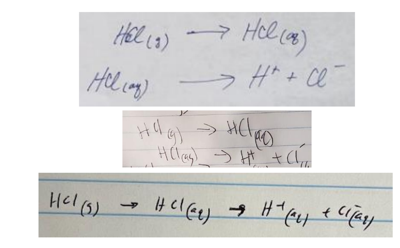
HCl gas dissociates



HCl gas hydrolyzes to form hydronium



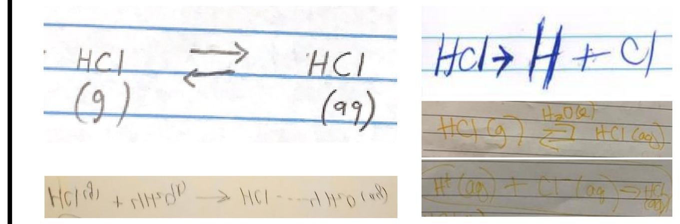
HCl gas dissolves, then dissociates/hydrolyzes



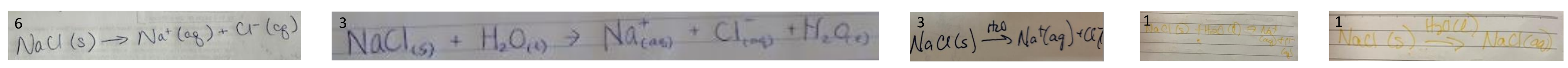
HCl(g) + H2O(l) --> HCl(aq) + H2O(l)

HCl(aq) + H2O(l) --> H3O+(aq) + Cl-(aq)

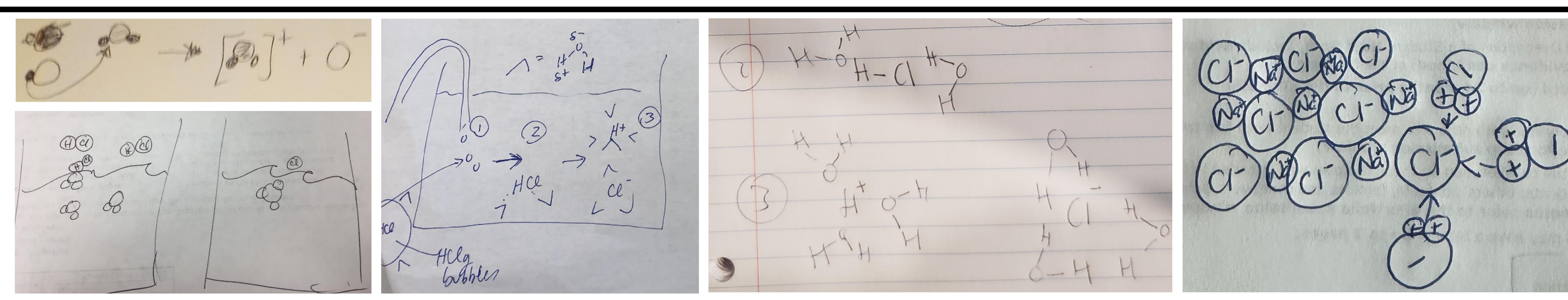
Other



NaCl Equations



HCl and NaCl diagrams and drawings



Quotes

- We've already talked about things dissolving. So I may have used HCl as an example, but we didn't talk about it as an acid. **We just talked about it as an ionic compound that falls apart** when um it's in um aqueous uh media."
- "Well, I I guess I could just go HCl gas makes HCl aqueous but it's like hardly there like that. And then the HCl aqueous to turn into H plus plus Cl minus aqueous. But I just - **I feel guilty doing** that because it's there for such a small amount of time."
- "I have learned that **the HCl …ionizes. It does not exist as ions when it's a molecule as HCl gas,** but it becomes ions in the water, so it ionizes as opposed to the **sodium chloride. Those are ions already in the salt**"
- "**molecular compounds, when they're in solution, they stay as molecules usually**, **although the HCl breaks up so that's like interesting**. Um but typically if you have a molecule and a molecular substance, and you put it in water, they'll stay together as molecules, and just be surrounded by the water molecules"

Methods

- This study was done through a series of thirteen interviews with various high school chemistry teachers.
  - Sampled from both public and private high schools
  - Taught many different levels of chemistry.
- Interviews were held over Zoom and crude transcriptions were collected via Zoom and later refined manually.
- Teachers were questioned on a series of key concepts regarding chemical compound dissolution and their teaching methods regarding the topic.
- To ensure validity of the questions, students, teachers, and experts were questioned to make suggestions to the questions for revisions prior to actual data collection.

"HCl is a molecular compound and a gas at room temperature. What happens when you dissolve a small amount of HCl gas in water?"

"Can you write an equation to represent the dissolution of HCl gas to make a solution?"

- Once transcription was complete, coding was done to identify common themes throughout the teachers' responses.
- All relevant responses from teachers were inputted into an Excel spreadsheet and key themes were manually noted.
- For questions where the participants were required to draw a picture, photographs were collected after the interview.

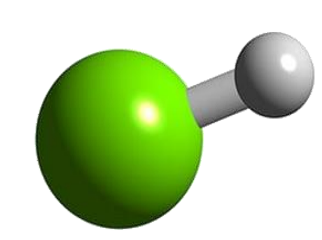
Breaks up into ions, H+ and Cl-
100% ionization
Mention H30+ forming
Water orientation to the ions
Water orientation to the molecules
Ion solvation
In words describe the gas going into solution to become aqueous
Strong Acid
Dissolves as is with no change in electronic structure
Other, explain

- Participants were also encouraged to "think out loud" and narrate the process by which they came to their answers. These were also transcribed and coded as a part of their final answers.
  - However, episodes during which the interviewee went especially off-topic were transcribed but not coded, as they had little relevance to this study.

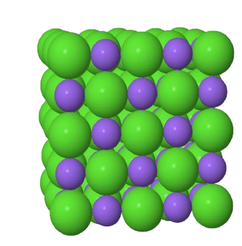
Discussion

- High school chemistry teachers overall have a mistaken understanding of HCl dissolution.
  - Nearly all teachers interviewed immediately hydrolyzed HCl without dissolving it.
  - Many teachers were confused by the possibility of HCl dissolution being a two-step process and could not write an equation describing them.
- The dissolution of NaCl on the other hand was universally understood by teachers.
  - While the exact details such as the placement of water in the dissociation equation and the sizes of ions differed between responses, the concepts displayed were by and large the same.
- The teachers who did have a correct understanding of both concepts were hesitant to teach their students in a similar manner, however.
- Reasons varied between worries of overcomplication, time management, or even not being relevant for a state test.
- Teachers were willing to put aside the truth, or at least what they believed to be the truth to teach an easier class

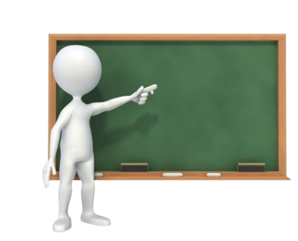
There is widespread misunderstanding of HCl dissolution



NaCl dissolution is relatively consistent



Teachers go against their judgement when deciding what to teach students

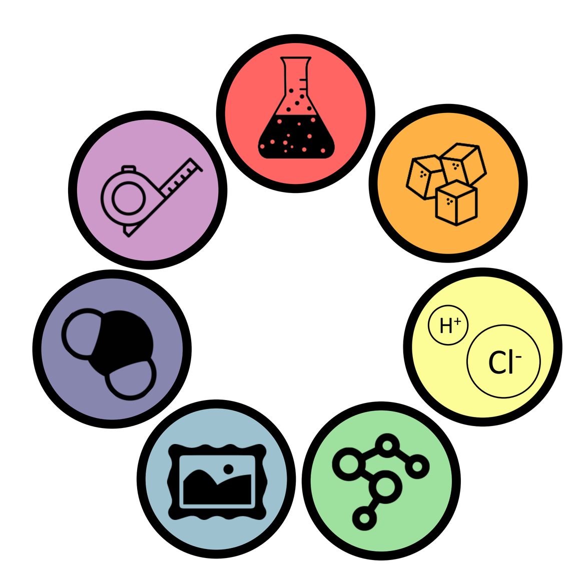


- Chemistry is an inherently cumulative subject. Every concept learned and every lesson taught builds upon its predecessors.
  - Thus, the foundational knowledge learned in a chemistry class must be as accurate as possible so that the concepts further built on such knowledge can be thoroughly understood. The ability of water to pull apart molecular compounds into ions is a concept seen far and wide throughout chemistry, and so it is important that at the most fundamental high school chemistry class level, the subject is taught correctly.
- Unfortunately, that is not what we found here. While teachers did an excellent job with the dissociation of NaCl and even drew expertly-modeled particle diagrams, many teachers, unfortunately, had a mistaken understanding themselves and passed those misconceptions to their students, which they carry with them.
- In these cases, efforts by professors must be directed toward correcting preexisting misconceptions instead of teaching new material, which is a waste of time and energy. In a larger sense, high school teachers already possess the skills needed to adequately prepare their students for college chemistry and beyond. If applied in a concerted, accurate manner, teachers are more than capable of furnishing their students with a solid knowledge of chemistry

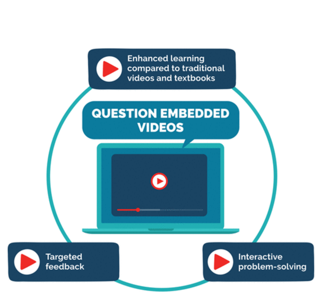
Future Work

- In the future, we would like to study student misconceptions along with teacher misconceptions.
- We could track how misconceptions are presented through their teachers and how they change over time throughout college.
- We would do this by interviewing two more cohorts of thirteen: students before they learn acid or ionic dissolution in chemistry 101 and students in chemistry 102 after they have learned how acids and ionic salts dissolve.
- Like the teachers, we will analyze these students' and teachers' understanding through the identification of seven major themes throughout the students' responses
  - Demonstrates an understanding that an acid in gas form must dissolve in water to become aqueous
  - Demonstrates strong understanding of dissolution of non-acidic molecular compounds
  - Describes, draws, or represents HCl as an ionic compound
  - Teaches students to develop a strong particle level understanding of processes
  - A preference for pictorial representation rather than equation
  - When teaching acid base chemistry, most teachers start with an aqueous solution
  - Relates process microscopic processes to observables/measurements.
- These themes, when paired up with our existing analysis of teacher misconceptions and teacher misteaching, should present a thorough view of how chemical misconceptions on the nanoscopic scale are born, propagate, and, hopefully, die.

High School Chemistry Teachers
↓ High school instruction
Students taking General Chemistry 1
↓ Undergraduate instruction
Students taking General Chemistry 2

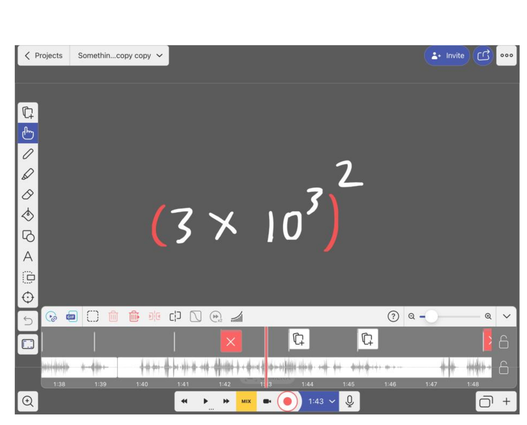


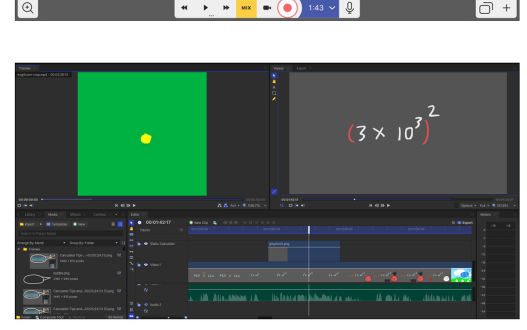
Question-Embedded Videos



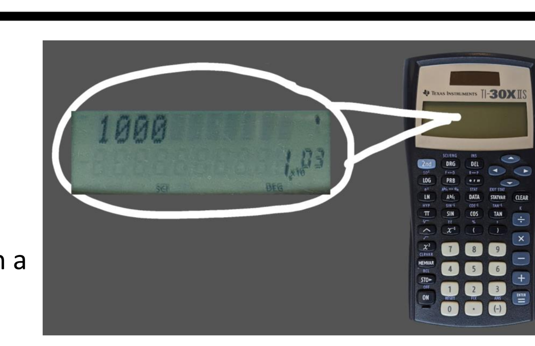
- Much of the struggles undergraduate students face in general chemistry lie in the underlying skills needed to master the content.
  - Called hidden prerequisites; not explicitly stated in the syllabus.
- Arithmetic with proper significant figures, unit conversions, and algebra
  - Such skills, while essential, are not taught in general chemistry.
- Students from Historically Marginalized Groups are disproportionately affected by hidden prerequisites.
- While remedial classes can help alleviate these differences, such classes take time and effort away that could be used in other areas.
- The purpose of the Question-Embedded Video (QEV) project is to create short videos in order to teach the most commonly-missed hidden prerequisites.

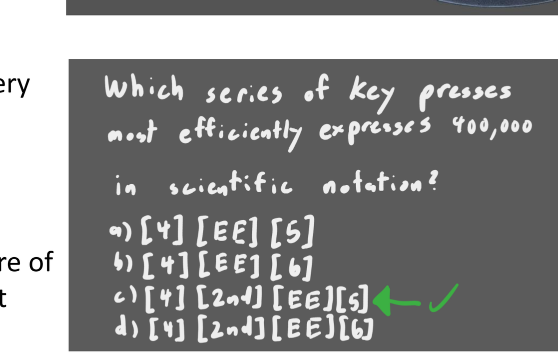
	Slice Name	Sub Slice Name	Topic Name	Average Mastery
1	Measurement	Measurement Math	Multiplication and division of measurements	**1%**
2	Stoichiometry	Moles and Molar Mass	Calculating and using the molar mass of diatomic elements	**2%**
3	Measurement	Measurement Uncertainty	Adding or subtracting and multiplying or dividing measurements	**2%**
4	Stoichiometry	Moles and Molar Mass	Finding mole ratios from chemical formulae	**2%**
5	Matter	Mass, Volume and Density	Finding the side length of a cube from its volume in liters	**3%**

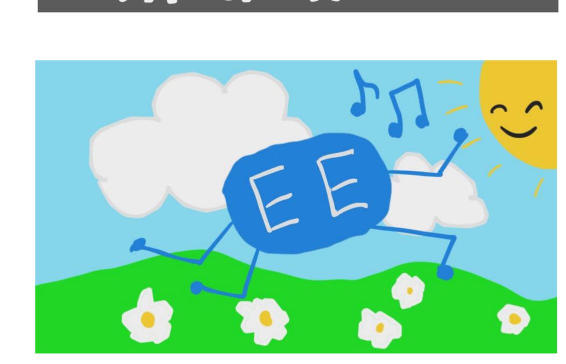




- Question-embedded Videos have been shown to be an extremely effective method of delivering information
  - Combines the auditory and visual stimuli of a video with the engagement of embedded questions
- These videos were recorded and drawn using the Explain Everything app and effects were added in post-production through the HitFilm video editing software.
- Each video guides the students through an introduction to the subject, a tutorial or lesson, and then a final application or extension to the topic.
- Questions are embedded throughout the video through on-screen text and through the EdPuzzle platform.
- Video topics were chosen via data collected prior to this project measuring average student mastery of various hidden prerequisite topics among new Boston University first year chemistry students.
  - Topics with the lowest average mastery were selected to have videos made of them.
- The exceptions to this methodology, however, were the two calculator skills videos, topics which relied on anecdotal evidence from lecturers and discussion leaders.
- The videos are each approximately six minutes long, the optimal time length, and include a mixture of formal notation, calculator animations, and more metaphorical drawings to help reinforce student retention of content.
- We hope that these videos, as we continue to produce them, help decrease the educational debts historically marginalized groups face.
- In the future, we hope to move these videos onto an adaptive platform, further reducing the time sacrifice needed to learn hidden prerequisites.
  - Despite the short runtime of each video, there are so many hidden prerequisites that to watch every video would be an unfairly large commitment.
  - An adaptive platform would allow a student to skip past all the information they already know and only focus on what they still need to learn.
- In addition, the efficacy of these videos would be worth analysis, as no quantitative data exists for this specific series of videos yet.







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