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## Exploring Retrieval Difficulties and Self-Confidence in an Assessment of General Chemistry Students

### Cover Page Footnote

Thank you to the Balabanoff group and to my graduate student mentor Casandra Koevoets-Beach.

# Exploring Retrieval Difficulties and Self-Confidence in an Assessment of General Chemistry Students

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## ABSTRACT

Developing self-assessment skills is an important aspect of learning. Framed by assessment developed for the year-long sequence of general chemistry, students were asked to rate their ability to answer conceptual questions. Using cognitive interviews, this study revealed that people rely on a range of characteristics other than content knowledge to assess their confidence, including doubt, retrieval difficulty, and test-taking methods. These findings imply that more explicit instruction may be required to encourage correct self-assessment. Students can develop their metacognitive skills and calibrate their perceived ability by completing examinations meant to emphasize content knowledge gaps.

**KEYWORDS:** chemistry, self assessment, education

## INTRODUCTION

To comprehend how limited knowledge, shortcomings, and feelings of uncertainty affect performance and pursuit of STEM success, undergraduate students must be able to accurately assess their own confidence (Thompson, Prowse Turner & Pennycook, 2011). Previous studies have shown that some students are able to accurately evaluate their knowledge, but many students are not (Connor, Glass & Shultz, 2021). It is critical for students to build their metacognitive skills by becoming aware of and comprehending their own thought processes through techniques like thinking aloud and self-examination, as well as calibrating their perceived ability through assessments meant to identify topic knowledge gaps.

One of the first science courses that STEM undergraduates take is General Chemistry, and as it is a required for the majority of STEM students, it provides an excellent opportunity to learn about the viewpoints and level of confidence that students have with their science knowledge. In the current study, we examine students' decision-making processes to determine how elements like retrieval difficulties, second guessing, and knowledge gaps affect their confidence and ultimately their self-assessment abilities. We also examine if these characteristics affect their performance. The following question served as a guide for the study:

How do students evaluate their own confidence while answering multiple-choice assessment items targeting general chemistry?

For the qualitative portion of our study, we used Social Cognitive Theory as the theoretical framework to examine the relationship between confidence and general chemistry knowledge. Social Cognitive Theory explains how personal experiences, other people's behaviors, and environmental circumstances affect people's habits (Glanz, 2022).

Participants were recruited from two student cohorts at two separate institutions (University of Nebraska-Lincoln and University of Louisville) following completion of their General Chemistry 2 course. Students first completed the assessment at the end of their course and then students were invited to take part in a series of semi-structured interviews. Interview consisted of asking students to provide reasoning or justify the answer of their choice for assessment questions and how they

## METHODOLOGY

rated their confidence. Detailed information was elicited from these interviews regarding the ideas, opinions, and attitudes that influence student behavior. We used semi-structured interviews because it allowed us to explore the beliefs, perceptions, and attitudes that influence the behaviors we are interested in, as well as to provide the interviewer the freedom to ask the subject to clarify, elaborate, or reiterate their responses. The analysis focused on eight interviews, with four participants from the University of Louisville and four from the University of Nebraska-Lincoln. The interviews lasted anywhere from 20 to 50 minutes. Following the data collection, the transcripts of the interviews were cleaned to prepare for analysis. Pseudonyms were employed throughout this study to protect the students' identities.

The analysis of these interviews included identifying the ways in which students determined their confidence and identifying overall themes (Miles, 2015). Coding was used to interpret the transcripts, identify, and organize related data sets, and allow the researcher to rapidly identify and categorize segments relevant to the research question. When coding, the researcher uses specific labels to add meaning to the segments being evaluated. The MAXQDA coding software was used to assess interview transcripts from both groups. The coding procedure made use of a theme-based codebook that had already been developed. These codes could be broken down into categories including test-taking strategies, confidence level, correctness, and content knowledge. Codes were improved and refined as coding progressed; certain codes were further altered for clarity or completely removed if they no longer met the criterion. Before assessing inter-rater consistency, coders

independently coded to verify reliability. Reliability is required since it determines whether the intended system is accurate by consistently producing the same outcome. Any disagreements in were discussed with the research team until a consensus was reached, and then their coherence and consistency were evaluated and compared throughout the transcripts.

By using in-depth analysis, the impact of more recurrent codes on confidence was evaluated. While concentrating on confidence and how it affects performance, the correctness of the students' answers to the questions was evaluated. Themes were identified across students after establishing connections between student performance, thought process, and confidence. Memos were then created to facilitate the extraction and use of information in subsequent work, as memos allow the researcher to expand on ideas and concepts observed during the coding process.

## RESULTS

This study discovered that students relied on a range of attributes other than content knowledge to measure their confidence, including doubt, retrieval difficulty, and test-taking strategies. Retrieval difficulty, which is characterized by the challenge of accessing information and the extended time needed to retrieve the necessary information for answering a question (Thompson, Prowse Turner & Pennycook, 2011), seemed to occur when students encountered unfamiliar concepts in the questions. This resulted in students avoiding answers that contained the unfamiliar concept. For example, Lily revealed her struggle with polarity in response to one of the assessment questions (Fig. 1) and chose to avoid the answers that contained the word

polar:

*"I may say B because I struggled a lot with polarity so I'm deciding to avoid the answers with "polar" and then I'm trying to remember what I know about intermolecular forces, and I feel like there needs to be more than one kind of molecule so I'm kind of debating between B and C. But I picked B because I feel like if there is an uneven amount of electrons, that's normally my go-to."*

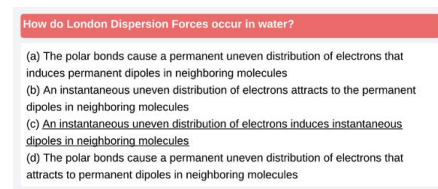


Fig 1. Assessment question targeting intermolecular forces. Right answer has been underlined.

Individuals that faced retrieval difficulties would doubt their ability to answer the question correctly, resulting in an average or low confidence level. This temporary inability to answer a question or recollect information presented students with the opportunity to second guess themselves and assume their information was incorrect. However, retrieval difficulty did not guarantee that the student would respond incorrectly; some students had retrieval difficulty but were still able to correctly answer the questions. These students showed evidence of engaging in a more in-depth cognitive process to remember correct information.

Students' confidence levels were consistently lower when they were unable to overcome retrieval difficulty or were confronted with retrieval difficulty more frequently across the assessment. This resulted in a negative evaluation of the student's own ability or status, which influenced their answer. Students indicated that if they did not know specific information, they would

not be able to get the answer right whether or not they attempted to work through the given assignment. As a result, we observed a relationship between negative self-evaluation and retrieval difficulty. One example of this is with Haley:

*"I'm not sure. I think it's just maybe the D2O threw me off because I've never seen that before or... I really could not remember. I'm pretty sure isotopes [were] something that I struggled with in Gen Chem when I was learning it. I just didn't understand it. So still not knowing it, like I knew from the beginning, I was like 'Okay I don't know what I'm doing.' So, trying to read the choices, I was like 'okay, maybe I can figure it out.' But I guess just going in seeing the word isotope and knowing 'I don't know this' kind of just made me feel like I wasn't going to get it right."*

Haley acknowledges she is unfamiliar with the concept of isotopes D2O and self-identifies a gap in her knowing by explaining she struggled understanding the concept of isotopes while learning it. This leads to Haley doubting herself and, as a result, giving a negative self-evaluation. As shown in Figure 2, unfamiliar concepts were observed concurrently with retrieval difficulty, which in turn can lead to variables such as negative self-evaluation, doubt, and self-identified gap ultimately influencing how students rate their confidence.

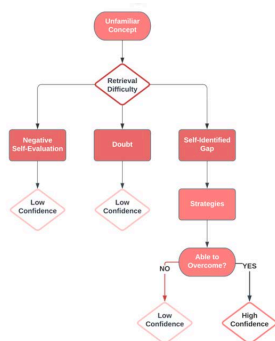


Fig 2. Flowchart depicting the relationship between retrieval difficulty and the other variables evaluated in this study, as well as the overall outcome of each in students' confidence ratings.

After experiencing retrieval difficulties, students appeared to be aware that they lacked the necessary content knowledge to answer the questions accurately. As a result, they turned to tactics such as elimination processes and the search for keywords that would provide information and lead to an answer. Past experiences, namely from coursework, were frequently used to retrieve information or to inform certain test-taking strategies. In certain cases, the student would look back at previous questions to determine whether they had any hints on how to answer the current question. Sharon explained:

*"What I usually do, when I have a test and there's certain things that I kind of remember but if as time progresses, I'll start to forget, I usually write them down first thing on the test, so I don't forget them, like a definite truth. Then I try to look back at those, or I try to see if any of the previous test questions have anything to do with the question I'm presented with now, or I'll just kind of like make a checklist of everything we learned in class. It's like, 'what's the one thing I'm forgetting that they haven't tested me on?' And then whichever one is like 'oh, we haven't discussed that on the test yet. Okay, well, we'll keep this in mind, and we'll go through the rest of the test.' Maybe something will help me there. And if not, then we'll just see if any of the topics are remembered. And if not, I guess we'll just 'pick C and move on.'"*

In contrast, retrieval ease, defined as the efficient and effective recall of information required to answer questions, resulted in a higher confidence rating. While a higher confidence level rating linked to

retrieval ease had a positive effect, it did not always imply that their answer would be correct, as the information being recalled could be inaccurate. When students recall information immediately after reading the question, their common belief is that the information recalled must be correct. This retrieval ease could be tied to a deeply held piece of misinformation or misconception which could give students a false sense of confidence in these circumstances.

## CONCLUSIONS

The continuous use of strategies such as process of elimination and keywords instead of explicit content knowledge can be damaging to students. Signals such as retrieval ease can nonetheless lead students to a false perception of ability. This study observed a relationship between content knowledge and retrieval difficulties; however, this does not imply that they are mutually exclusive. Students demonstrated that even if they have the necessary content knowledge to correctly answer the assessment questions, they can still struggle with retrieval difficulties. Students with a comprehensive chemical knowledge may encounter retrieval ease, retrieval difficulty, or both. Students who experienced retrieval difficulties less frequently and effectively overcame them often assessed their confidence as greater than those who were unable to do the same. This could be due to students pushing past the obstacle and finding information relevant enough to help them answer the task at hand. Students in this situation most likely needed to engage in a more intensive cognitive process to arrive at an answer. Retrieval difficulties led to self-doubt and a decline in confidence for students who were unable to do the same. Additionally,

it was noted that retrieval difficulty did not necessarily indicate that a student would answer wrong, just as retrieval ease did not always indicate a student would choose the right answer.

While students frequently implemented test-taking strategies, these techniques did not always produce the same results. Most students employed the elimination strategy to narrow down the options; however, some eliminated based on correct content knowledge, while others eliminated certain options merely because they were unfamiliar. For some students, elimination worked to disclose the correct answer, for others it did not. The use of context clues by students was common even though, like elimination, it did not always lead to the correct answer. Promoting accurate self-evaluation is a critical skill for students to develop as they progress through their STEM education. If students can improve their metacognitive skills and calibrate their perceived competence through examinations meant to identify topic knowledge gaps, they may produce better scores and a greater retention rate in STEM majors. Students' awareness of their lack of content knowledge in different areas could be beneficial to them, particularly in exam preparation. If students are aware of where they are underperforming, they will be able to focus on these specific areas prior to an evaluation.

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