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A Conceptual Understanding of Concepts in Organic Chemistry

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Honors Capstone Project

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Abstract

As students continue to make the transfer into organic chemistry from general chemistry, they will have to adjust to the new type of thinking required so that they will not fall behind in understanding material and will have success in the course. For this research project, I explored which concepts taught in organic chemistry are the most difficult for students to grasp. I had two main goals for this project. The first one is the central idea that I focused on, which was to see which concepts that have been taught in Organic Chemistry 1 the students are most confident on and which ones they find to be the most difficult. Additionally, I explored their success rate in solving sample problems relating to each fundamental concept introduced throughout the course. By doing so, my hope is to use my results to give insight to organic chemistry professors on students' areas of confidence and areas of struggle. This information could help organic chemistry instructors make instructional modifications and devote more time to problematic areas.

Introduction

Most students majoring in one of the sciences must take organic chemistry at some point during their undergraduate studies in order to meet graduation requirements as well as the prerequisites for graduate schools and professional schools. Oftentimes coming into organic chemistry straight from general chemistry, students find that the type of thinking required for this course is very different from what they are used to. While general chemistry revolves around thinking analytically and performing calculations, organic chemistry is more conceptually based, requiring memorization of processes, reactions, and the patterns that exist within them to succeed. As a student who has completed organic chemistry, I have found that this is a course that builds on an understanding of concepts taught earlier on in the course, and a lack of understanding of one or more basic concepts impacts the ability of a student to grasp the more complex ideas later on. This is why it is so important that students put forth an effort to grasp this content starting from the beginning of the semester by showing up to class, studying, and taking advantage of the resources that are provided to them. Because I did these things, I acquired a thorough knowledgebase from Organic Chemistry I, and when I moved on to Organic Chemistry 2 the next semester, I was able to better understand the new concepts because I already had a firm grasp on the fundamental ones. There was no need for me to go back to the basics and relearn material, something that would have cost me a significant amount of additional time and effort. This study seeks to determine the level of difficulty in which students perceive certain concepts while comparing that to their accuracy and confidence levels in answering sample questions.

My Honors Thesis project gave me the opportunity to further explore a course that was fundamental in my undergraduate education as well as in my preparation for the MCAT, which I took this past year. I was taught these challenging concepts in a way that helped me understand and retain them, and finding a way to improve the education of future students starts with determining where their areas of struggle are. Hopefully, this project will not only serve as an insight as to what common areas of struggle are but will give professors valuable feedback as well so that they can better help their students as they try to comprehend the challenging ideas presented in organic chemistry.

Materials

The foundational organic chemistry concepts that were used in this study were determined from existing literature ("Thinking Like an Electron: Concepts Pertinent to Developing Proficiency in Organic Reaction Mechanisms", Sachin Nedungadi). These foundational organic chemistry concepts included electronic configuration, hybridization, molecular geometry, polarity, resonance, Brønsted acids and bases, alkene stereochemistry, optical activity, arrow pushing mechanisms, radical arrow pushing mechanisms, electrophiles and nucleophiles, carbocation stability, alkane conformations, cyclohexane conformations. A standard undergraduate organic chemistry textbook ("Organic Chemistry: 7th Edition" by Marc Loudon) was used to help design sample questions related to these foundational concepts. The review sections at the end of each chapter consisted of several practice problems, and I was able to reference this format to come up with original sample questions related to each major concept. In order to gather student data, I used the Qualtrics survey platform to generate the survey that was sent out to students taking Organic Chemistry 2. This was made accessible via smartphone or computer and was designed to take less than 15 minutes to complete for the convenience of the students without sacrificing the quality of data collected. Data analysis was also performed through Qualtrics. Tables and figures were created using Microsoft Powerpoint.

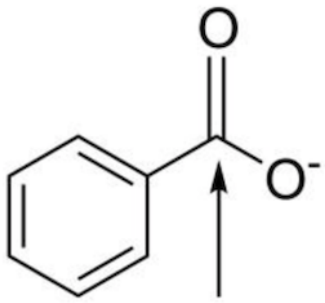
Methodology

To initiate my research, I crafted a comprehensive survey aimed at gathering insights from individual students presently enrolled in Organic Chemistry 2 regarding their perspectives on the perceived difficulty levels of various concepts integral to the organic chemistry curriculum. The survey's construction involved attention to detail and strategic planning to ensure its efficacy in capturing a variety of student perspectives. Using the survey platform Qualtrics, I developed and formatted the survey to optimize data collection efficiency. The survey link was distributed to students via a Canvas announcement, ensuring widespread accessibility and participation among the students.

The survey's structure was designed to elicit detailed responses from participants, beginning with an initial section prompting students to assess the perceived difficulty of a list of organic chemistry concepts on a scale ranging from 1 (indicating very easy) to 5 (indicating very difficult). Following this assessment, a series of sample questions were presented to participants, each tailored to assess their comprehension and confidence levels across diverse organic chemistry topics. This section of the survey has the following format: the title of the concept, a multiple-choice question, and an inquiry regarding participants' confidence levels in addressing that specific question on a scale from 1 (indicating minimal confidence) to 5 (indicating utmost confidence). An example problem included within this survey is shown in Figure 1, serving as a representative sample of the questions asked.

Question 2

What is the state of hybridization of the labeled atom?



- sp
- sp2
- sp3

What is your confidence level in answering this question?

	Not Confident	Slightly Confident	Somewhat Confident	Fairly Confident	Completely Confident
Confidence Level					

Figure 1. Sample problem included in the Qualtrics survey sent to students. The first portion includes a multiple-choice practice problem related to one of the concepts being studied, and the second portion asks on a 5-point scale how confident students were in their answer.

Results/Data Analysis

The dataset provides valuable insights into students' perceptions, confidence levels, and accuracy in answering questions related to various organic chemistry concepts. Concepts such as electronic configuration and cation structure and stability were widely regarded as easy, with students demonstrating a high level of confidence and achieving notably high accuracy rates of 94% and 88%, respectively. This suggests a strong foundational understanding among students in these fundamental concepts of organic chemistry. However, the moderately difficult concepts of alkane conformations and resonance, although tackled with fair confidence, yielded mixed results in accuracy rates, standing at 94% and 75%, respectively. While students exhibited a commendable understanding of alkane conformations, as reflected in the high accuracy rate, resonance presented a more nuanced challenge, with a lower accuracy rate indicating potential areas for further exploration or clarification.

Notably, cyclohexane conformations emerged as a notable challenge among the concepts examined. Despite its moderate difficulty, students expressed lower confidence levels when addressing this topic, resulting in a corresponding accuracy rate of 65%. This discrepancy between perceived difficulty and confidence highlights a potential gap in students' understanding or comfort level with the subject matter. Conversely, despite being perceived as easy, concepts like molecular geometry and polarity saw slightly lower confidence levels, yet still resulted in moderately high accuracy rates of 70% and 83%, respectively. This suggests that while students may find these concepts relatively straightforward, there may still be opportunities to enhance confidence levels or deepen understanding through targeted instructional approaches.

Moving to the moderately difficult concepts of acids and bases and stereochemistry, a disparity between perception and confidence was evident. Despite being perceived as moderately difficult, students displayed lower confidence levels when tackling these topics, which corresponded to lower accuracy rates of 47% and 54%, respectively. This discrepancy underscores the importance of addressing both confidence-building and comprehension in areas where students may face challenges or uncertainty. Nonetheless, challenging topics such as arrow pushing mechanisms were confidently tackled by students, resulting in higher accuracy rates of 92%. Conversely, radical arrow pushing mechanisms, despite similar difficulty, showed lower

confidence levels and accuracy rates of 53%. This highlights the influence of confidence on performance in tackling complex organic chemistry concepts.

Organic Chemistry Concept	Reported Difficulty (%)				
	Very Easy	Easy	Moderate	Difficult	Very Difficult
Electronic Configuration	21	**47**	29	2	1
Cation Structure/Stability	10	**30**	27	29	4
Alkane/Cyclohexane Conformations	1	19	**43**	28	9
Hybridization	18	**46**	29	7	0
Molecular Geometry	14	**50**	26	10	0
Polarity	16	**41**	31	9	1
Resonance	2	19	**42**	32	6
Brønsted Acids and Bases	6	25	**47**	16	4
Stereochemistry	3	16	**47**	29	5
Arrow Pushing Mechanisms	3	27	29	**30**	11
Electrophiles and Nucleophiles	3	23	**39**	31	4

Table 1. Perceived difficulty of different organic chemistry concepts reported by students taking Organic Chemistry 2 . Percentages are calculated from a total of 116 students.

Organic Chemistry Concept	Confidence Level (%)					Students who Correctly Answered (%)
	Not Confident	Slightly Confident	Somewhat Confident	Fairly Confident	Completely Confident	
Electronic Configuration	1	9	14	43	34	94
Hybridization	1	8	15	46	33	86
Molecular Geometry	5	8	28	37	20	70
Polarity	3	5	28	33	30	83
Resonance	5	19	28	33	16	75
Brønsted Acids and Bases	17	31	23	20	9	47
Alkene Stereochemistry	8	23	24	30	15	61
Optical Activity	16	21	26	31	6	54
Arrow Pushing Mechanisms	2	8	15	40	34	92
Radical Arrow Pushing Mechanisms	12	9	25	32	20	53
Electrophiles and Nucleophiles	11	25	25	28	7	65
Carbocation Stability	3	10	33	23	29	88
Alkane Conformations	5	14	21	34	25	94
Cyclohexane Conformations	20	28	23	22	6	65

Table 2. Confidence levels of students on various organic chemistry concepts compared to their accuracy in answering sample questions.

Conclusion

In conclusion, the analysis of the dataset reveals several important insights regarding students' perceptions, confidence levels, and accuracy in tackling organic chemistry concepts. Overall, students demonstrated a strong understanding of foundational concepts such as electronic configuration and cation structure/stability, as evidenced by high accuracy rates and confidence levels. However, challenges were observed in certain areas, particularly with cyclohexane conformations and acids and bases, where lower confidence levels were reflected in lower accuracy rates.

The findings underscore the importance of addressing both confidence-building and comprehension of complex organic chemistry concepts. Educators may consider implementing targeted interventions to bolster students' confidence in challenging topics while providing additional support and resources to enhance comprehension. Furthermore, fostering a supportive learning environment that encourages students to engage with and seek clarification on difficult concepts could contribute to improved performance and confidence levels across the board.

Moving forward, future research could explore the effectiveness of specific instructional strategies or interventions in addressing confidence gaps and improving overall performance in organic chemistry education. Additionally, longitudinal studies could track changes in students' perceptions, confidence levels, and accuracy rates over time to assess the long-term impact of educational interventions and instructional approaches.

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