Using Memes as Educational Vectors: Analyzing Understanding Amongst College Students in Introductory Organic Chemistry

By

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Abstract

Educators continuously strive to find new and effective ways to convey interest and understanding to their students. Some instructors attempt to bring pop culture and social media into their classrooms and assignments to encourage engagement and excitement for the material. This study aims to probe the use of pop culture, through the use of internet memes, to not only engage and excite students, but to also act as a delivery method for the course material in a way that is digestible to the student. Two popular memes were used to convey organic chemistry topics to act as learning aids for organic chemistry students. The students completed assessments with two sections, the first section consisted of acid-base questions and the second consisted of an S_N1 reaction mechanism question. Students first completed the assessment without any meme or content-specific hint, but were then given a meme or textual hint, and then were allowed to revise their answer. Results showed students made few revisions to their answers, however, those who received a meme in place of a text hint were more likely to alter their answers. In addition, the students who received the meme for the S_N1 reaction mechanisms questions were more likely to acknowledge their errors and correct their answers. Memes have the potential to provide a new approach for instruction at all levels of education as they can appeal to different styles of learners while also increasing engagement with course content. This may be achieved by utilizing the mnemonic nature and the social entertainment of the meme formats to further engage and reinforce complex concepts.

Acknowledgements

I would first like to thank my Faculty Mentor Dr. Matthew Casselman for all of his guidance and support for the past 1.5 years. My original ideas for the research were immature and un-polished. Dr. Casselman helped me refine what I wanted to focus on in my research and helped me determine how I would even go about conducting the research. Prior to agreeing to be my Faculty Mentor, I had taken a couple of his courses and it was during those courses and in office hours I came up with the idea of conducting research on the use of memes in education. During Dr. Casselman's class I would make Organic chemistry memes and share them with him in office hours. His positive feedback made me see the potential memes have in education and encouraged me to look into existing research. Thank you Dr. Casselman for all of your help and I am so glad you agreed to mentor me through this project.

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Introduction

1. What is a meme and how could they be used in education?

Memes are a relatively new emergence of social expression via the internet and social media. The term ‘meme’ was originally defined by Richard Dawkins as a unit of culture that is mutated, transferred and hosted in the thoughts of one or more individuals (Dawkins, 1976). He derived the term from the similar behavior he noticed from the transfer of genes. Since then, other researchers have built upon or redefined the term. The most common denotation of a meme is “a piece of culture, typically a joke, which gains influence through online transmission” (Davison 2012, 122). This ‘piece of culture’ could be in the form of an image, a text file, gif, or video. Another important aspect of a meme is the editability and transformation of the idea. The constant modification allows memes to access different types of people and can be extremely niche or universal. For this reason, memes can be adapted to fit educational settings and act as a vector to communicate various concepts. Educators have implemented memes into their lectures and classrooms in various ways. Some have used them for comedic relief to help relax students and create a comfortable learning environment. As well as, attempt to use the meme to reinforce a topic or test current understanding (Bini, 2021; Purnama, 2017; Wells, 2018). Since memes are still relatively young there are not significant amounts of research on their effects when used in an educational setting. However, the concept of using graphic images in instruction to instill understanding is far from new. Educators have previously attempted to use educational comics as a way to explain and help in understanding physical phenomenon (Koutnikova, 2017;Tatalovic, 2009) which is similar to how memes could be used. Political cartoons can also contribute to a student’s understanding of past events, culture, and atmosphere as well as invoke a discussion (Werner, 2004).

This study will use memes that convey an idea intended to educate or instruct the reader and will be referred to as *educational memes*. This is different from traditional memes that do not have a goal of educating the audience. For example, Figures 1a and 1b could both be considered organic chemistry memes because they each are referencing the subject of organic chemistry. However, Figure 1a does not convey any greater understanding to the subject as it simply communicates the idea that many compounds in organic chemistry contain hexagonal structures and are frequently drawn. In contrast, Figure 1b activates the reader's understanding of an S_N2 reaction mechanism to reinforce the idea that there is no intermediate in the reaction mechanism. As a result this could be used in an educational setting to reinforce the concept that S_N2 reactions occur without the formation of an intermediate. The memes utilized in this study will be educational memes similar to Figure 1b.

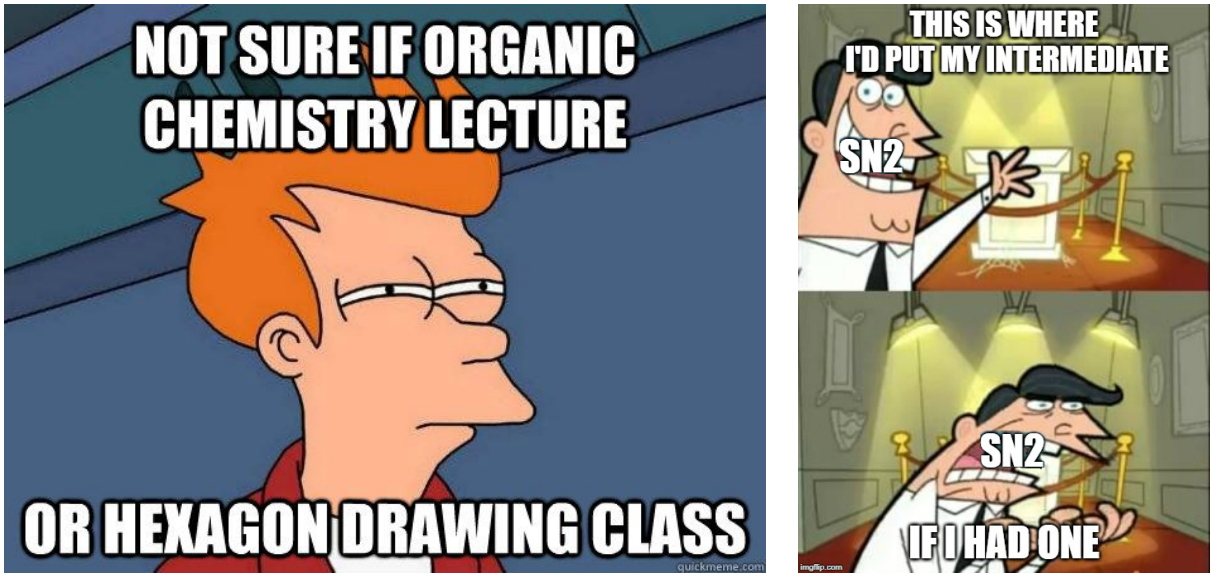


Figure 1a (left). Demonstrates a non-educational meme. It utilizes the "Futurama Fry" meme format to convey that organic chemistry is essentially a course where all you do is draw hexagons. **Figure 1b** (right). Utilizes the "This is Where I'd Put My Trophy, If I Had One" template to convey the missing intermediate in S_N2 reaction mechanisms. [Source: Reddit]

2. Pop culture and Social Media

Young adults often struggle in advanced educational courses such as organic chemistry due its complexity and seemingly unrelatable nature. Researchers, like Dr. Niel Garg of UCLA, have attempted to lessen the disconnect between students and these courses by relating the topics to popular culture. Although popular culture references may improve interest, they may not promote greater understanding and retention of the subject material. Dr. Neil Garg and Tejas Shah developed an online course called BACON (Biology and Chemistry Online Notes) to teach organic chemistry by drawing mechanisms in videos. Once the material is taught the narrator then relates aspects of it to popular culture. An example is provided on their website's trailer video, where a Diels-Alder reaction is explained, followed by a connection between cortisone and its role in anti-itch medication used by baseball players. The connection to baseball is intended to show students why reactions, like Diels-Alder, are important, and to generate further interest in organic chemistry (Shah and Garg, 2017). However, the connection between the Diels-Alder reaction and baseball players is weak and may only increase student interest while not increasing student understanding about the material. The loose connection between the popular culture and subject material may lead to younger students interpreting these programs as poor attempts by older instructors to "speak their lingo" and further detract student engagement (Tapscott and Williams, 2007).

3. Mnemonics, Visual Aids, and Rhetoric

Memes tend to have memorable aspects as they are often referenced in conversations to convey ideas or feelings. Since memes tend to resonate in youth's minds and memory, they draw parallels to mnemonic devices. Mnemonics function by encoding a system to call on important facts or processes, with examples including acronyms, acrostics, and keywords. Mnemonics have

exceptional efficacy when the information is to be recalled in a specific order. In a 1980 study, Roediger quantified the rote memory improvement over four mnemonic devices. Each group of participants was tested with one of five conditions, comprising one control and the four mnemonic devices. Results showed that in both short and long term recollection, when compared to the control, participants had improved memory (Roediger, 1980).

Mnemonics can be closely tied with using images to reinforce retention of concepts. When combining images with varying styles of mnemonic texts the reader can interact with the concept visually and verbally. Furthermore when using images with underlying comedic purposes, for example political cartoons, the reader can further interact with the content emotionally. A 2009 study on the effectiveness of political cartoons in communicating social issues found that those who were introduced to a political cartoon rather than an editorial were more receptive to issues presented and gained a better understanding of the underlying issues. The concern that the cartoon would be viewed as just a “passing chuckle” was overturned and showed that it can elicit deeper understanding (Abraham, 2009).

Similarly additional studies used scientific comics to illustrate different natural phenomena and communicate scientific ideas through storytelling. One of which found it was easier for children to understand the concepts and material presented through illustration rather than text because it was more engaging and utilized different senses (Koutníková, 2017). Another study saw greater recall when employing comics, like scientific graphic novels, on participants' memory; however more studies need to be conducted to fully understand the capabilities of comics on long-term retention (Tatalovic, 2009).

Comics, cartoons, and other educational illustrations have been found to have benefits in education through semiotics and visual rhetoric. Due to many similarities, memes have found to

have similar persuasive power by engaging viewers and eliciting deeper thoughts. The style of meme, when and by whom it was created, and the origin can all contribute to a larger idea and creates a large potential for their uses in education and other facets (Huntington, 2013).

4. Memes in Education

A few studies created assignments to encourage students to make memes to demonstrate understanding of material. One study had students, who were non-English speakers, utilize their own creativity to create memes to demonstrate their understanding of English. The study found the use of the memes increased student engagement with learning English and argued that using memes caused students to be more receptive to learning since it created a relaxed environment (Purnama, 2017). Another study found that creating memes in reference to political events were able to promote critical thinking skills as well as their understanding of current political affairs (Wells, 2018). An additional study utilized a specific meme template, Spider-Man Pointing at Spider-Man, which consists of two Spider-Men meeting and pointing at each other to illustrate that they are the same. The study had students from 6^{th}-12^{th} grades demonstrate their understanding of their current math course by modifying the Spider-Man meme template to convey math concepts they learned. Similar to the former mentioned studies, the researchers concluded that the use of memes created a more engaging learning environment. Furthermore, the study found that students who participated in the study scored higher on a post-summer break test, compared to those not involved in the study (Bini, 2021).

This study aims to show that integrating memes into student learning has the potential to not only increase student interest, but to also reinforce student understanding through the utilization of a current internet meme template. In addition, capitalizing on the perception that memes possess a similar effect of mnemonic and visual aids, they will aid in the retention of the

topics presented. This can engage different levels of thought among the students by appealing to them visually, entertaining them, and teaching a concept. In turn, students may be more persistent in difficult higher education courses and in pursuing careers in the STEM field.

During the COVID-19 pandemic that caused the American education system to shift to an online environment, coupled with the popularity of TikTok (a social media application) increasing, more educational videos were gaining popularity using current internet memes and trends. One such channel that debuted on Instagram and later transitioned to TikTok called Lab_Shenanigans created by a research technician, Darrion Nguyen (Darrion Nguyen; n.d.). Darrion creates short educational videos ranging from Biology to Chemistry topics using current social media trends to teach major ideas. The videos have millions of views and demonstrate the effectiveness of mixing entertainment with education. A recent study analyzed the effects of integrating Social Media, specifically TikTok into online education and found that it bolstered creativity and their ability to demonstrate the material (Escamilla-Fajardo et al., 2021).

Due to the progression of technology, it has already worked its way into education in numerous different formats. The accessibility of technology by each student has allowed for more tools to be utilized by educators. The next natural step is the integration of social cultures and memes into the education field. It would be counterintuitive to continue to segregate education and youth entertainment, especially when something like memes, that are highly adaptable can be so easily integrated (Ershler & Stabile, 2015).

Rather than trying to loosely relate these subjects to popular culture, this study utilizes popular culture, in the form of memes, as vectors for translating organic chemistry subject material into a more familiar and digestible format. Students will be provided memes to determine if they can activate prior knowledge and assist students during an assessment, where

students can revise their responses after viewing a meme or receiving a more formal scientific hint.

Methods

1. Design and Sample

An online assessment was administered to 31 volunteer students enrolled in an UCR Introduction to Organic Chemistry course (CHEM 8A) during the Fall 2020 Quarter. Participants were recruited through announcements on their course iLearn page as well as during lectures asking for participation in the study. The study has no effect on the participants grades other than it may act as an additional study tool. The study was submitted to the UCR International Review Board and approved as "Exempt" under protocol HS 20-185.

The participants were all proficient english speakers and were randomly assigned to two treatment groups, Group #1 (N=16) and Group #2 (N=15). The student participants in this study were not representative of the class as a whole. The participants had an average GPA of 3.54 (A-), whereas the class had an average GPA of 2.78 (C+).

The assessment consisted of two sections: a set of multiple choice questions related to acid-base chemistry (5 total) and a single free response question related to the S_N1 reaction mechanism. Participants were instructed to answer the questions initially with no help from their notes or textbook. Prior to a second attempt, students were provided additional information that consisted of either a meme (treatment) or a subject-related textual statement (control). The textual statements/hints provided, use formal scientific language to explain a phenomenon. Group #1 received a meme for the acid-base questions and textual hint for the S_N1 reaction question; while Group #2 received a textual hint for the acid-base questions and a meme for the S_N1 reaction question. After completing the first attempt of the section the participants were then

given their designated treatment. This provided that each group acted as a control for the other group.

The assessment was administered using a Google form that only allowed participants to view one section at a time. The participants were also instructed to screen record, through the program YuJa, while taking the assessment to ensure they were not backtracking through questions as well as searching for answers online. At the end of the assessment the participants were prompted to end their recording and share it with the researcher. The assessment had no effect on their course grade and was specified that it could serve as a supplementary study method for their upcoming final exam. Participants were able to complete the assessment on their own time during the time frame of November 25th through December 11th, 2020. After completing the assessment, students were instructed to complete an additional survey about their experience with memes in classes, as well as their opinion of the specific memes used in this assessment.

2. Acid-Base Multiple-Choice Questions

Both groups received the same five-question acid-base assessment (Figure 2a). Each question asked students to identify either the acid or base in the reaction provided. The questions were presented in multiple choice format with the options: A, B, or Unsure/unable to determine. Students were able to view and answer questions in this section all at once in any order. After students provided their initial answers to the questions, students were provided either a meme (Group #1, see Figure 2b) or the textual hint (*"Lewis acids are defined as those that accept electron pairs."* Group #2). Students then completed the quiz again where they were able to change their answers after being given the treatment.

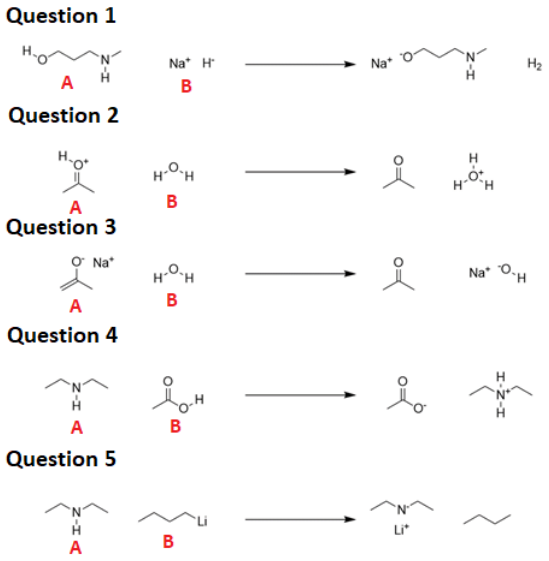


Figure 2a (left). These were the questions provided in the assessment. During the assessment each question was broken into separate images to make it easier to see. **Figure 2b** (right). Depicts the popular meme format of Bernie Sanders called "I Am Once Again Asking for Your Financial Support" where the last part of the sentence is replaced with Electrons to describe the natureof Lewis Acids [Source: Reddit].

3. S_N1 Reaction Mechanism Free Response

Following both attempts on the acid-base question set, the participants were instructed to complete a free response question on the topic of the S_N1 reaction mechanism. The participants are asked to propose a reaction mechanism for the reaction shown in Figure 3a. A reaction mechanism consists of an arrow pushing formalism that explains the electron flow in a reaction. The participants were instructed to upload an image of their answer and could either be hand drawn or digitally drawn using a program like MarvinSketch. The participants were not told the reaction involved the S_N1 reaction mechanism, but needed to determine that based on the contextual clues provided in the reaction itself.

After submitting their first attempt, both groups received either a textual hint *"Strong acids can activate hydroxyl groups in substitution reactions by protonation"* (Group #1) or a meme (Group #2, see Figure 3b). The participants are then instructed to use the resource to

revise their answer if they chose or to resubmit their previous mechanism if they do not wish to make any changes.

Both groups of participants were given a reaction, asked to draw the mechanism (Figure 3a) and then graded on a 5 point scale. In order to receive full credit for a response the participant must have included an initial proton transfer (½ point if wrong arrow direction was used), protonated intermediate (½ point if missing charge), loss of leaving group, carbocation intermediate (½ point if carbocation is missing a charge), and 1pt nucleophilic attack (½ point if wrong arrow direction was used).

Two t tests were conducted. One between Group #1 and Group #2 before treatment and a second between Group #2's first attempt (before treatment) and second attempt (after treatment). Since Group #1 did not vary their response a third t test was not conducted.

Figure 3a (left). The image provided during the S_N1 reaction mechanism section of the assessment. Students were asked to draw a reaction mechanism to explain the figure. **Figure 3b** (right). A meme template composed of screenshots from the children's cartoon "Spongebob Squarepants". The template is utilized to illustrate a strong acid using a free proton to create a better leaving group. The leaving group then detached from the carbon that it was bonded to, causing it to become an unstable carbocation.

4. Survey Questions

After completing the subject material assessment, participants accessed the post-assessment survey which asked three free-response questions shown in Table 1 with the general responses that were coded by the researcher.

Table 1. The left column shows the questions presented in the post-assessment survey and the right column shows the general responses for the question. Question 1 had numerous varying responses for the type of memes presented and their use. The responses were coded based on the overall similarity of feedback between responses. Breakdown for Question 1 in Figures 6a and 6b; Question 2 in Figure 7; and Question 3 in Figures 8a and 8b.

Survey Questions 1-3:	General responses
Have you ever experienced memes in any classes before? If yes, please explain how they were used and their effect on you/your education.	Yes (educational) ● Reinforce Understanding ● Memory ● Instructional ● Instructional + Memory Yes (humor) Yes (retention/memory) No
Would the integration of memes relating to course material in lectures help you remain more interested in the material or would it act as a distraction?	More Interest Better Memory/Retention Increase both Interest and Retention Distraction Depends on use
Did the memes presented in the quiz help you answer the questions or help correct a mistake you made on the first attempt?	Realized missing info Confirm their attempt Helpful (not specified) Helped recall/think Unsure Not helpful/Confusing

Results

1. Acid-Base Multiple-Choice Questions

Results on the multiple-choice assessment, related to acid-base chemistry, showed a high level of student understanding even before being presented with a meme or textual hint. The average score on the assessment before treatment was 85.3% with individual item scores by treatment group reported in Table 2. After completing the first attempt, groups received a meme (Group #1) or textual hint (Group #2) and were allowed to revise/change their answers. The average score after treatment was 83.3% and individual item scores by treatment group reported in Table 2.

Table 2: The table shows the average amount of points awarded per group before and after treatment. Group #1 received a meme and Group #2 received a textual hint for their second attempts.

	Group #1 Average	Group #2 Average	Both Groups
Before: Points scored	4 / 5	4.53 / 5	4.264 / 5
Before: Percent Correct	80%	90.6%	85.3%
After: Points scored	4 / 5	4.33 / 5	4.165 / 5
After: Percent Correct	80%	86.6%	83.3%

While the averages before and after were similar, it might appear that students did not revise/change their answers, but a number of students changed their answers after receiving the meme or textual hint. After the treatments for both Groups #1 and #2, the most commonly missed question was item #4 with 7 incorrect final answers (31 total) followed by items #2 and #3 with 6 incorrect final answers each. Items #1 and #5 each had 4 incorrect final answers.

The changes from correct to incorrect responses is depicted in Figure 4a for Group #1 and in Figure 4b for Group #2. The left column shows the initial attempts (before any treatment) and the right shows the responses after treatment (meme for Group #1; textual hint for Group #2). The flow graphs show which participants changed their answers and if they are changing it from the correct answer to an incorrect answer or vice versa.

For the meme treatment group (Group #1, Figure 4a), 21 answers were revised after meme treatment - 12 responses were switched from correct to incorrect, while 9 responses were switched from incorrect to correct. A similar number of participants switched their answer for each item (2-3 per) except for item #4 where 4 answers were switched to incorrect and only one switched towards correct.

For the textual hint group (Group #2, Figure 4b), participants switched their answers less frequently compared to Group #1. A total of 13 answers were switched, 8 of them switching from correct to incorrect and 5 switching from incorrect to correct (Figure 4b). Items #1 and #4 both were answered 100% correct on the initial assessment, but after treatment, 2 participants switched away from the correct answer to an incorrect answer. Items #2 and #3 had about the same amount (2-3) of switching from correct to incorrect and vice versa. Item 5 had no change in answers, 13 participants answered correctly and did not change their answer and 2 participants were incorrect and did not modify their answer.

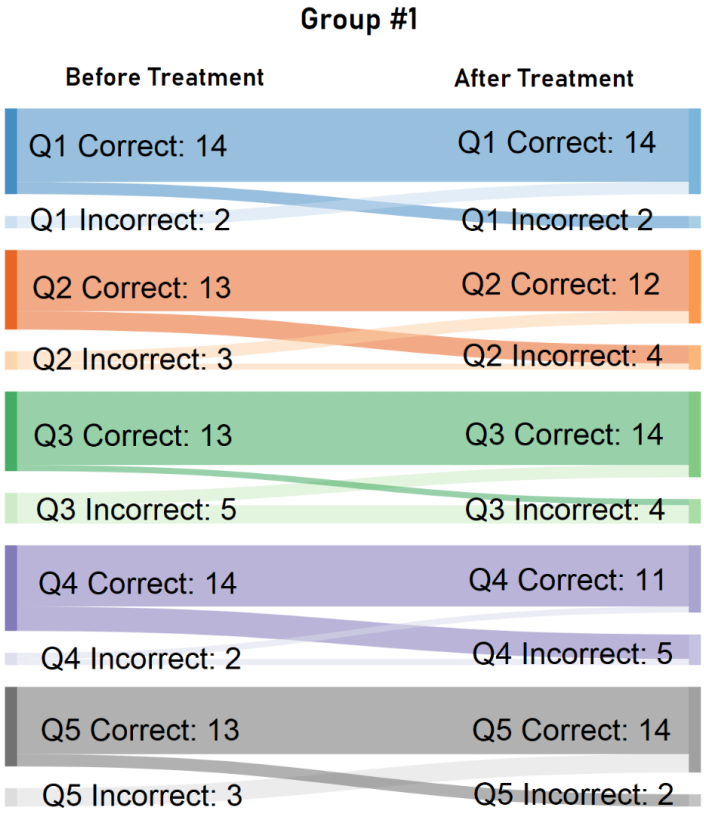


Figure 4a. Depicts Group #1's change in response before and after treatment. The left column shows responses before receiving the meme treatment and the right column shows the responses after receiving the meme treatment.

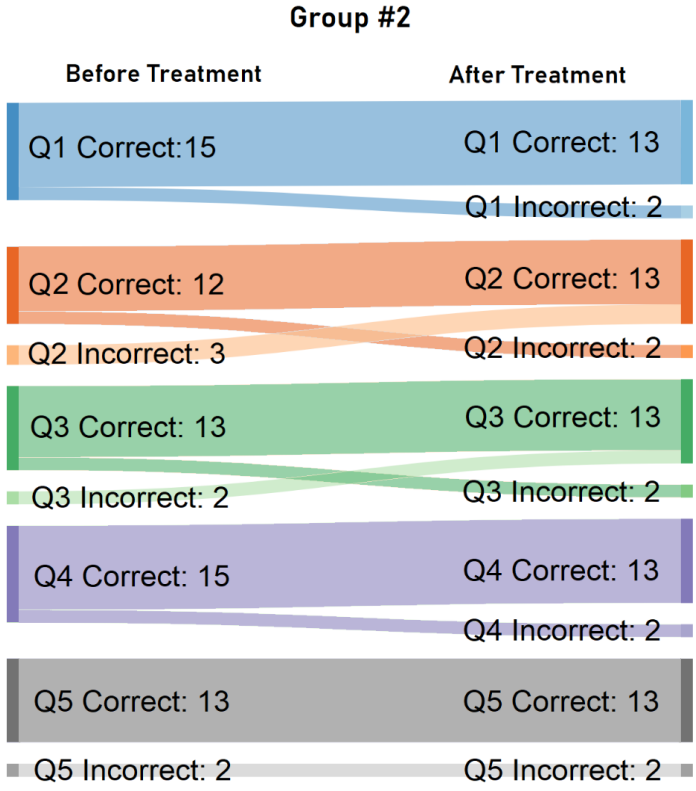


Figure 4b. Depicts Group #2's change in response before and after treatment. The left column shows responses before receiving the textual hint and the right column shows the responses after receiving the textual hint.

2. S_N1 Reaction Mechanism Free Response

The two groups, despite being randomly assigned, had very different results on the first attempt. Group #1 scored an average of 3.78 out of 5 points with a standard deviation of 1.69; 43.8% participants receiving full points, 12.5% received no points. Group #1 received the text hint after their first attempt and no participants revised their answer. One participant, however, added a note that based on the hint they believed it to be an S_N1 reaction, but did not modify their mechanism because it already depicted an S_N1 reaction.

On the first attempt, Group #2 scored an average of 2.82 out of 5 points with 3 participants (21.4%) receiving full points, 4 received no points (28.6%) and a standard deviation of 2.03. Group #2 received the meme (Figure 3b) after their first attempt and 42.9% of the participants modified their answer in some way. After the second attempt, average increased to 3.64 out of 5 points for Group #2. Figure 5 shows the points awarded per step before and after treatment for Group #2.

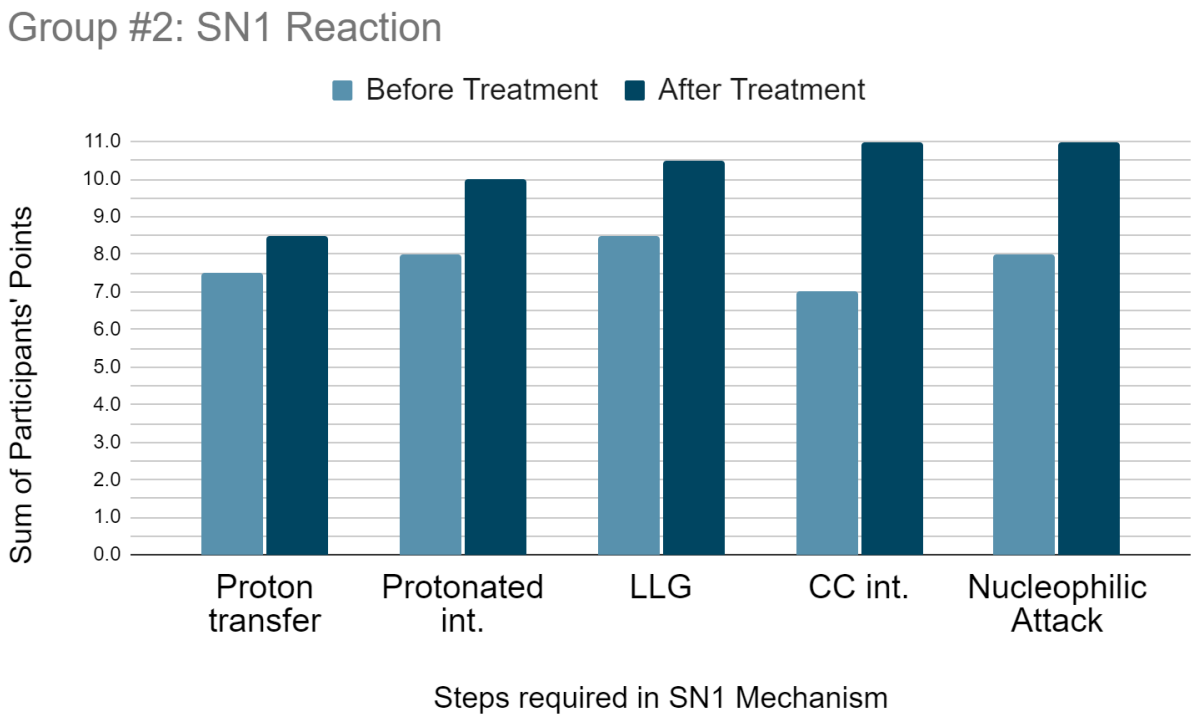
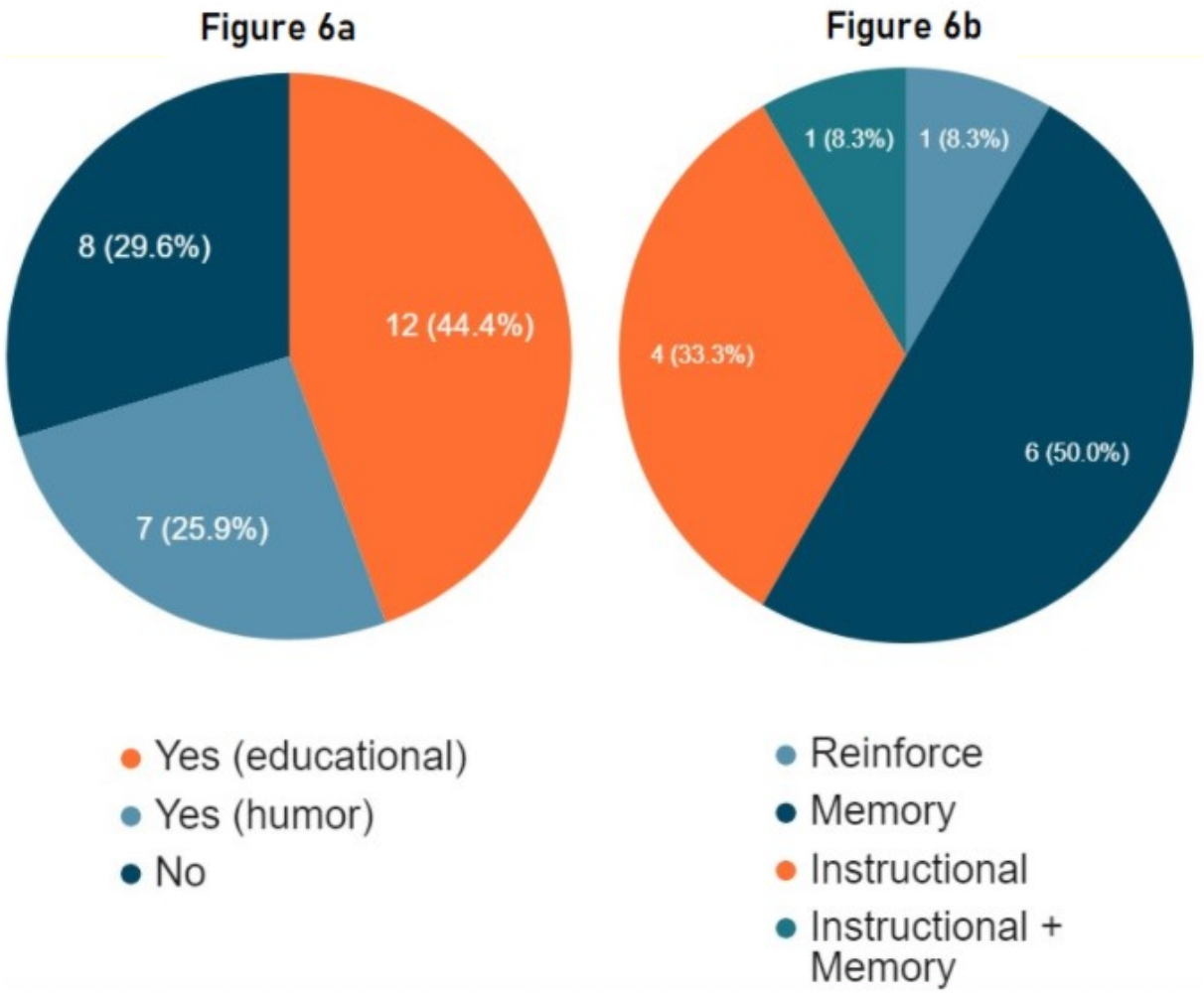


Figure 5. The Graph depicts the amount of points awards for Group #2 per step of the question. There was 14 total participants in Group #2 so the maximum points per step was 14. Abbreviations: "int." Intermediate; "LLG" Loss of Leaving Group; "CC" Carbocation.

3. Survey Responses

Survey responses on students' experience with education memes were collected via a follow-up survey with 27 out of 31 students completing this additional survey. The three survey questions and the coded general responses from the participants are found in Table 1.

Figure 6a shows the breakdown of what participants have experienced memes in a class setting (Survey Question #1). The 'yes' answers were then split based on how the participant described the use of the meme. If the meme contributed to learning, memory/retention, comprehension, etc it is classified as 'educational'. If the meme did not contribute to student learning and did not convey any educational content it was denoted as 'humor'. In Figure 6b the Yes (Educational) responses are then further broken down by how students categorized the educational benefit.



Figures 6a. Depicts the general responses for Survey Question #1: "Have you ever experienced memes in any classes before?" **Figure 6b**. Depicts the elaborations for the Yes (educational) responses on how they helped the student. Both figures include all responses fromGroups #1 and #2.

The responses to Survey Question #2 were reviewed for commonalities and then shown on the graph based on the major idea in their response. The categories for responses are shown in Figure 7 and are as follows: more interest, better memory/retention of the material, both increased interest and retention of the material, the memes would act as a distraction, and finally, depends on the use. 14 participants (51.9%) stated that the integration of memes into the classroom would increase interest in the material, but did not provide a specific reason why. 6

participants (22.2%) responded that the integration of memes would contribute to better memory/retention of the material, but did not state that it would increase interest in the lecture itself. 4 participants (14.8%) said memes would increase their interest in the lecture while also contributing to their memory/retention for the material. 2 participants (7.4%) stated that depending on how the meme was integrated into the course, as well as what type of meme it is, would influence how much interest it would tract. Finally, 1 participant (3.7%) stated that the integration of memes into lectures would act as a distraction, but did not provide any additional reasoning.

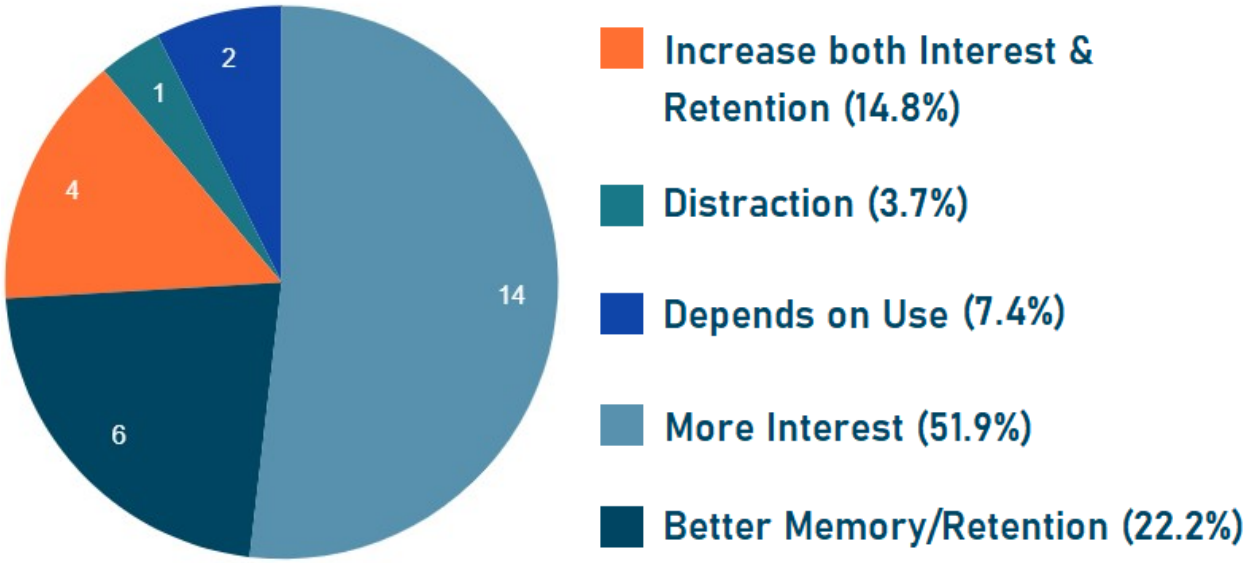


Figure 7. Depicts the general responses to Question 2: "Would the integration of memes relating to course material in lectures help you remain more interested in the material or would it act as a distraction?" from both Groups #1 and #2.

Survey Question #3 responses were split between Figure 8a and Figure 8b for Group #1 and Group #2 respectively, since they received different memes for different questions. Group #1 (Figure 8a) had the following general responses: the meme confirmed their thinking for their first attempt (6 responses, 42.9%), the meme helped them recall info or think about the question (3 responses, 21.4%), it was not helpful or confused them (2 responses, 14.3%), they are unsure of

how the meme affected them (2 responses, 14.3%), and lastly, the meme was helpful but did not specify how (1 response, 7.1%).

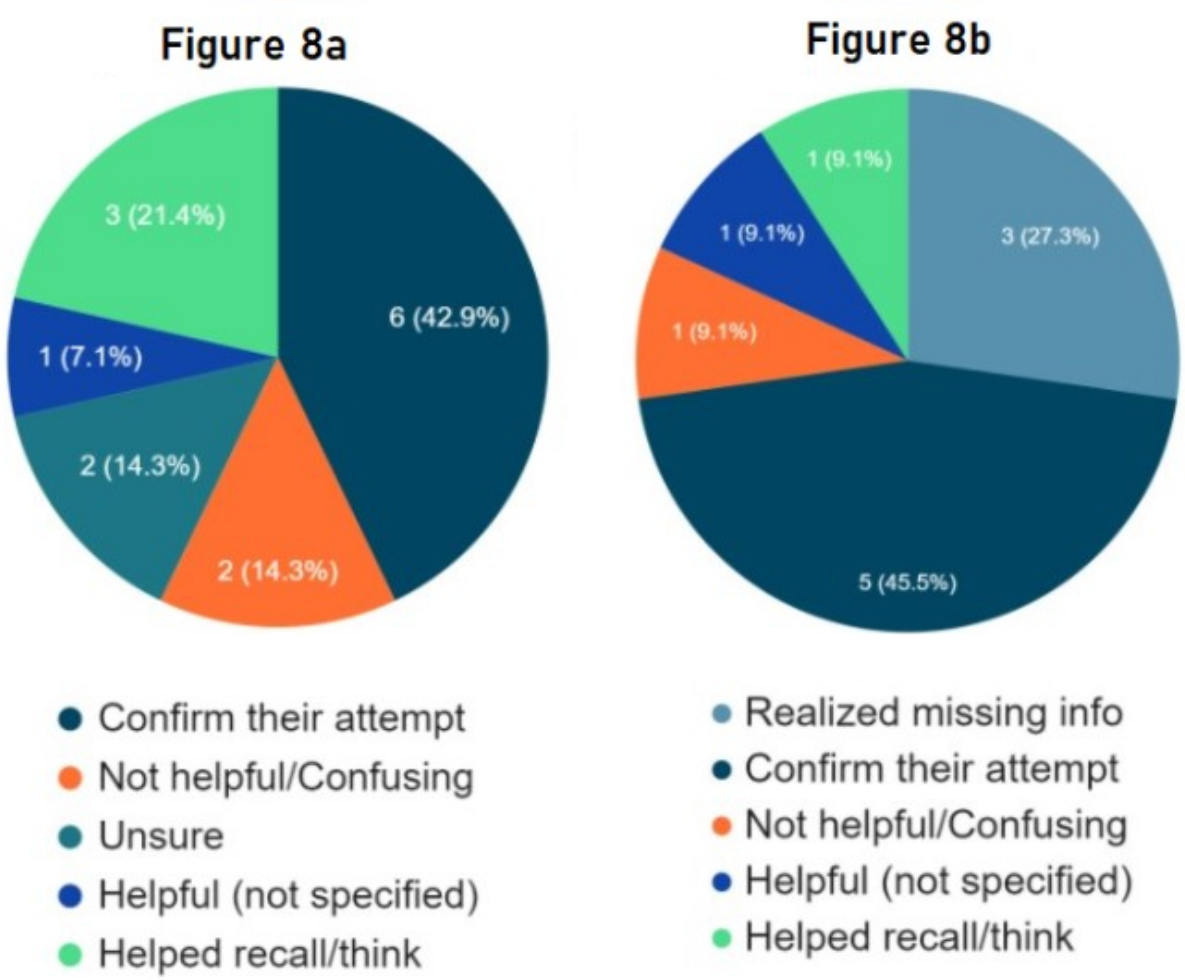


Figure 8a and 8b. "Did the memes presented in the quiz help you answer the questions or help correct a mistake you made on the first attempt?" Figure 8a shows the response breakdown from Group #1, who received a meme for the Acid-Base questions. Figure 8b shows the response breakdown for Group #2, who received a meme for the S_N1 Reaction Mechanism question.

Group #2's general responses were the following: the meme confirmed their thinking for their first attempt (5 responses, 45.5%), the meme helped the participant realize they were missing info in their reaction mechanism (3 responses, 27.3%), the meme helped them recall info or think about the question (1 response, 9.1%), it was not helpful or confused them (1 response, 9.1%), and lastly, the meme was helpful but did not specify how (1 response, 9.1%).

Discussion

1. General

Due to the multiple different components of the study, the following discussion will be broken up into the different sections of the assessment. Generally, the group receiving textual hints were less likely to alter their answers than the group that received the meme. This could be due to the text not being interesting enough for the students to engage in more critical thought of their responses similar to the use of editorials versus political cartoons (Abraham, 2009). This generally supports the hypothesis that memes may serve a beneficial role in classroom instruction.

Overall, the participants noted in their survey responses their personal enjoyment of the use of memes in the study as well as their past instructors who shared memes with them. Whether the memes presented in the personal experiences were educational or not it reinforces the concept that memes can establish comfortable learning environments (Bini, 2021; Purnama, 2017; Wells, 2018), which can pave the road to allowing students to be more receptive to asking questions and making mistakes.

2. Acid-Base Multiple-Choice Questions

Group #1 participants (meme treatment), scored an average of 4 out of 5 questions correct for both before and after treatment, however there were a roughly equal number of students switching from the correct answer to the incorrect answer and vice versa. This could be due to the nature of the reactions shown and the meme provided. In each question from this section the acids could all be classified as a Brønsted-Lowry acid-base pairs, where the acid donates a proton (H^+) and the base accepts the proton. However, the meme referenced the more general Lewis acid-base definition. The Lewis definition is still useful in determining acid-base

roles, but it may be possible that the use of the two different definitions contributed to student confusion. This was noted in three of the participants responses from Survey Question #3 (Figures 8a and 8b) stating that they were unclear of what the hint was providing or confused them overall. This may provide an explanation for why we see switching in both directions as shown in Figure 4a. However, a large proportion of the participants did not change their answers after seeing the meme as they were mostly correct to begin with. When considering the survey responses, it appears the meme simply helped to confirm their thinking and their final answer.

Group #2 received a textual hint for the acid-base assessment and there was fewer students electing to change their answers compared to Group #1. However more students switched to the wrong answer rather than switching to the correct answer (Figure 4b) and this may be due to confusion of the hint/meme referring to the Lewis acid-base definition as opposed to the Brønsted-Lowry definition leading to confusion and students second guessing themselves.

Due to the similar scores and outcomes between groups and the relatively small sample size, it is difficult to determine if either the meme or textual hint had a significant influence on the participants' responses. The data suggests that the two treatments had similar effects on the students due to a similar proportion of students switching from correct to incorrect and incorrect to correct. This may be the case because students overall had greater understanding of acid-base reactions as were less likely to benefit from the hints. Acid-base chemistry is typically covered in the first few weeks of the course, and at the time of the study, students had already practiced and mastered this concept.

3. S_N1 Reaction Mechanism Free Response

On the second assessment, Group #1 (textual hint) had no participants that elected to revise their answer. This treatment group had a very high average of 3.78 out of 5 points (75.6%)

on the initial assessment so the observation that students did not revise their answers could be attributed to a greater understanding of the reaction mechanism without the additional help. This group, while randomly assigned, does not appear to be representative of the class population.

Whereas Group 2's first attempt, which had an average of 2.82 out of 5 points, shows their overall performance during the assessment is more consistent with the class average. Due to the small sample number for both groups the data is not a good estimate for the general student enrolled in organic chemistry. However the trends observed could still lead further understanding of the influence of memes on student understanding.

Group #2's first attempts were lower in comparison to Group #1 which allows for more room to improve after receiving the meme treatment (Figure 3b). Of the participants who altered their initial mechanism, no participant scored lower after revising their answer, and the average increased by 0.82 points compared to their first attempt score (2.82 to 3.64). Figure 5 shows that the most missed point in the initial assessment was demonstrating the formation of a carbocation intermediate, which only occurs in the S_N1 reaction mechanism. The participants (35.7%) who edited their first attempt, had submitted mechanisms reflecting an S_N2 reaction mechanism, in which a carbocation does not form. The meme conveyed to the students that it could not be an S_N2 reaction due to the presence of the unstable carbocation formation (Spongebob) in the bottom right panel (Figure 3b) which is more indicative of an S_N1 reaction mechanism.

Two t tests were conducted. The first for Group #1 found a p value of 0.1686 was acquired which shows the averages between the two groups are not statistically significant. The second t test was conducted on the before and after treatment of Group #2, a value of 0.2597 was determined to not be statistically significant.

Table 3a. This table shows the mean, standard deviation, sample size, and p value between Group #1 and Group #2 before treatment in the S_N1 Reaction Mechanism Free-Response portion of the assessment.

Before Treatment	Group #1	Group #2
Mean	3.78	2.82
Standard deviation	1.69	2.03
Sample size	16	14
P value	0.1686	

Table 3b. This table shows the mean, standard deviation, sample size, and p value between Group #2's first and second attempt for the S_N1 Reaction Mechanism Free-Response portion of the assessment. Group #2 received the meme treatment (Figure 2b).

Group #2	Before meme treatment	After meme treatment
Mean	2.82	3.64
Standard deviation	2.03	1.73
Sample size	14	14
P value	0.2597	

4. Meme vs Text treatments

After examining both groups when they received memes versus receiving the text hint, it appears that the meme treatment tended to result in more participants revising their answers whereas when participants received the text hint, there were few revisions made. On the multiple-choice acid-base assessment, participants who received the meme treatment were 44% more likely to revise their answer, even if their revisions resulted in an incorrect answer. In the free-response mechanistic assessment, only the students who received the meme treatment revised their answer. This may be attributable to the memes inducing more interest and being more engaging than the text hint. This resulted in participants giving more thought to their

answer regardless if they performed better after revision (as in the case of the acid-base questions).

5. Survey Responses

A large proportion (70.3%) of the participants reported having experienced a meme in a classroom setting, while nearly half (44.4%) reported them used in an educational context. The participants elaborated that they believed the educational memes contributed to their understanding and retention of the course material. They stated that they still often think of the memes they saw when presented the course content again. This shows the potential for educational memes to influence the understanding and retention of course materials for current and future students.

A significant majority (66.7%) directly stated that the integration of memes into course material would increase their interest in lecture. This supports the conclusion that this situational interest would keep students more engaged in a course where it was more designed to appeal to current student trends and ideas. The integration of memes reduces the disconnect that many students feel between themselves, their professors, and their education. In other words, memes and popular culture references may make coursework more relatable for students. This was a notable theme in other studies that found students enjoyed the learning environments where memes were integrated compared to non-meme learning environments (Bini, 2021; Purnama, 2017; Wells, 2018). Other participants (7.4%) responded that the memes used may or may not result in greater individual interest, depending on how the meme is used and its integration into the course. These participants would find a non-educational meme to be more distracting and uninteresting compared to an educational meme (see Figure 1 for clarification of non-educational vs educational memes).

In Group #1 the majority of the participants found the meme to help confirm their original answer. However, for some participants, the meme was confusing due to the mixture of acid-base definitions. Multiple participants from Group #1 directly commented on their appreciation for using an up-to-date meme (featuring Bernie Sanders) because it felt more relevant as the 2020 USA presidential election had just occurred in the previous month. This is a common trend noted on social media, where using an outdated meme format detracts from the joke or message intended. This further demonstrates the importance of using memes that relay information in a digestible way, but also ensuring it remains relevant for the target population.

Conclusions

Results in this study suggest that memes engage the students more than textual hints and may result in more thought about their responses. Participant feedback also suggests that up-to-date memes increase their engagement with the material and may have a larger effect on their retention of the material. However, whether or not the memes lead the students to the correct answer more than the textual hints remains unclear.

This study was not without its limitations. Due to the small sample size, the data collected from the study cannot for certain state that memes have a positive influence on student understanding of some organic chemistry concepts. Another limitation might include the effort put into the questions from some of the participants; the study was conducted during the last two weeks of school and many participants were very preoccupied with exams and other projects. Some participants may have disregarded the memes or text hints and resubmitted their answers without putting thought into it. The data could then be further skewed due to the limited number of participants. Lastly, the participants in the study were not reflective of the average population of introductory organic chemistry students. 51.6% of students who participated in this study

received a final course grade of an A or A+. Only 21.9% of students received an A/A+ from the entire population of organic chemistry students that quarter.

The participants in this study reported that memes were a positive influence on their education, however more studies would need to be conducted to ensure the effects of memes on student understanding, excitement, and retention of course material. These studies could provide numerous styles of memes, humorous and educational, then have students rank their interest in the meme itself, and possibly explain the content of the meme. Other studies could further test the retention of content when integrating memes into a lecture. There could be two groups, and each receives a lecture on a topic. In addition to the lecture one group will be shown a meme that relates to the content. The two groups will take a mini assessment immediately after the lecture and then again 2 weeks later to see if there is a difference in the amount of understanding and concept retention between the two groups.

Memes show promise in encouraging students to engage in lectures and the classroom. Their exact effects would require additional studies, but from the data collected they perceive to contribute to additional thinking toward the questions presented.

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