Active learning practices in organic chemistry: A deeper look at student dialogue in group activities

S. R. Mooring[a], N. L. Burrows[b] and S. Gamage[a*].

[a] Georgia State University, Atlanta, GA [b] Monmouth University, West Long Branch, NJ

*corresponding email address: smooring@gsu.edu

ABSTRACT/WEB SUMMARY

Organic chemistry is a prerequisite course for students pursuing advanced degrees in STEM and health professions. Students face various challenges in this course, including learning complex organic chemistry concepts, applying them to solve organic problems, and navigating curved arrow notation to depict organic chemistry mechanisms. Organic chemistry is also plagued with substantial attrition rates. Given these challenges, many chemistry education practitioners and researchers have focused their efforts on implementing and assessing pedagogical practices that can produce positive outcomes for all students. In this chapter, we describe flipped classroom pedagogy as an evidence-based practice in organic chemistry that have improved student outcomes and addressed learning challenges in the course. A review of various aspects of this practice is discussed. Given that group activities are a common component of flipped classrooms, we will present a case study to analyze students' dialogue when engaged in a group quiz activity as a component of a flipped organic chemistry course. Suggestions for how this practice can be implemented to improve students' reasoning skills will also be discussed.

X.1 Introduction

Organic chemistry is a challenging course for students. Student difficulties with organic chemistry concepts[1] and high withdrawal and failure rates[2] are well documented in the literature. To alleviate some of these challenges and to improve students' motivation in the course, some organic chemistry educators have turned to active learning approaches. Active learning has been shown to improve student outcomes and benefit students traditionally underrepresented in STEM disciplines.[3, 4] One approach that has gained traction in chemistry courses is flipped or blended learning, in which some or most of the lecture material is moved online. Students typically review the content videos before class, while class time is reserved for problem-solving, group work and enhanced discussions.

In general, studies of flipped organic chemistry courses have found that failure and withdrawal rates decrease.[5-7] For example, Flynn reported that student achievement increased in organic chemistry courses as evidenced by increased students' grades and decreased failure rates.[6] In the same course, the withdrawal rates were also reduced when compared to previous years. Similar results were separately reported by Fautch [5] and Mooring et al.[7]

Student perceptions and attitudes were also positively impacted by the flipped organic chemistry classrooms.[7, 8] Rau et al. found that active learning had positive effects on students' ratings of the textbook.[9] Shattuck reported that students commented on their development of transferable skills due to the flipped classroom. For example, students reported improvement in their comfort level in using technology outside of class, working in groups, and participating in active learning activities.[10, 11] Furthermore, Shattuck reported that students felt that the flipped class improved their critical thinking, problem-solving ability, connection with course concepts and transferring knowledge to future courses.[10, 11]

In the section below, we examine some key components of the pre-class and in-class activities of flipped classrooms and their reported impact on student outcomes in organic chemistry.

X. 1. 1. Pre-class activity: Videos

One of the prominent components of the flipped classroom involves moving lecture information outside of the classroom. The primary form of presentation in most implementations was online videos. Students are typically required to watch the videos before class. Seery[12] and Christiansen[13] both reported consistent video viewing by students before in-class activities. A recent study by Casselman found that the asynchronous online learning environment (pre-class videos) played a more significant role in student learning when compared to in-person collaborative group work.[14] The online learning component also appeared to account for most of the improvement in post-test scores observed in the flipped classroom treatment.[14]

Students listed the pre-class videos of the flipped classroom as an important contributor to their performance.[7, 14, 15] Shattuck used student survey responses and focus groups to gather student comments about the flipped classroom.[10, 11] Students' comments often stated that one of the major benefits of flipping was the ability to re-watch the videos in studying, pause them as needed, and watch them at a time of day when they were mentally alert. Mooring et al. reported similar comments from students, where the majority of positive comments referred to students' ability to re-watch and clarify concepts using the videos.[7] In Rossi's study, students enjoyed the on-demand lecture videos in conjunction with the increased structure of the course.[16] Though these studies reflect students positive perceptions of video lectures, it is still unclear how the delivery of video lectures affect student learning and reasoning about organic chemistry concepts.

X. 1. 2. Pre-class activity: Quizzes

In a few studies, students were asked to answer low stake quiz questions after or during the pre-class video. Pre-class quizzes were used for a variety of reasons which include: the promotion of notetaking,[17, 18] facilitate better engagement with the content,[7, 13, 15, 19] provide evidence of gained knowledge to students,[6] guide students to important learning objectives, and to guide mini-lectures given for instructors.[5, 6, 20] Quizzes were either given online directly after watching a video,[5, 7] right before beginning in-class activities,[6, 18] or a combination of both.[21] Learning management systems were typically used to administer pre-class quizzes.

Most studies have used quizzes as a follow-up to the pre-class online videos; however, only one study investigated the pre-class versus post-video quiz outcomes. Christiansen et al. investigated student preferences and knowledge gains for *online* pre-class quizzes versus *in-class* pre-class quizzes.[21] In a small study, the authors found that most students preferred in-class quizzes. It was also found that students performed worse with take-home quizzes. Feedback from students in that study indicated that online quizzes de-incentivized attendance, video-watching before class, and decreased engagement with the videos. In many studies, authors often point to the importance of using post-video quizzes to motivate students to watch videos; however, there are limited formal studies on the outcome of the quizzes on student engagement and learning.

X. 1. 3. In-class activity: Student Response Systems

Student response systems were implemented in many large flipped organic chemistry courses as a formative assessment to provide "just-in-time" instruction for students.[6-8, 14, 16-18, 20, 22, 23] A few studies have examined outcomes and perceptions of student response systems in the flipped classroom. Mooring et al. found approximately 92% of students agreed that in-class clicker questions helped them better understand the course material.[7] Flynn examined student's comments on course evaluations and found that some students thought clicker questions enhance learning and problem solving while giving proof of their real-time comprehension.[6]

X. 1. 4. In-class activity: Group Work

In many flipped classrooms, group problem-solving was the most used activity during class meetings. Group activities in flipped classrooms involved worksheets done as group work[6], peer assessment,[13] group quizzes,[22] Process-Oriented Guided Inquiry Learning (POGIL),[17] or Peer-led Team learning (PLTL).[7, 8] Group work activities occurred in small groups of three to five students with questions developed by the instructor or textbook publisher's repository. Groups were randomly put together, [7, 16, 18] selected based on complementary student characteristics,[5, 10] or selected based on POGIL roles.[17]

Many studies discussed students' positive comments regarding group work. For example, Flynn reports students leaving comments in course evaluations that the in-class group work helped them prepare for exams.[6] One study reported that students consistently gave high ratings to in-class group problem-solving activities.[18] However, others report no statistically significant exam scores for students completing group work in the flipped classroom compared to the students in the traditional lecture with collaborative group learning.[9] However, there were indications that students in the flipped collaborative condition show higher ability to reason about concepts than the traditional lecture collaborative condition.[9]

When exploring why students enjoyed group work, a few common trends were highlighted across several studies. Muzyka and Christiansen both reported that students enjoyed explaining and teaching information to peers.[13, 20] Similarly, using survey responses and focus group comments Shattuck found that students appreciated the in-class problem sets, writing answers on the board, and felt that they had more time to ask questions in class.[10] Fautch, through instructor observations, reported a student group debating back and forth on correct versus incorrect attributes of the arrows involved in the problem.[5] Students in this study expressed that explaining concepts to others made it easier for them to remember the information, and consolidate their understanding of material .[5]

A few studies have utilized evidence-based Peer-led group discussions in the organic chemistry flipped classroom environment.[7, 8, 22, 24] These studies examined the facilitation of small group discussions and activities through peer-led team learning (PLTL) for large enrollment Organic chemistry flipped courses (O-Flip-PLTL). PLTL replaced a typical lecture session with small groups ranging from 10 to 19 students per leader. In most studies, peer leaders received training on how to facilitate the sessions.[7, 8, 24]

One study comparing O-Flip-PLTL with traditional lectures showed better student performance for the O-Flip-PLTL students.[23] Most studies found differences in students' attitudes, motivation, and course retention outcomes instead of statistically significant grade performance. In general, studies using assessment instruments such as the ASCI[7], other survey items,[25] and open-ended comments[7] have found that most students positively viewed O-Flip-PLTL.

Another study, which looked specifically at student motivation, found that students were less *amotivated* in an O-Flip–PLTL instructional environment.[8] More specifically, they uncovered a significant and negative correlation between *amotivation* and exam grades. This can also explain the observed outcome of lower DFW and increased ABC rates frequently reported for other O-Flip PLTL courses.

Several studies have highlighted increased course retention of O-Flip-PLTL, and the data suggest that O-Flip-PLTL promotes a more uniform, less dichotomous grade distribution, particularly with students underrepresented in STEM.[19]

McCollum and co-authors took an in-depth look at social interactions in the O-Flip-PLTL classroom.[22] The authors postulate that two factors were essential to deepening students' conceptual understanding and developing problem-solving skills: peer-leader support and student-student interaction. They also found that numerous students identified the formation of peer-peer relationships as a key benefit of the flipped classroom. Students expressed the desire to contribute to the team, support peers, and contribute to peer feedback, thus allowing students to self-regulate. In addition, the authors observed that as students discussed and debated their understanding with one another, they were learning to articulate their thought processes.[22]

X. 2. Student dialogue in active learning environments – A case study

In the previous section, we described how active learning, particularly flipped classroom environments, have positively contributed to student success in organic chemistry courses. [6, 7, 10] Most studies report the overall outcomes of the flipped classroom environment, and few have focused on how the individual components of the flipped classroom contribute to positive student outcomes. As previously noted, a primary goal of many flipped classroom implementations is to reserve class time for increased student engagement with the content and with each other. As such, group learning has become increasingly important for students to engage in problem solving and reasoning together. However, few studies focus on the nature of the discussion that students have during group activities, the discourse moves involved in the construction of ideas, reasoning, and learning about organic chemistry concepts.

Theories of social constructivism and social cognitive theory [26, 27] suggest that engaging in problem solving through social interaction is expected to result in student learning gains. These learning theories also note that when students discuss the material with their peers, it helps them clarify ideas, and engage in sense-making about concepts. [28, 29] The efficacy of collaborative learning approaches is dependent on the quality of students' interaction. Therefore, simply putting students into groups and encouraging discussions may not result in productive group discourse. The study by McCollum and co-authors, previously discussed, emphasized the importance of peer-peer relationships in the outcomes of group activities in flipped classrooms.[22] Towards this end, we will describe a case study to examine the nature and quality of students' dialogue as they engaged in a group quiz. The group quiz was part of ongoing group-centered activities in a blended learning, organic chemistry course. We will characterize the nature of students' dialogue through the Interactive-Constructive-Active-Passive (ICAP) framework [30-32] and the quality of the groups' dialogue through the presence of the argumentative elements of oppositi.[33, 34] We will then discuss the potential impact and implications of the findings of this case study on the use of group discussion to elicit student reasoning in active learning organic chemistry courses. The following research questions will be addressed:

1. What is the nature of students' discourse during the group quiz as defined by the ICAP framework?
2. What is the quality of students' discourse during the group quiz as defined by the presence of opposition and rebuttals?

X. 2. 1. *The Interactive, Constructive, Active, Passive (ICAP) Framework*

The ICAP framework, developed by Chi, [32] proposes that the benefit of learning from collaboration depends on the type of dialogue patterns in which students are engaged. This framework is defined by four overt engagement levels: *passive* at the lowest engagement level, *active*, *constructive*, and then *interactive* at the highest engagement level. This framework posits that these observable behaviors are indicators of students' underlying cognitive processes and level of learning [35]. That is, as students become more cognitively engaged in the material, their learning and understanding is hypothesized to increase.

Passive engagement, in the context of group discussion, refers to instances where the student is receiving information but does not exhibit any additional overt behavior. [32, 35] For example, reading silently or uttering agreement without elaboration. Passive engagement results in minimal understanding since students do not have the opportunity to connect new information to their prior knowledge [32, 35].

During *active* dialogue, students are typically receiving information, describing or repeating what is already in the given learning material [32, 35]. Some examples of active engagement include reading the question prompt out aloud and repeating what is presented by peers in the group activity. Active dialogue typically results in shallow understanding since the student has opportunity to integrate new knowledge with related prior knowledge, but it is limited.

In *constructive* dialogue, students introduce new knowledge to the group based on their own reasoning and beyond what is presented in the activity or by other peers. The constructive dialogue pattern is associated with deep understanding since new information is activated and integrated with prior knowledge and gives rise to new understandings.

Finally, *interactive* engagement occurs when a student's contribution is in response to another peer's input. In this case, an exchange of ideas occurs between peers and is, therefore, co-constructed knowledge [30, 32, 35]. Interactive dialogue leads to the deepest understanding and results in new understanding that would not have been generated by students individually [32].

We will use the ICAP framework to characterize the cognitive nature of students' discourse and their hypothesized learning gains during the group quiz discussion.

X. 2. 2. *Argumentation and student reasoning in organic chemistry*

Argumentation plays an important role in students' learning of scientific concepts and is central to the process of thinking and scientific reasoning, development of conceptual understanding. Few studies in organic chemistry examine student reasoning through argumentation. Most studies have involved interviews with students to investigate their conceptual understanding, [36] or analyzing students written responses.[37] Pabuccu and Erduran have published work on argumentation in organic chemistry.[33, 34] In one publication, they examined how pre-service teachers engage in argumentation about conformational analysis of alkanes in a group activity [34]. The authors identified practical difficulties in using Toulmin's' argumentation framework when distinguishing between data and warrants or between warrants and backings. Therefore, they have derived a method to determine the quality of argumentation by counting the occurrences of opposition and the strength of the rebuttal that followed. The authors argue that rebuttals indicate the quality, level of sophistication, and complexity of the argument.[34] Rebuttals in which the counterclaims were unrelated were characterized as low-level argumentation. In contrast, if the rebuttal was in direct reference to data, warrants, or backings offered by the opponent, they considered it as higher-level argumentation. In the case study analysis presented here, we will also examine the number of oppositions and quality of the rebuttals in the group discussion using the criteria proposed by Pabuccu and Erduran.

X. 2. 3. *Course Context and Participants*

This case study includes video observations students engaged in a group quiz activity about Newman projections. In this course, students viewed lecture videos, accessed practice problems, and completed assessments independently through the institution's learning management system. Students were also provided with a slide deck for each chapter, instructor-developed reading guides, and problem sets for class discussions. Students completed an online pre-quiz for each topic consisting of ten to fifteen multiple-choice prompts that varied in difficulty.

Group activities were an integral part of every 50-minute class meeting. In the first five to ten minutes of a typical class period, the instructor answered student questions about the previous class period. This process of content delivery spanned fifteen to twenty minutes. Students used the think-pair-share model [38, 39] to complete the problem set during the the class period. At the end of a topic, students completed a post-quiz to assess their mastery of related concepts. Student typically remained in the same groups throughout the semester. This study includes organic chemistry students at an institution in the southeast United States. All students in the groups with female and of African descent. Two groups will be discussed. Group A had three students with pseudonyms, Ashley, Candice, and Tiffany. Group B had four students with pseudonyms, Brittany, Dawn, Farrah, and Jasmine.

X. 2. 4. *Group Quiz Format*

During group quiz sessions, the students could not use supplemental information, but were required to discuss the prompts with group members to arrive at a solution. Students were given the topic before the quiz and were expected to review the relevant concepts. The instructor was available if the group needed clarification on the quiz prompts.

The quiz discussed here is related to alkane conformations. This topic required students to process structural information relating to the three-dimensional spatial relationship of groups or atoms represented by the rotations around a carbon-carbon single bond. Such structural information is typically depicted in a Newman Projection of the molecule. Students responded to a series of prompts to demonstrate their ability to correctly draw staggered and eclipsed conformations and compare the relative stability of two molecules based on their conformations.

X. 2. 5. *Data Collection and Analysis*

Each group was video and audio-recorded using overhead cameras set at a fixed angle. iPads equipped with the screen capturing app Explain Everything [40] were used to record group responses to the quiz. The recordings in which all group members were visible on camera, and had clear audio were chosen for analysis. The recordings were transcribed, and the transcripts were arranged by speaking turn, with each line of the transcript representing each time a different student begins to speak. Each speaking turn in the dialogue was coded as interactive, constructive, active, or passive using the definitions indicated by the ICAP framework.[35] If the student's speaking turn was not related to the group quiz, it was coded as "off-task."

The transcripts were also coded for any instances of opposition. Each instance of opposition was also rated for the quality of argumentation based on the criteria by Pabuccu and Erduran.[34] We searched the transcripts to find words or phrases that one group member disagreed with another. We also observed that the students used questioning as a subtle form of opposition to further probe a peer's ideas. [41, 42] The coding for opposition and level of argumentation was first collaboratively coded by SG and SRM then another section was coded separately by SRM and SG to establish reliability of the codes. Coding continued until satisfactory interrater reliability was reached between coders. A Cohen's kappa for interrater reliability was calculated as 0.73, which indicates a moderate to good agreement between coders. [43]

X. 3. Findings

In this section, we will discuss the findings from the case study to compares the dialogue patterns between two groups (A and B) on one prompt from quiz 2 (See Table X. 1.). We will provide a summary description of each group's dialogue. Then compare the two groups on the nature of students' discourse using the ICAP framework and students' reasoning through instances of opposition and the quality of argumentation.

The group responded to the following quiz prompt:

Explain the stability of the least stable eclipsed conformations of butane defined for the rotation around the C2-C3 axis in comparison to that of octane defined for the rotation around the C4-C5 axis.

X. 3. 1. Group A Summary

The dialogue between students in Group A on this prompt consisted of only 11 speaking turns (See Excerpt X. 1). The group spent the first half of their conversation trying to determine what they needed to do to address the prompt or what the prompt was asking them to do (lines 1 - 5). They seemed to struggle to decipher the meanings of less and more stable as it related to Newman conformations (lines 2 - 4):

Line 2: Ashley: So, were just explaining why that is? the stability, it's less stable in butane than in octane - that's what it says

Line 3: Tiffany: So, you're saying butane is more, you said it's more stable?

Line 4: Ashley: That's what it said. No, it's least

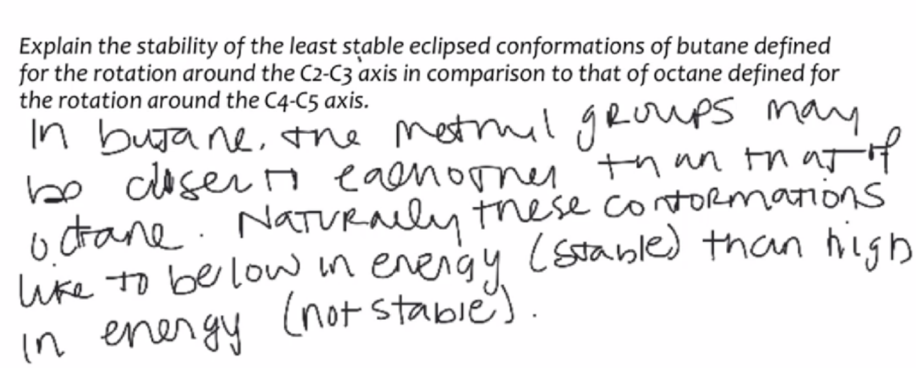
Also, Candice determined from the beginning (line 1) that the group's approach to answering the prompt should be through words rather that drawing. The other group members did not disagree with this suggestion.

Excerpt X. 1. **Speaking turns for Group A's responses to the quiz prompt**

ICAP Code*	Speaking Turn
A	1. Candice: (reads prompt aloud). 4 carbons, 8 carbons, I think more of us explaining, than drawing
A	2. Ashley: So, were just explaining why that is? the stability, it's less stable in butane than in octane - that's what it says
A	3. Tiffany (Scribe): So, you're saying butane is more, you said it's more stable?
A	4. Ashley: That's what it said. No, it's least
A	5. Tiffany: (rereads the prompt and refers to the previous prompt about comparing the least and most stable conformation of heptane). That's what the question is saying. So basically, in the previous question it's on top of each other (meaning eclipsed)
P	6. Ashley: I don't know why
C	7. Tiffany: Well like, it's because it needs more energy to… because I know it takes a lot of kilojoules, to like, for something break, break apart, or it's like how they're close to each other
I	8. Ashley: When they're close together, they're high in energy, but they wanna be low in energy
I	9. Tiffany: Yeah. So can we say that for butane the methyl groups may be closer to each other than that of octane (Tiffany scribes this on iPad).
A	10. Tiffany: So, is that a good enough answer?
P	11. Ashley: I think it is
P	12. Tiffany: Because I don't know what else it would be

*ICAP Codes: NP = negative passive, AP = active passive; A = active, C = constructive, I = interactive

Tiffany introduced the first piece of information that was not explicitly mentioned in the prompt (line 7) in response to Ashley's request for why they should be looking for the least stable (line 6). Tiffany's idea was that energy may be related to when "things" are close to each other, and that energy is used to "break things apart." Ashley follows up on Tiffany's idea to clarify that when the atoms are close together, they are high in energy. In line 9, Tiffany incorrectly states that the groups in butane are closer together than the ones in octane. Unfortunately, this is where the group ends their discussion. Although Tiffany did not articulate all the details regarding the groups being closer together, this statement could have generated additional ideas about how group size in butane and octane may affect the energy and stability of the Newman projection. They also did not make any drawings of the Newman projections during their discussion to further clarify their understanding of the concept. The group concluded their work by writing up their answer as shown in Figure X. 1. Their written answer to the prompt does not explain or compare the differences in the eclipsed conformations of butane and octane. Overall, the group struggled to understand what was required and spent most of their time trying to figure things out. It is possible that the members of the group did not have the appropriate prior knowledge to address the prompt sufficiently.


Explain the stability of the least stable eclipsed conformations of butane defined for the rotation around the C2-C3 axis in comparison to that of octane defined for the rotation around the C4-C5 axis.

In butane, the methyl groups may be closer to eachother than that of octane. Naturally these conformations like to be low in energy (stable) than high in energy (not stable).

Figure X. 1. Group A's final answer to the quiz prompt

We can also observe the relative contributions of each student in Group A to the overall dialogue The three group members did not contribute equally. Ashely and Tiffany each contributed about 45% of the group's dialogue, and Candice only had one speaking turn in line 1 as she read the prompt to the group and suggested a strategy for answering the question.

X. 3. 2. *Quiz 2, prompt 5 – Group B*

Group B's dialogue for the same prompt was almost double in length to that of Group A (Excerpt X. 2). This group initially worked independently for about two minutes before any discussion began. Farrah started the group off by correctly stating that the least stable conformation of butane would be an eclipsed conformation (line 2). She then continued her line of reasoning on line 4 to say that the least stable of both butane and octane was needed in their response. Brittany simply agreed with Farrah each time (lines 3 and 5) but there was no audible response from the other two group members - Jasmine and Dawn. The conversation that followed from lines 8 through 24 is composed almost entirely of co-constructive dialogue between Brittany and Farrah. Their discussion allowed them to think more carefully about the problem as they probed each other about their input. For example, on lines 19 through 25, Brittany and Farrah have an exchange about the end groups (CH_2 or CH_3) for the Newman projection drawings. On line 19, Brittany questions whether the end group for octane should be CH_2. Farrah responds (though incorrectly) on line 20 to explain why the end groups should be a CH_2 group. It is noted that the Newman projection of octane offered by the group is incorrect (See Figure X. 2), and there is not a significant size difference between CH_3 and CH_2. However, despite the flaw in the drawing, the group has a course of dialogue that allows them to surmise the relationship between the size of interacting substituents and the resulting energy cost (line 21 – 23). They correctly rationalized that the larger interacting groups have a higher energy cost than smaller interacting groups. In the end, Brittany dictates to the scribe a summary of the group's final answer (line 23), which includes drawings.

Group A was composed of four members; however, only two of them contributed to the group's response to this prompt. The video recording of the group showed that one of the group's members was the scribe and therefore, may not have contributed as much to the dialogue. The other student was actively writing on her paper throughout this discussion. For both students, their body language suggested that they were actively listening to the conversation, even though they did not contribute to the group's response to this prompt.

Excerpt X. 2. Dialogue for Group B discussion of the quiz prompt

*ICAP Code	Speaking Turns
A	1. Brittany: (reads prompt out loud)
	(Students work independently on paper for approximately 2 minutes)
C	2. Farrah: So, the least stable of the butane will be an eclipsed of the butane, right?
P	3. Brittany: Yeah
A	4. Farrah: So, it's the least stable of both
P	5. Brittany: Yeah
	(Students work independently on paper for 30 seconds)
C	6. Brittany: The structures will pretty much look the same, but we just have to... it's probably something that has to do with how big it is
I	7. Farrah: The only difference I have is just the groups that are on it, like butane are ethyl groups… I mean methyl groups and then for octane I just gave them CH_2's like for heptane, but still [carbons] 4 to 5
A	8. Brittany: Is it methyl groups for that one?
A	9. Farrah: For butane?
A	10. Brittany: Yeah, it just says for carbons 2 and 3 so I was looking at the middle ones
A	11. Farrah: For butane it still should be that?
A	12. Brittany: CH_3?
I	13. Farrah: Yeah this (pointing to paper) is [carbon] 2 and [carbon] 3, if you're looking at what's on the ends…these are just methyl groups
I	14. Brittany: I wasn't looking at the ends. I was looking at the carbons 2 and 3, but we need to look at the end?
I	15. Farrah: Yeah, that's gonna determine like what's up and what's down [on the Newman projection]
P	16. Brittany: Right, you're right
I	17. Farrah: So yeah… just what we were doing before, see the butane one looks like this, base it off the two ends
I	18. Brittany: So, for octane it will be the CH_2?

I	19. Farrah: Yeah, it literally looks the same as heptane, it's just a CH_2, CH_2, up and down
I	20. Brittany: So…wouldn't the butane have the higher energy with the CH_3 and therefore be more stable?
I	21. Farrah: Yes, CH_3s are worth more than CH_2s I would think. What do you call that, not cost, their overall energy cost?
A	22. Brittany: Yes! the energy cost is greater for the CH_3. (Brittany restates the integrated form of the answer.09
A	23. Brittany: (dictates to the scribe): I would write the Newman projection. Ok. So. For butane. I would Just write the Newman projection. So, we are drawing eclipsed conformations. So for butane the two overlapping would be the CH_3 groups, but for butane CH_2 groups are overlapping. CH_3 groups have more energy. Like so, the energy cost for these to overlap are greater than one with CH_2. And you know for molecules, the higher the energy the less stable it is because they are always trying to get to the lowest energy possible. So that's why this is the least stable because the has the most energy.

*ICAP Codes: P = passive; A = active, C = constructive, I = interactive

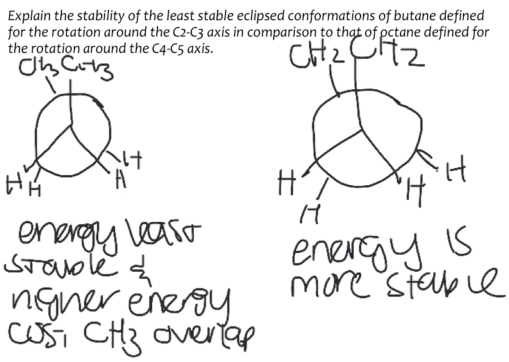


Figure X. 2: Group B's response to the quiz prompt

X. 3. 3. ICAP Analysis -Comparison of Group A to Group B Group B spent almost half of their dialogue in the interactive/constructive mode. Whereas for Group A only 25% was interactive and constructive (See Figure X. 3.). Group A's dialogue can be characterized as primarily active/passive since most of their dialogue (75%) focused on restating the question and repeating information that was already given in the prompt, but limited portions of the dialogue were the sharing of new ideas by individual students (constructive) or co-construction of ideas among members of the group (interactive). Interactive and constructive dialogue leads to the deepest level of learning, while active and passive dialogue leads to shallow learning outcomes [31] Although Group B's dialogue was dominated by two of the four group members, Farrah and Brittany, their discussion was more likely to have generated deeper learning gains for all the group members since there were several opportunities expand their knowledge through incorporating peers' reasoning with their own and co-constructing their understanding together.

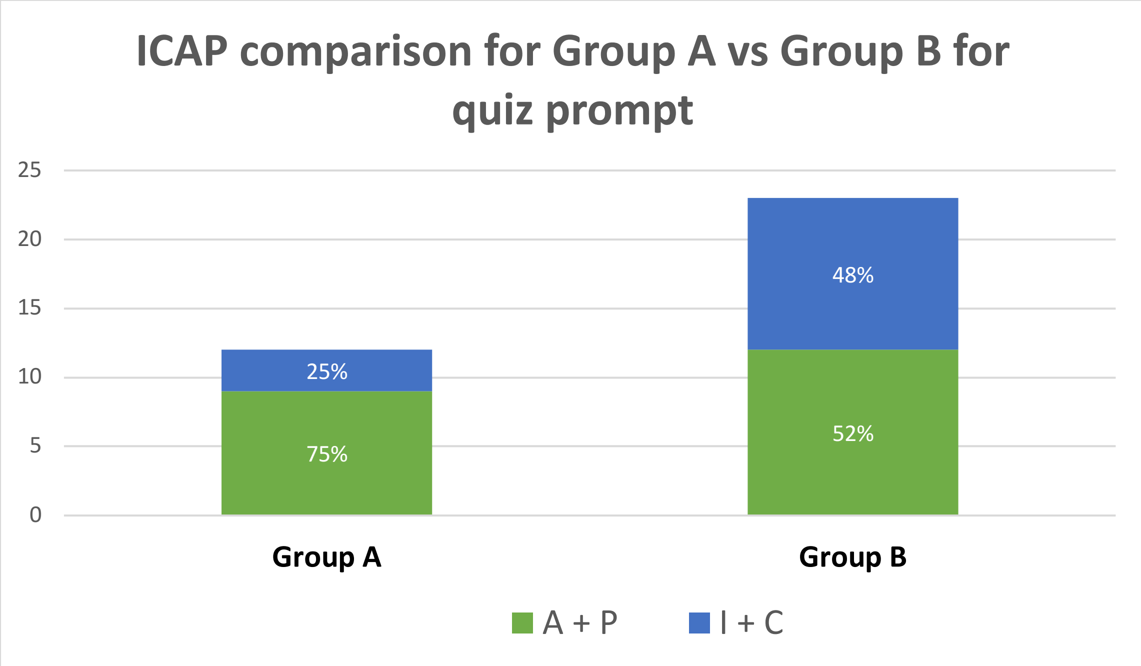


Figure X. 3. ICAP comparison for Group A vs Group B for Quiz 2 Prompt 5

ICAP Codes: I + C = Interactive and constructive, A + P = active and passive

X. 3. 4. Argumentation- Comparison of Group A to Group B. For Group A, there are no instances of opposition and therefore no argumentative elements present in the discourse. For Group B, there are no direct instances of opposition. That is, there are no instances in which a student says something like: "No, that is not correct" or "I do not agree". However, there are instances in which Brittany present oppositions to Farrah's claims by posing them as questions (line 8, 11, 13 and 15). From lines 8 through 19, Farrah and Brittany have an interactive discussion on how the Newman projections of butane and octane should be drawn. For example, on line 7, Farrah suggests that the end group on butane's Newman projection should be methyl groups and for octane in should be CH_2 groups (see the group's final answer in Figure X. 2). Brittany seems to oppose in asking if it should be a methyl group for butane.

However, she does not give any further reason as to why so was unsure. Brittany follows up with an explanation in line 10 that she is looking at the groups attached to carbons 2 and 3. Farrah does not seem convinced and asks: “For butane it still should be that?” Farrah uses her drawing (line 13) to show that there are methyl groups on the ends and Brittany agrees with here in Line 16. Brittany and Farrah go through a similar but shorter exchange for octane as Farrah ties to convince Brittany that the end groups for octane should be CH2 (lines 18 – 19. The exchange between Brittany and Farrah forces them to further explain their positions.

X. 5. Conclusion and implications

An analysis of only the final answers presented by the two groups may indicate that neither group was successful in answering the question. However, an analysis of the dialogue between students of Group A and Group B tells a different story. A focus on the process of how students in the group co-constructed knowledge seems more important than the final outcome. Group A primarily used an active dialogue, which according to Chi’s ICAP framework would produce shallow learning gains. Additionally, students in this group had no instances of opposition and is indicative of a low-quality dialogue. It is unlikely that this dialogue generated significant learning gains for the students in this group. For Group B, half of the conversation of interactive or constructive and argumentative elements were evident through questioning. This conversation was more likely to provide deeper learning for the entire group.

Given that cooperative group activities are a common component of active learning classrooms, it is critical that chemistry educators pay attention to how these activities are designed and if they are eliciting productive types of discourse. The findings of the case study suggest several aspects of group activities that need attention:

Scaffolding questions to promote argumentation. Scaffolding is needed for students to ask the right types of questions. Students’ questions foster critical dialogue, thinking and brainstorming towards a group consensus and is a key to orchestrating argumentation[41, 42, 44] Question asking is also a metacognitive tool that can broaden the nature and frequency of argumentation patterns.[45] In our analysis of Group B, we observed Farrah and Dawn's exchange through questioning (See Excerpt X.2) was able to foster a extended stream of co-constructive dialogue.

Research by others suggest that supporting students in question-asking could stimulate them to engage in meaningful argumentation.[41, 45] Therefore, creating conditions to foster productive collaborative discourse include having students pose questions and respond to each other when they were put together in small groups. Questions such as: What is the evidence to support my view?" can help scaffold the question-asking process. We also observed that group B spent two minutes thinking before they began to discuss the problem. One study suggests that students brainstorming individually about what questions they have and then verbalizing them out loud helps other students to be more aware not only of what they and did not understand.

Students often have difficulty in disagreeing with a peer's ideas. Students try to be supportive instead of offering disagreement.[46] Therefore, providing students with prompts that appear as part of the assignment and perhaps less confrontational can be useful. Asterhan & Schwarz [47] used the following prompts to promote opposing ideas: "Ask your partner a question about an utterance that is unclear " and "Describe opposite ideas against your partner's idea or claim". These prompts foster argumentation that could facilitate more productive interaction among students in groups.

Group Composition and Roles. Groups that operated at the higher ICAP levels had at least two students who frequently interacted in interactive/constructive dialogue and there were some groups in which students did not contribute or had limited contributions. WE observed that in Group B, the scribe was not actively discussing the problem but actively paying attention to record the answer. Therefore, it may be important to assign students group roles so that each student is responsible for a task. Similar ideas are expressed in the formation of groups for POGIL activities.[17, 48] These roles can include Cheerleader/Encourager, Facilitator, Spokesperson, Scribe, Quality Control, Process Analyst, Manager, Recorder, Reader, or

Materials Manager. Students can rotate roles so that each member can contribute to the group in diverse ways and foster accountability.[49]

Incorporating student observations in assessment of group activities. Based on this case study, instructors or teaching assistants should consider observing students during group work. These recordings can be audio and video recorded or field notes made by the instructor during student discussions. The insights gained from these recordings can be invaluable in helping instructors decide how to make changes to support group dynamics and provide scaffolding to further improve student reasoning about concepts together.

Overall, our discussion here supports the need for more research studies that provide further insight into student dialogue during group activities and how the introduction of specific prompts, scaffolding, and group roles have on student argumentation and reasoning in the context of organic chemistry. More research is also needed on the individual components of flipped courses such as video recordings to better enhance how they are implemented and maximize student success.

ACKNOWLEDGEMENTS

The authoers thank Dr. Leyte Winfield and Dr. Joy Ballard for their contributions to this work.

REFERENCES

1. G. Bhattacharyya, *Chemistry Education Research and Practice*, 2014, **15**, 594-609.
2. L. T. Tien, V. Roth and J. Kampmeier, *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 2002, **39**, 606-632.
3. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt and M. P. Wenderoth, *Proceedings of the national academy of sciences*, 2014, **111**, 8410-8415.
4. E. J. Theobald, M. J. Hill, E. Tran, S. Agrawal, E. N. Arroyo, S. Behling, N. Chambwe, D. L. Cintrón, J. D. Cooper and G. Dunster, *Proceedings of the National Academy of Sciences*, 2020, **117**, 6476-6483.
5. J. M. Fautch, *Chemistry Education Research and Practice*, 2015, **16**, 179-186.
6. A. B. Flynn, *Chemistry Education Research and Practice*, 2015, **16**, 198-211.
7. S. R. Mooring, C. E. Mitchell and N. L. Burrows, *Journal of Chemical Education*, 2016, **93**, 1972-1983.

8. Y. Liu, J. R. Raker and J. E. Lewis, *Chemistry Education Research and Practice*, 2018, **19**, 251-264.
9. M. A. Rau, K. Kennedy, L. Oxtoby, M. Bollom and J. W. Moore, *Journal of Chemical Education*, 2017, **94**, 1406-1414.
10. J. C. Shattuck, *Journal of Chemical Education*, 2016, **93**, 1984-1992.
11. J. C. Shattuck, in *Active Learning in Organic Chemistry: Implementation and Analysis*, ACS Publications, 2019, pp. 167-186.
12. M. K. Seery, *Journal of Chemical Education*, 2015, **92**, 1566-1567.
13. M. A. Christiansen, *Journal of Chemical Education*, 2014, **91**, 1845-1850.
14. M. D. Casselman, K. Atit, G. Henbest, C. Guregyan, K. Mortezaei and J. F. Eichler, *Journal of Chemical Education*, 2019, **97**, 27-35.
15. C. Cormier and B. Voisard, *Frontiers in ICT*, 2018, **4**, 30.
16. R. D. Rossi, *Journal of Chemical Education*, 2015, **92**, 1577-1579.
17. M. P. DeMatteo, in *Active learning in organic chemistry: Implementation and analysis*, ACS Publications, 2019, pp. 217-240.
18. L. A. Morsch, in *The Flipped Classroom Volume 1: Background and Challenges*, ACS Publications, 2016, pp. 73-92.
19. J. Mutanyatta-Comar and S. R. Mooring, in *From General to Organic Chemistry: Courses and Curricula to Enhance Student Retention*, ACS Publications, 2019, pp. 145-157.
20. J. L. Muzyka, *Journal of Chemical Education*, 2015, **92**, 1580-1581.
21. M. A. Christiansen, A. M. Lambert, L. S. Nadelson, K. M. Dupree and T. A. Kingsford, *Journal of Chemical Education*, 2017, **94**, 157-163.
22. B. M. McCollum, C. L. Fleming, K. M. Plotnikoff and D. N. Skagen, *Canadian Journal for the Scholarship of Teaching and Learning*, 2017, **8**, n3.
23. B. G. Trogden, *Journal of Chemical Education*, 2015, **92**, 1570-1571.
24. C. O. Welder, in *Active Learning in Organic Chemistry: Implementation and Analysis*, ACS Publications, 2019, pp. 119-148.
25. K. S. Rein and D. T. Brookes, *Journal of Chemical Education*, 2015, **92**, 797-802.
26. A. Bandura, *American journal of health promotion: AJHP*, 1997, **12**, 8-10.
27. N. Mercer, in *Language and the Joint Creation of Knowledge*, Routledge, 2019, pp. 156-186.
28. A. R. Cavagnetto, *Review of Educational Research*, 2010, **80**, 336-371.
29. M. C. Wittrock, *Educational psychologist*, 1989, **24**, 345-376.
30. M. T. Chi, S. Kang and D. L. Yaghmourian, *Journal of the Learning Sciences*, 2017, **26**, 10-50.
31. M. T. Chi and M. Menekse, *Socializing intelligence through academic talk and dialogue*, 2015, 263-274.
32. M. T. Chi and R. Wylie, *Educational psychologist*, 2014, **49**, 219-243.
33. S. Erduran, 2019.
34. A. Pabuccu and S. Erduran, *International Journal of Science Education*, 2017, **39**, 1154-1172.
35. M. T. Chi and M. Menekse, eds., *Dialogue patterns in peer collaboration that promote learning*, American Educational Research Association, Washington, DC:, 2015.
36. D. C.-R. de Arellano and M. H. Towns, *Chemistry Education Research and Practice*, 2014, **15**, 501-515.
37. J. M. Deng and A. B. Flynn, *Chemistry Education Research and Practice*, 2021.
38. R. J. Marzano and D. J. Pickering, *Building academic vocabulary: Teacher's manual*, ERIC, 2005.
39. M. Kaddoura, *Educational Research Quarterly*, 2013, **36**, 3-24.
40. , 2021.
41. C. Chin and J. Osborne, *The journal of the learning sciences*, 2010, **19**, 230-284.
42. C. Chin and J. Osborne, *Journal of research in Science Teaching*, 2010, **47**, 883-908.
43. F. M. Watts and S. A. Finkenstaedt-Quinn, *Chemistry Education Research and Practice*, 2021.
44. D. Kuhn, *Educational Research Review*, 2009, **4**, 1-6.

45. J. Osborne, S. Erduran and S. Simon, *Journal of research in science teaching*, 2004, **41**, 994-1020.
46. E. M. Nussbaum, C. M. Kardash and S. E. Graham, *Journal of Educational Psychology*, 2005, **97**, 157.
47. C. S. Asterhan and B. B. Schwarz, *Cognitive science*, 2009, **33**, 374-400.
48. *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*, Stylus Publishing, Sterling, VA, 2019.
49. A. Moon, C. Stanford, R. Cole and M. Towns, *Journal of chemical education*, 2017, **94**, 829-836.

[Insert Figure X.1 here]

[Insert Table x.1 here]