A Study of Problem-Based and Discussion Prompts in Learning and Knowledge Retention in Organic Chemistry Workshop

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Abstract

This paper explores how student learning and knowledge retention, as measured by the production of correct answers on a quiz, is effected by the manner in which the learned material is originally presented, specifically focusing on problem solving versus discussion prompting presentations. Although both discussion capability and problem solving skills are essential to a conceptual and practical understanding of a topic, establishing a favorable ratio between each style would maximize student learning. The mechanism of ozonolysis was presented to students through either a prompt that promoted student discussion or one that promoted problem solving skills. Students were then presented with a quiz on the mechanism of ozonolysis and a survey designed to measure reported student prompt preference. Subsequent data analysis of prompts and quizzes showed that, given a problem prompt, students demonstrated better comprehension of the mechanism’s focused details, however given the discussion prompt, students demonstrated better global comprehension of the mechanism. Interestingly, survey results indicated a preference for problem prompts, without a demonstration of greater efficiency. We concluded that each prompt promotes greater student learning in the areas where the other prompt did not, and that neither prompt alone promoted greater overall student comprehension.

We propose that future research be done with larger sample sized to replicate our findings and to determine a favorable balance between each style of knowledge presentation. We hope that as soon as this favorable balance is found future workshops can be designed with this balance in mind to maximize student learning.
A Study of Problem-Based and Discussion Prompts in Knowledge Retention

Although the most important aspect of workshop is the students interacting and learning from each other, the prompts and questions presented to the students during workshop do have an effect on how well the students learn the material. Prompts that focus on discussion of a concept between students are necessary to provide an environment where student interaction is encouraged. Research by Smith and Wood (2009) show that students who discuss a concept with other students, even if none of them could previously answer a question based on that concept, show a higher understanding of the concept after discussion than before talking it over with other students. It is, however, important to present prompts that help students develop problem solving skills in the context of the subject that the workshop covers. The need for discussion to understand concepts and the need for developing problem solving skills, however presents a small discrepancy. We argued that a good discussion of a concept does not involve coming to a solution of a problem based on that concept, but instead focuses on how the concept applies to the field of study. However, one of Jonassen’s (1997) aspects of an ill-structured problem is one that has non-convergent solutions. While a well formulated prompt can have aspects of both problem solving and discussion, we decided to compare the effectiveness of a discussion oriented prompt (with no single solution) and a problem-based prompt (with a single convergent solution) to determine which type of prompt is leads to better learning.

This particular study was performed at the University of Rochester on students who attended an Organic Chemistry workshop. The Organic Chemistry course requires the students to master both understanding of many fundamental concepts and practical problem solving skills making it a good fit for our study. We decided to test whether discussion prompt of a synthesis reaction, ozonolysis in this study, would lead to better learning than a problem-based prompt in
organic chemistry workshop. We expected that students would achieve higher learning after completing problem based prompts because of the direct-approach nature of problem solving strategies.

Methods

At the beginning of Organic Chemistry workshop, students were distributed prompts on the mechanism of ozonolysis. One prompt was designed to promote the usage of student problem solving skills in order to learn the mechanism; four students completed this prompt. The other presented prompt was designed to promote student discussion of the mechanism, and to promote a cooperative strategy of learning the material; ten students completed this prompt. Students were allocated 10-15 minutes to complete prompt activity. The discussion prompt can be found in appendix A. The problem prompt can be found in appendix B.

Students were distributed a quiz on the mechanism of ozonolysis after the completion of the prompt and the Organic Chemistry Workshop. The quiz was designed to measure for student retention of information through three means. Presence of correct electron pushing arrows demonstrated an understanding of the mechanism. Presence of a correctly drawn intermediate demonstrated that patterns to form the intermediate were understood. Correctly drawn products demonstrated a global understanding of the ozonolysis reaction. A total of 14 students were quizzed. The distributed quiz can be found in appendix C.

After the quiz was completed, students were distributed a survey designed to measure student self-reported study methods. We believe that the manner in which a student prepared for an upcoming exam is indicative of a preference for either discussion or problem type prompts. The first two questions directly asked students for their preferences of problem or discussion based prompts. The third question asked students how well they thought reviewing lecture notes
would prepare them for an exam. We felt that review of lecture notes was indicative of activating memories of conceptual discussions held in lecture. The final question addressed the frequency in which students use previous year’s exams to prepare for upcoming exams. We felt that a preference for completing practice problems from previous year’s exams indicated a preference for problem based prompts. The survey can be found in appendix D.

Scratched notes on Prompts were analyzed for demonstration of successful student acquisition of material. Subsequent quizzes were analyzed for number of correct answers in respect to electron pushing, proposed intermediate, and proposed product to demonstrate successful student retention of material

Results

The students who answered the problem-based prompt showed a higher proficiency in understanding the mechanism of ozonolysis, showing correct arrow pushing diagrams and correct intermediates. Two out of the four students who completed the problem-based prompt showed the correct arrow-pushing mechanism on the quiz as opposed to three out of 10 students who completed the discussion styled prompt. Likewise, one out of the four students who completed the problem-based prompt showed the correct reaction intermediate on the quiz as opposed to none of the students who completed the discussion styled prompt showed the correct intermediate.

Students who answered discussion styled prompts showed a higher proficiency in obtaining the correct product of the reaction, but did not show the correct mechanism or intermediate steps. Three out of ten students who completed the discussion styled prompt showed the correct product on the quiz, while none of the students who completed the problem-based prompt were able to produce the correct product.
Students who completed the survey showed a greater preference for studying for test with practice problems as opposed to discussion with peers. Thirteen students completed the survey and they rated solving practice problems 4.8 (out of 5) in helpfulness on studying for exams as compared to discussion with other students, which was rated at 3.8 in helpfulness. Reviewing lecture notes was rated at 3.3 in helpfulness and solving problems from old exams was rated at 4.1.

**Discussion**

The results showed that the problem-based prompt led to a better understanding of the details of a reaction (mechanism, intermediates), but did not lead to the students finding the correct outcome of the reaction. The discussion styled prompt showed that students gained a better understanding of the outcome of the reaction, but they did not help the students understand the mechanism of the reaction. These results were surprising as they did not correspond with our prediction that the problem-based prompts would lead to a better overall understanding of the reaction when compared to the discussion styled prompts. These results also come despite the fact that, when surveyed, the students found solving problems was more helpful than discussing concepts with other students in learning and knowledge retention.

It is possible that the problem-based prompts led to correct mechanisms and intermediates, but not the correct product because the students who solved the problem-based prompt did not learn what to expect from an ozonolysis reaction. When solving the prompt, they simply had to write down the mechanism, intermediates, and product. The only discussion that went on was students with each other to see if they wrote down the correct solution. When the students completed the quiz, they may have remembered the mechanism and intermediates, but also could have forgotten how to identify the expected product from them.
The students who completed the discussion prompt were able to understand the outcome of ozonolysis better than the students who completed the problem-based prompts, even though none of the discussion students were able to produce the correct intermediate. We think that student discussion led to a better understanding of the outcome of the reaction because the students were asked to discuss strategies on how ozonolysis can be used to produce a desired result. Less emphasis was placed on the mechanism of the reaction during the discussion, while the students discussed what the outcome of ozonolysis was. We believe that this is the reason why students were able to produce the correct product on the quiz without always knowing the reaction mechanism.

Our findings show that both discussion and problem-based prompts have strengths and weaknesses that the other prompt does not possess. These findings, however, were obtained from a small sample size in a specific type of workshop. Further study is needed on a larger number of workshop students in order to produce more accurate results. Also, this study was only conducted on Organic Chemistry students, whom may possess traits that would act as a confounding variable.

Our study shows that both discussion and problem-based prompts have different strengths when it comes to learning a topic in organic chemistry. Problem-based prompts helped the students memorize the reaction mechanism and learn the details of ozonolysis. The discussion styled prompt, however, helped the students learn the big picture of the reaction and be able to recognize the products that are formed by ozonolysis. Therefore it can be concluded that a successful workshop would use a combination of both methods.
References


Figures

**Figure 1.** Students preferred problem solving rather than discussion when studying for organic chemistry exams.

**Figure 2.** Performance on the quiz.
Appendix A

Discussion Prompt:

Below is an incomplete mechanism for the ozonolysis reaction of an alkene.

Discuss with your workshop where the arrows for electron pushing should be placed in each step of the mechanism. You are not required to know the mechanism of the reduction of trioxolane to the carbonyls. Also, come to an agreement on the structure of the carbonyl and carbonyl oxide (note that the flip carbonyl step only changes the orientation of the carbonyl in space, it does not cause a structural change).

Finally, hypothesize with those around you how this process can be used to break a cyclic carbon chain (e.g. cyclohexane, cyclopentane).
Problem Prompt:

The reaction above follows the standard mechanism for ozonolysis. Show all of the steps for the mechanism in step one (use arrow pushing). Give the structure for the trioxolane (product A) and the carbonyls (products B and C).
Appendix C

Quiz:

Do not use your notes or discuss this problem with those around you. Simply write your answer in the space provided.

![Chemical structure](image)

Show the arrow pushing mechanism for all of the steps in 1 that lead to product A. Give the structure of products A and B.
Appendix D

Survey:

Answer the following questions on a scale of 1 to 5, with 1 being not helpful and 5 being very helpful. Feel free to elaborate in the space below the question.

1) How well do you think discussion with other students of a topic prepares you, as a student, for an examination on that topic? ______

2) How well do you think working on a problem set focused on a particular topic prepares you, as a student, for an examination on that topic? _____

3) In your experience, how well does reviewing through previous lecture notes prepare you, as a student, for an examination? ______

4) In your experience, how well does past years exams prepare you, as a student, for an examination? ______