CHEMCompete: An Organic Chemistry Card Game To Differentiate between Substitution and Elimination Reactions of Alkyl Halides

Kristin Gogal,† William Heuett,‡ and Deana Jaber*,†

Department of Biology and Physical Sciences† and the Department of Mathematics‡ Marymount University, Arlington, VA 22207

1. Why Use a Card Game for Organic Chemistry?

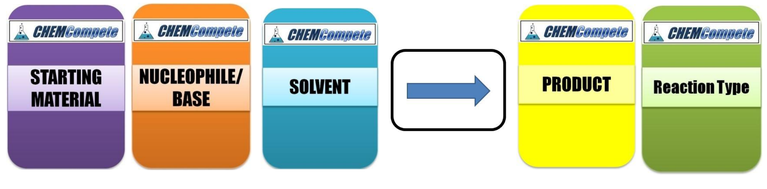
Gamification has been shown to impact the ability of learners to gain a new perspective through active engagement. It has been used as a teaching tool to promote desired learning behaviors and has been applied to diverse fields. Effective gamification has been shown to enhance learning in chemical education. Educational games that have been developed for organic chemistry can be divided into four categories: puzzle games, card games, board games, and electronic games. Incorporating pedagogical methodologies to engage students in interactive, enjoyable cooperative learning that promotes critical thinking is an emerging and supplemental method of instruction. Traditional chemistry education focuses on conveying chemistry knowledge via lectures and recitations. One of the main pitfalls for students in organic chemistry is rote memorization, which leads to a superficial understanding of concepts.

Differentiating between substitution (S_N1 and S_N2) and elimination (E1 and E2) reactions is a difficult concept for students of organic chemistry to grasp. These reactions are foundational for understanding many chemical reactions. It is crucial that students learn and understand these reactions, the mechanisms through which they occur, and their contributing factors.

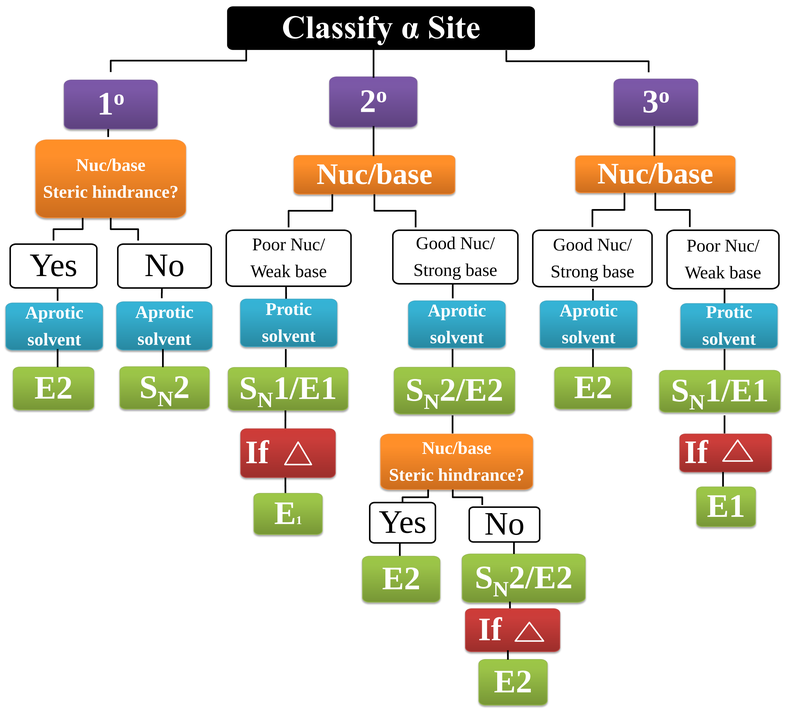
There have been multiple card games developed for organic chemistry concepts, however, there are no published records of card games specifically designed to help students differentiate between substitution and elimination reactions. We designed a new card game (*CHEMCompete*) for substitution and elimination reactions of alkyl halides. The goals of *CHEMCompete* are to provide the students with a study aid to (1) predict the product of the reaction and (2) classify the reaction as S_N1, S_N2, E1, E2 or a combination of four types of reactions.

2. The Cards

CHEMCompete is a card game that consists of a 96-card deck and can be played by 2-10 players. The 96 cards are distributed in six categories: starting material (18 cards), nucleophile/base (18 cards), solvent (17 cards), arrow (15 cards), product (10 cards), and reaction type (18 cards). The cards can be printed, preferably on cardstock, and cut out for use in the classroom. A flow chart depicting possible reaction sequences was designed and used while playing the card game.



3. The Flow Chart



4. Playing the Card Game

The game was played in groups of four players split into teams of two players each. Each player has four cards at all times; a starting material, nucleophile/base, solvent and reaction type card. At the start of the game the dealer deals one of each of these four card types from their respective stacks to each player. The arrow cards and product cards are in two respective draw piles that players can draw during the game. The cards are played in order. Teams alternate turns, with each playing one card per turn (either continuing a sequence already on the table, or beginning a new reaction). A maximum of three reaction sequences can be in progress at any time. Each team has the option to trade one card per turn; exchanging one card of the same type from the respective draw pile. The team that plays the reaction arrow has to play a product card and a reaction-type card simultaneously. This team has a chance to win the reaction if it correctly predicts the product and classifies the reaction. In order to win the reaction, the team also has to defend its reasoning to the other team (preferably by drawing the mechanism). If the other team catches a mistake in the opponent's defense, it can attempt to steal the reaction sequence by correcting the mistake. The team that wins a sequence must start a new sequence on its next turn. The game ends when a team completes five reaction sequences. Game duration varies but typical game length observed was 15-20 minutes.

5. Results

The 46 participants in the card game were students enrolled in an introductory organic chemistry course in the fall of 2015 and received two lectures on substitution and elimination reactions of alkyl halides delivered by one faculty member. Upon completion of these lectures, students attended one of three consecutive workshops to play the card game. There were 14-16 students in every workshop session. The workshops proceeded as follows:

Quiz scores on both the pre- and post-quizzes were analyzed. A box plot of the total quiz scores on both pre- and post-quizzes demonstrates a definite shift in average quiz scores from 3.53 to 7.37 (the maximum total score is 14).

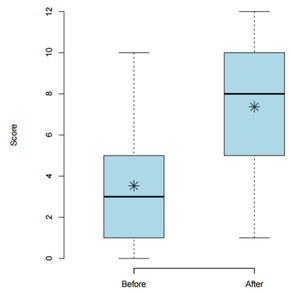


Figure 1. A box plot comparison of total quiz scores on pre- and post-quizzes. The asterisk indicates the average for both graphs.

Results showed that after the game was played, the average of all students' quiz scores increased by 108%. In addition, the effect was widespread among students who played the game with 91% seeing an improved score on their post-game quiz.

Survey statements were analyzed to identify the effect of the game on students' self-rated understanding of substitution and elimination reactions. An analysis of post-game statements found 96% of students agreed or strongly agreed that the card game "was a helpful study aid", 98% agreed it "made studying substitution and elimination reactions more fun" and 96% agreed they "would recommend the game to others".

6. References

Raker, R. J.; Holme, T. A Historical Analysis of the Curriculum of Organic Chemistry Using ACS Exams as Artifacts. *J. Chem. Educ.* **2013**, *90*, 1437-1442.

Bhattacharyya, G.; Bodner, G.M. "It Gets Me to the Product": How Students Propose Organic Mechanisms. *J. Chem. Educ*. **2005**, *82* (9), 1402-1407.

Carpenter, S. R. Incorporation of a Cooperative Learning Technique in Organic Chemistry. *J. Chem. Educ*. **2003**, *80* (3), 330-332.

Samide, M. J.; Wilson, A. M. Games, Games, Games; Playing to Engage with Chemistry Concepts. *Chem. Educ*. **2014**, *19*, 167-170.

Bhapkar, V. P. A note on the equivalence of two test criteria for hypotheses in categorical data. J. Am. Stat. Assoc. **1966**, 61 (313), 228−235.

djaber@marymunt.edu

We thank Marymount University and the Virginia Foundation for Independent Colleges for financial support of this work.