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Using Web-Based Video as an Assessment Tool for Student Performance in Organic Chemistry

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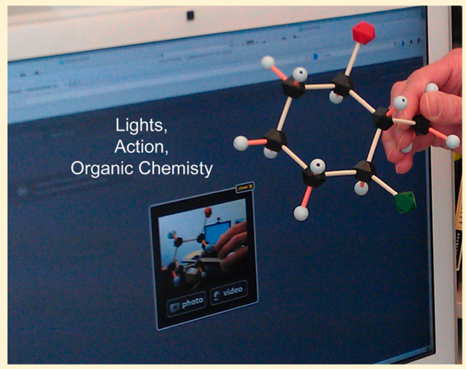
S Supporting Information

ABSTRACT: This article shows the potential for using video responses to specific questions as part of the assessment process in an organic chemistry class. These exercises have been used with a postbaccalaureate cohort of 40 students, learning in an online environment, over a period of four years. A second cohort of 25 second-year students taking the organic chemistry course onsite has been using these exercises over a period of three years. The questions in this exercise require the students to use a molecular model kit. The problems presented to the students involve standard concepts in organic chemistry relating to geometric issues with molecules or organic reactions. This method of assessment allows the instructor to see a student's higher-order thinking on a particular topic to a greater degree than is generally afforded with clicker questions. Students are acclimated to this new environment for assessment through practice exercises that are evaluated and critiqued, but not counted towards a grade. A transition to similar exercises follows that counts towards the students' grades. Constructive feedback to the students for their nongraded and graded responses, as well as the types of errors and misconceptions they display in their videos, are also described.



KEYWORDS: *Second-Year Undergraduate, Continuing Education, Organic Chemistry, Misconceptions/Discrepant Events, Testing/Assessment, Conformational Analysis, Enantiomers, Stereochemistry, Student-Centered Learning*

■ INTRODUCTION

From the times of Socrates or Protagoras, depending on the historical source,[1] students have gone through the process of learning by discussion, reading, and attending lectures with accompanied note taking. The quantity and the quality of the course content that students acquired have then been assessed in the form of in class exams and quizzes with the possible addition of a project assignment. In more recent times the lecture, where the instructor wrote on a blackboard (or white board), was supplanted with additional aids such as overheads or the occasional 35 mm slide from a carousel projector. As time has progressed, content delivery has been aided by use of PowerPoint slides, and some innovative chemistry instructors have also made well-produced recordings of chemical and biological concepts set to popular songs.[2,3] Most recently, Benedict and Pence have reported[4] students using cell phones to produce video content as a means of learning chemistry. While there have been gradual changes over time to the method by which content has been delivered to the students, there has been little movement in the methods used for student assessment. Yes, quizzes have moved from in-class to an online environment,[5] but they are still quizzes. There has been a lot of discussion in editorial articles[6−11] and the literature[12−16] about student assessment, but much of this has dealt with fine-tuning the wording in quiz or exam questions or curriculum content leading to exams. One different assessment method[17] that has been used is a student–teacher interview; however, this method, though different, does not appear to be common. Oral exams have also been explored as an assessment tool,[18] and a student portfolio, for a portion of the grade, has been reported at the high school level.[19] The individual with the most "out of the box" thinking in the realm of student assessment has been Zafra Lerman.[20−22] The students that she taught already possessed significant art, music, and dance skills in their range of abilities. Lerman blended the students' art skills as a way to demonstrate chemical concepts, and the resulting performances were used in assessing their chemistry knowledge.

The work described here is not as groundbreaking as Lerman's work;[20−22] however, we are attempting to use the technology available, along with the apparent skills the students already possess in this age of YouTube, in order to give graded oral responses to chemistry questions as an added alternative to written exam responses. The impetus for taking a slightly different approach to assessing student performance was, in part, because of the inception of a postbaccalaureate certificate in science program (at the Brandywine campus).[23] The students accepted into this program already have a degree in a nonscience area but wish to switch career paths and go to medical, dental, physician assistant, or nursing school. One of us (MB), an instructional design specialist became involved in the program development and decided that as part of the

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assessment process (because we were delivering much of the content online, with the exception of laboratories) that maybe we should also include some slightly different assessment techniques in addition to quizzes and exams, such as video assessment of student responses to specific questions.

In order to facilitate the video assessment, we needed to develop suitable questions that would mirror quiz and exam questions. In addition, the students would need to use readily available video techniques that were easy to use, in order to describe and explain their answers to designated organic chemistry problems that are posed to them. The questions used in the exercises would require the students to use a specific, cheap, readily available, molecular model kit to create structures that are used in their explanations. The students would need to use the same kits for consistency and the fact that many of the questions would show the students individual component parts that they would need to use in their explanation. The fact that YouTube is ubiquitous, and that the ease of use of video technology by students has already been noted,[4] made the project an interesting possibility.

The following gives a description of the students involved in the video quizzes, the model kit they were required to use, a few examples of the types of questions, and exercises posed to the students along with the video capture methods that have been employed over the past four years. In addition, we will describe some of the types of mistakes that our students made and how we use the video to quickly address student misperceptions with regards to chemistry content.

■ THE STUDENT COHORTS

The video capture method has now been used with two different cohorts of students. The initial group consisted of postbaccalaureate students (total 40 students) who already have a degree, and who are fulfilling the science requirements to gain admission to medical, dental, or veterinary school; these students are considered nontraditional students[23] that have used video capture responses to questions for four years. This cohort of students created the impetus to come up with a way to provide rapid feedback regarding concepts of organic chemistry principles. The students were studying the material at home and meeting with the instructors in an online environment for class discussion and lecture. This technique has since been expanded to a second cohort of undergraduate second year students, of traditional age, in a classroom environment. The traditional age group of students (total 25 students) has been subjected to the video capture responses for two years.

■ ASSESSMENT

Both cohorts of students have been graded for the clarity of their response with regards the chemistry content (by one of us, J.T.), and they are also graded by a communications professor (one of us, S.F.) for the overall quality of their video production. The students are given a grading rubric by both instructors indicating the type of chemistry, production, and content issues that each instructor is looking for in the student's presentation. The communication grading rubric and the chemistry grading rubric are provided in the Supporting Information. The types of issues addressed by the communications instructor are in regards to the use of "... errr," "ummhh", and "you know" during the presentation. It was decided early on to have both a chemistry score and a communications score so that the students could become adept at delivering a short, novel piece of information in a clear and concise manner. In today's world many students go out into the workforce and have to give presentations, and there was a desire to show the students that communication skills are valuable in the field of chemistry. The overall score for both the chemistry content and the communication quality of the video was no more than 10% of their overall course grade.

■ THE MOLECULAR MODEL KIT

Students were required to obtain the Maruzen molecular model kit number 1013A[24] (the details are provided in the Supporting Information). The Maruzen kit contains component parts that allow the students to build models with atoms that can yield any geometry discussed in a first or second-year chemistry course. In addition, the kit has the capacity to show molecules with a π bond using p orbital lobes as well as component parts that emulate a double bond. In addition, there are also component parts that allow students to show the position in space that lone electron pairs will occupy.

■ THE VIDEO COMPONENT

The two video capture tools that we have utilized with the students are Kaltura[25] and Voice Thread[26] (additional details are supplied in the Supporting Information). Two different video capture tools have been used over the past four years because these were available through Penn State's licensing agreements; these agreements have changed; hence, the product that we use has changed from Kaltura to Voice Thread. The two products have slightly different features, but none that greatly impact the ease or degree of difficulty of use experienced by the students. In addition, neither product affects the assessment process described herein. It should be noted that in the case of Kaltura and Voice Thread the video quality and voice quality has not been an issue. The students create the video using Voice Thread and post the URL to the discussion forum. The video is made public but only the instructor can see it until each student has posted their video. They are given a short demonstration in class on how to complete the aforementioned steps by the instructional design specialist (one of us, M.B.).

To begin the assessment, the students were given some nongraded exercises so they can familiarize themselves with the video capture tools and the chemistry kit itself. Some examples of the graded and nongraded exercises are shown in Table 1. The first nongraded exercise listed in Table 1 is actually part of a larger set of exercises to familiarize the student with the model kit. The Maruzen kit that is used (as with all the other Maruzen kits) has two types of black atoms: one atom, if placed as the central atom, leads to octahedral and trigonal bipyramidal geometries; the other leads to tetrahedral geometries. Even though this was pointed out to the students in the instructions, they needed to be led through this type of initial exercise to reinforce the point. Each exercise included a photo of the component parts that the student would need to use for that particular video. The component parts required, as an example, for video Exercises 2 and 3 (Table 1) are shown in Figure 1 and Figure 2, respectively.

The initial exercise given to students consisted of familiar topics, such as molecular geometries, stereochemistry, and reaction outcomes based on these. The geometry exercise was chosen because the students were already familiar with the

Table 1. Example Titles Used in Video Capture Exercises

	Exercise	Comment
1	Make an octahedral molecule with a *cis* geometry.	Ungraded exercise
2	Make a molecule that has a double bond with a *cis* geometry for the red atoms about the double bond.	The array of component atoms is displayed at the question site.
3	Make a molecule that has a double bond with a *trans* geometry (for the red atoms) with overlapping p orbitals forming a π interaction. Use the colored lobes provided to give: (i) a valence bond picture; and (ii) a molecular orbital view of the bonding within the molecule.	
4	Make a model of *cis*-1,4-cyclohexanediol in a chair conformation and answer the following questions: Show your model and explain why it is in the chair form. Explain why the geometry for the two OH groups is *cis*. Explain why, if the molecule goes into a boat conformation (and show it doing so in the video) that there is a possibility that the molecule may stay in this boat conformation even though it is not normally favored.	
5	Make a model of molecule *X* [(1*R*,2*R*,3*S*) 1-bromo-2-methyl-3-chlorocyclohexane]. You are to use the appropriate atoms and bonds provided in the kit: points will be deducted if you do not use the appropriate bonds and atoms of the correct geometry. Use a blue atom to represent chlorine and a red atom to represent bromine. You will see in the scheme presented below* that molecule *X*, when it undergoes E_2 elimination, should produce the Saytzeff (Zaitsev) products *A* (6-chloro-1-methylcyclohexene) and *B* (6-bromo-1-methylcyclohexene); however, this does not occur. Part 1: Explain why, using your model that an E_2 process does take place, but products *C* (4-chloro-3-methyl-1-cyclohexene) and *D* (4-bromo-3-methyl-1-cyclohexene) are formed instead of *A* and *B*. Part 2: Explain why *C* would be the major product and *D* would be the minor product.	*No reaction scheme is shown in this table. The reaction scheme given to students shows products and reactants using line notation structures.

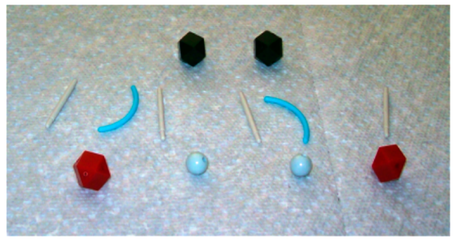

Figure 1. Component parts that are shown to the students for Exercise 2 shown in Table 1.

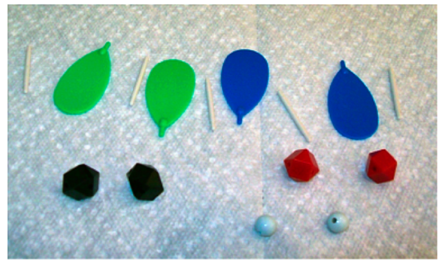

Figure 2. Component parts that are shown to the students for Exercise 3(i), shown in Table 1.

topic and they could focus more on the video production aspect of their response. The initial exercise was introduced at the beginning of the second week of class, and they were allowed 3 days to prepare their responses. All the exercises were posted in the discussion forum in ANGEL, and the students posted the URL for their video in the discussion forum. The discussion forum (in ANGEL) was configured to require students to post first. With this setting, students do not see anything in the discussion forum until they submit a post; this has yet to be a problem regarding any security concerns one might have. Further the use of the tracking feature in ANGEL can determine whether a student has been active on the site. In addition, it has been clear to date from the IP addresses that show up in ANGEL, for the generation and uploading of the video content, that all the students are completing these exercises at home. This is not unexpected with the postbacc cohort as they are spread over a large geographical area during the week. Since Brandywine is a commuting campus within the Penn State system, the cohort of residential instruction students are also using their home computers to generate the video content.

After the introductory practice exercise has been completed and feedback given to the students, each additional organic chemistry video exercise was introduced as the related topic was being discussed in class. Students were given no more than 72 h to complete the exercise. Each year there have been minor variations to the questions to prevent students from copying previously posted versions online.

■ THE VIDEO RESULTS

Although this video capture technique requires an additional time commitment on the part of the instructor to review the videos, it provides a relatively quick way of determining a student's higher order thinking processes. In addition, it allows them to see what they do not know or have misconstrued concerning any range of organic chemistry topics that have been covered. Clicker questions give a snapshot of how the class perceives a particular question, but they give no insight into the students' thought processes. In fact one has to go, after class, and look at the i> grader file created from the clicker responses to see how each student has answered each question. The video capture idea was developed, in part, because polling students in an online class is slightly more cumbersome than using clickers in class. Further, there is a response privacy concern with polling techniques used in the online environment. The length of time it takes to go back and look, in detail, at the attendance and question analysis information in i> grader from a week's worth of classes for a course is marginally quicker than looking at ten 2 min videos.

As shown in Table 1, the degree of difficulty to the question type in each video exercise increases as the semester progresses. The list of exercises in Table 1 is not exhaustive, and the list of mistakes made by (PSU Brandywine) students and described here are also not exhaustive. This purpose of this manuscript is designed to give a flavor for the technique being described. Anyone wishing to adopt this technique will probably have their own ideas on which questions that they wish to adopt.

Descriptions of common student errors (made by PSU Brandywine students) that are seen in the videos follow, and the actual videos are available as Supporting Information.

In the exercises concerning geometries (Exercise 2) students show the correct *cis* structure but often omit the concept of a geometric plane in their presentation. This was the case even though the terminology had already been used frequently, to all of the students during the class discussions, when feedback was given in the ungraded exercise, Exercise 1.

In Exercise 3(i), the students again had the correct structure but they did not talk about the two p orbitals overlapping to form the π-bond in the valence bond picture. When it came to talking about the molecular orbital approach for the π-system, a few students did not realize the significance of matching up the same colored lobes adjacent to each other to give a representation of the bonding molecular orbital and then having a nodal plane with dissimilar colors adjacent to each other for the antibonding molecular orbital. A screen capture of a student correctly responding to this exercise is shown in Figure 3A. A screen capture of a student error for the same exercise and one capturing a student who continued to misunderstand geometric requirements for p-orbital lobes and atom positions for an alkene is shown in Figure 3B.

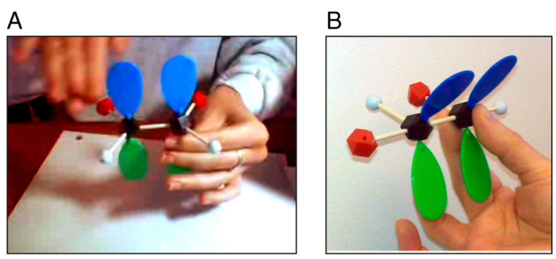

Figure 3. A: A screen capture of a student responding correctly to question Ex. 3(i) (for the *cis* configuration), in Table 1; B: A screen capture of a student responding incorrectly to question Ex. 3(i), (for the *trans* configuration), in Table 1.

In Exercise 4, nomenclature misconceptions became apparent, let alone a chair conformation. There was a whole array of incorrect structures given. The mistakes ranged from students giving a *trans* configuration to others who placed the hydroxy groups 1,3 to each other, to one student who showed a dihydroxymethylcyclopentane, which had a total of six carbons but clearly was not a cyclohexane; one of the biggest mistakes seen to date. Because of this major error, the student was unable to make sense of the rest of the exercise. A rapid intervention made a big difference in future exercises and exam performance for this student. Shown in Figure 4 are two screen captures of a student who gave a correct response in this exercise and showed the intramolecular hydrogen bonding.

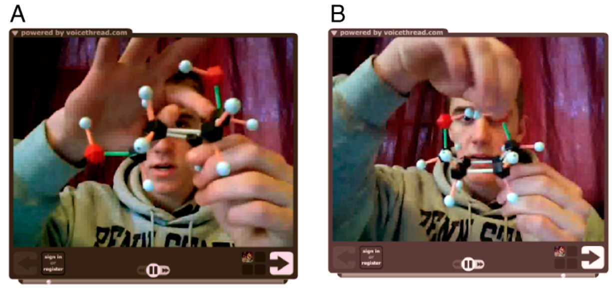

Figure 4. A Voice Thread screen capture of a student responding to Exercise 4, Table 1.

In Exercise 5 (Table 1) the problem was multifaceted involving these concepts: nomenclature; chirality; elimination, specifically E_2; Saytzeff (Zaitsev) versus Hoffman elimination. Some students captured all areas well, while some students struggled in one part of the exercise or another, such as the *anti*-periplanar geometry required for an E_2 process. Again, it was possible to go over the issues with the students who struggled with the concepts, and they showed improvements when it came to answering similar questions on exams.

■ CONCLUSION

The video capture method of having students respond to questions was initially developed for a new (at the time) online version of the standard Penn State Chemistry 210/212 organic chemistry course sequences. The concept was also developed as an alternative means to assessing student performance by allowing them to display their thinking patterns to the instructor in a manner not afforded using a clicker type approach. The method also afforded a quick intervention method for a cohort of students who were learning organic chemistry at an accelerated pace. The method was extended to a second cohort of students who were taking the organic classes (Chem. 210/212) during a regular semester, in class, environment. This report is purely qualitative and gives an overview of these observations made by the authors with regards to the utilization and application of a new technology. In addition, it was the goal of the authors to explore new methods of assessing student performance in the application of this new technology. At this point in time, approximately 65 students have completed the Kaltura or Voice Thread video capture exercises. The commercial video capture tools worked well for these exercises with minimal technical issues for the students and the instructors. The students were more at ease in their video presentations than has been previously observed when students are asked to perform in class presentations. Anecdotal feedback from students showed that a significant number of students enjoyed completing the exercises and found it to be a useful learning exercise. They had a greater awareness of the value of molecular model kits than had previously been observed with classes prior to using this technique. These exercises allowed the students to hone their presentation skills in a subject area that they were also in the process of learning. The method further allowed for rapid electronic feedback by the professors to the students regarding concepts that they had not fully grasped, and which was clearly evident in some of their responses. The videos were limited to a 2 min explanation; the vast majority of the students complied. This 2 min production limitation made reviewing the videos a manageable exercise on the part of the instructors. It was realized that, for this to be a successful learning experience for the students, a consistent kit that matched the question types being asked in the exercises was required; hence the choice of one model kit for all the students. Other, more expensive kits with more components would add more possibilities for questions and exercises, but this would also increase the expense to the students. The types of errors that were seen in the video responses were more egregious for the traditional age students than the postbaccalaureate group. We assume that this was because the postbaccalaureate students' study skills were better than the traditional students, as the postbaccalaureate group had more clearly defined career goals in their sights and had already obtained a degree.

The use of Voice Thread has now been extended (once, so far) in its use for a previously described classroom exercise.[27] The use of Voice Thread in this environment is still under review.

Overall, this method of assessment appears to be a viable, additional tool for grading student performance. Its application allows for cross-discipline collaboration (Chemistry and Communications), and anecdotal feedback indicates that the students appear to enjoy answering organic chemistry problems orally via video capture. Finally, the biggest plus to the video capture technology is that the technology is being used to enhance instructor−student interactions. The technology is not removing instructor-student interactions as is the case where students are doing homework using Web Assign,[28] ALEKS,[29] or OWL.[30]

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Grading rubrics used by the chemistry instructor; Grading rubrics used by the communications instructor; Sample videos. This material is available via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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