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Effectiveness of Student-Generated Video as a Teaching Tool for an Instrumental Technique in the Organic Chemistry Laboratory

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ABSTRACT: Multimedia instruction has been shown to serve as an effective learning aid for chemistry students. In this study, the viability of student-generated video instruction for organic chemistry laboratory techniques and procedure was examined and its effectiveness compared to instruction provided by a teaching assistant (TA) was evaluated. After providing selected lab sections with either video or TA lab instruction, student participants were given an assessment to evaluate the effectiveness of each presentation. Videos were found to prepare students for lab more effectively, with an average of 17% more students answering questions correctly after watching the video than after receiving TA instruction. Additionally, according to direct observations, students were 37% less likely to require TA assistance during the lab when presented with video instruction. By providing students with short and concise student-generated video instructions, students in the observed courses were able to be more independent throughout the lab and perform better than students who had received TA instruction alone.

KEYWORDS: *Second-Year Undergraduate, Organic Chemistry, Collaborative/Cooperative Learning, Internet/Web-Based Learning, Multimedia-Based Learning, Instrumental Methods, Laboratory Equipment/Apparatus, Student-Centered Learning, TA Training/Orientation, Computer-Based Learning*

Instructional videos are widely used as a teaching tool in the organic chemistry classroom; although in use for many years, videos are rapidly growing in popularity for content provision and assessment due to the widespread use of technology.[1−3] Many benefits may be realized by providing students with instructional videos. With the ability to pause, speed up and slow down, and repeat portions of a video, students are able to learn at a comfortable pace and may revisit the material on demand when needed.[4,5] This may be especially helpful for students with language challenges. Multimedia laboratory instruction has generally been found to increase student's skill while decreasing the time spent learning the skill.[6]

Moreover, using videos to supplement classroom learning more closely reflects and acknowledges the dramatically different learning style of the current generation of students.[5] Modern day students have remarkable information and communication technology skills. It would, then, seem obvious to leverage this developed skill in the classroom for educational benefit. Not only can students serve as an audience for multimedia content but they may prove to be capable of producing it as well.

Most of the reported uses of video for chemistry-related lab instruction in the literature focus on the faculty development of prelab content,[1,7−9] which is undoubtedly useful for student preparation but does not address the material from a student perspective. The goal of this study was to allow undergraduate students to generate video content that could be made available to other students as a means of supplemental lab instruction and to evaluate the usefulness of this peer-to-peer information distribution model.[10,11]

■ PROJECT DESCRIPTION

Upon reviewing relevant laboratory instructional videos already available online, a group of four undergraduate student volunteers who had previously completed the first semester organic chemistry lab course (CH222) conducted a social media survey via Facebook and Twitter. Based on the survey responses, it was determined that many of the videos available on YouTube were considered too lengthy. The available videos often contained several minutes of lecture before demonstrating

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the experimental procedure, or drew out the process over the course of a real-time video. Thus, the group of undergraduate student volunteers, under the guidance of a faculty member, set out to create a series of concise laboratory instructional videos that were tailored to the students at North Carolina State University, which provided accurate, useful, and readily available information to review lab techniques in a short amount of time. Decreasing the amount of time it took to review the content was expected to increase the likelihood that students would engage with the material, and conveying the material in video format was expected to reduce students' reluctance to study it.[5,12] Additionally, these videos could provide uniform access to information across very large programs (over 3,000 students a year between first and second semester organic chemistry laboratories), mitigating any discrepancies between teaching assistant (TA) instruction in laboratories.[12]

Laboratory equipment was transformed into smart objects with 2D barcode, or QR code, links to the instructional videos, evolving the laboratory space to reflect changes in the learning style of modern day students. These QR codes have been shown to make course material more accessible for students and have been used to help students visualize problems in class.[13] By placing QR code links to instructional videos on laboratory equipment students can have easy and instant access to information at the pivotal moment during lab when questions arise.[12]

Over the course of the summers of 2013 and 2014, the group developed a series of student-created short films demonstrating laboratory techniques for the first semester organic chemistry lab experiments and tested some of them to determine whether these videos could be considered as comparable to the lab presentations offered by TAs. The videos contained voiceovers, instructional slides, simple video effects, on-screen callouts, and optional closed captioning and were made publicly available on YouTube, a widely accessible platform.[14] The video effects consisted mainly of time lapses, which were used to condense lengthy procedures into a concise explanation in an attempt to capture and maintain student attention for the entire duration of the video. On-screen callouts are text displays which label items mentioned in the voiceovers, such as identifying key parts of lab equipment or detailed steps to use software, and were found in a pilot study conducted by the group to increase student understanding of experimental procedure.

■ METHODS

To create these instructional videos, student volunteers put together multimedia presentations including film, voiceover, and PowerPoint, using Camtasia 8.4 video editing software (TechSmith) to assemble the content. Student volunteers (science and engineering majors) that had completed the first semester organic chemistry laboratory course within the past two years were invited to write the voiceover scripts, which served as the backbone of the instructional video, under the supervision of a faculty member familiar with the material. The students were able to easily recall what was helpful for them when performing the lab experiments and facilitated a community learning experience by explaining things in simple terms and focusing on the technique being described.[15] Some student volunteers were not science majors, had not taken the lab, and were mainly involved in technical production aspects as well as video evaluation.

This study examines the data collected for the first laboratory experiment in first semester organic chemistry lab, infrared spectroscopy (IR). Prior to the experiment, a panel of six experienced graduate TAs was asked to do a focus group and provide feedback on the IR instructional video. The video was revised to incorporate the TA feedback before being released to the students. The video is 2 min long, is available on YouTube,[16] and is representative of the group of videos produced so far. The video opens with a brief description of the use of infrared spectroscopy and continues on to demonstrate step by step how to take the IR spectrum of a liquid sample using the instrumentation available in our laboratories (M4000-E, Midac Corporation). There are also screen captures to show the appropriate sequence of commands for the operation of the software (Essential FT/IR, Spectronic Camspec Ltd.), highlighted on screen. The presenter on the video is a student, and the video is narrated by two student voices, alternatively, one male and one female. On-screen callouts describe each required step. A link to this video is available as a QR code on the IR spectrometers in the laboratory, and it is also embedded in the lab e-manuals.

Data were collected across 5 different lab sections with a total enrollment of 71 students. Participation was voluntary, and all enrolled students opted to participate in the study. Two treatment groups were selected: one group received instruction by video, delivered to each computer station in the lab and thus available to all the students (3 sections, 41 students), and the other group was given a presentation by the lab TA (2 sections, 30 students, same TA for both sections). The TA in the control sections was trained at the beginning of the academic year, and for this experiment had been asked to present the students with the relevant information required to successfully take an IR spectrum, including the use of the required software.

All students then took an anonymous pre-experiment questionnaire to determine their preparedness for the experiment. The questionnaire consisted of the following eight questions:

1. Do you feel prepared to take an infrared spectrum?
2. Do you understand each step of the procedure?
3. Why is it important to run a background IR?
4. What does an IR spectrometer do? Why is it important?
5. Handling salt plates requires the use of what safety equipment?
6. Why is the above safety requirement important?
7. What software is used in this experiment?
8. Select the correct set of commands for operating the IR software.

The first two questions were designed to assess how confident students were in their ability to carry out the experiment, and required a yes/no answer. The rest of the questions related to the experimental procedure. Students were given 15 min after watching the video or the TA presentation but before starting the lab to complete the questionnaires. All the students observed completed the questionnaire during this time.

Additionally, two observers assessed student performance throughout each lab, recording the number, content, and complexity of questions asked during the experiment. Lab participants were assigned color-coded tags to facilitate the observation and to maintain anonymity. Once the lab observation was concluded, the level of assistance required by each individual student was ranked according to the number

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and type of questions (directly related to the video/TA instructions) that were directed at the TA during the lab period according to the following rubric:

- Extensive assistance: A student was considered to need extensive assistance when he/she asked two or more questions that required a lengthy explanation by the TA, or when they asked for extensive reassurance or help from the TA or other students in using the instrumentation.
- Some assistance: Students were ranked as requiring some assistance when they asked one question that required a lengthy explanation by the TA, or when they asked for brief reassurance from the TA or other students in using the instrumentation.
- No assistance: Students were considered to need no assistance when they were able to take an IR spectrum without asking for help from the TA or other students.

After collecting and organizing the data, Stata (StataCorp LP), a statistical analysis software package, was used to calculate the binomial mean and standard error. These binomial statistics were calculated for two data sets, the responses for students who received video instruction and the responses for students who received TA instruction, to compare the effectiveness of each type of instruction.

The QR codes placed on various laboratory equipment were obtained from an online QR code generator (QRStuff.com). A link to the YouTube video was submitted on the Web site, and a QR code was automatically generated. These codes were then printed onto stickers, which were placed on the laboratory equipment. Links to the videos were also made available in the e-book provided for the laboratory course and the course Web site.

RESULTS

A summary of the pre-experiment questionnaire results is displayed below as Figure 1. Students who watched the video

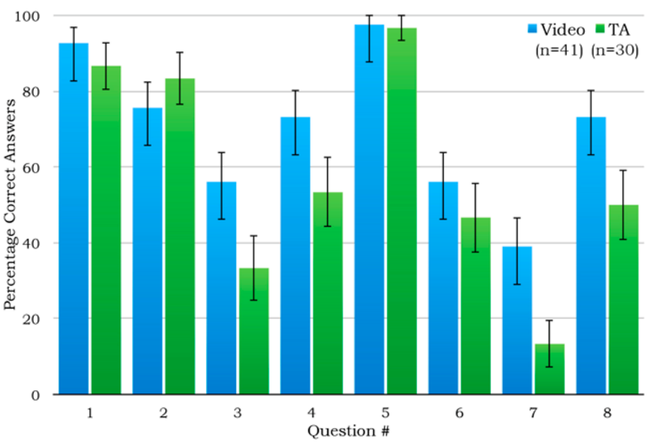

Figure 1. Results of the pre-experiment questionnaire.

prior to the experiment felt well prepared, confident in their ability to take an infrared spectrum. However, it should be noted that the figure shows that more students who received TA instruction felt confident in their understanding of the laboratory procedure than students who received video instruction. It is possible that students believed TA instruction to be superior to video and responded to the pre-experiment questionnaire revealing this subconscious bias. When asked specific questions about the experimental procedure, students who received video instruction performed 17% better on average than students who received laboratory instruction from a TA presentation. Furthermore, students who received video instruction were 23% more likely to remember the correct set of commands explained in the laboratory procedure. This is likely the most important question, as it determines whether or not students will be able to perform the required task independently. Overall, we observed a trend that video instruction yielded better student performance. These results confirm Burewicz and Miranowic's findings that multimedia lab instruction increased a student's skill compared to traditional means of instruction.[6] Comments received as part of the course evaluations indicate that some students were surprised at how helpful they found the short lab videos, and that they used them again when reviewing for the final lab quiz.

During the lab, it was observed that students who were shown the video were also more independent, requiring less TA assistance as shown in Figure 2. Moreover, these students were

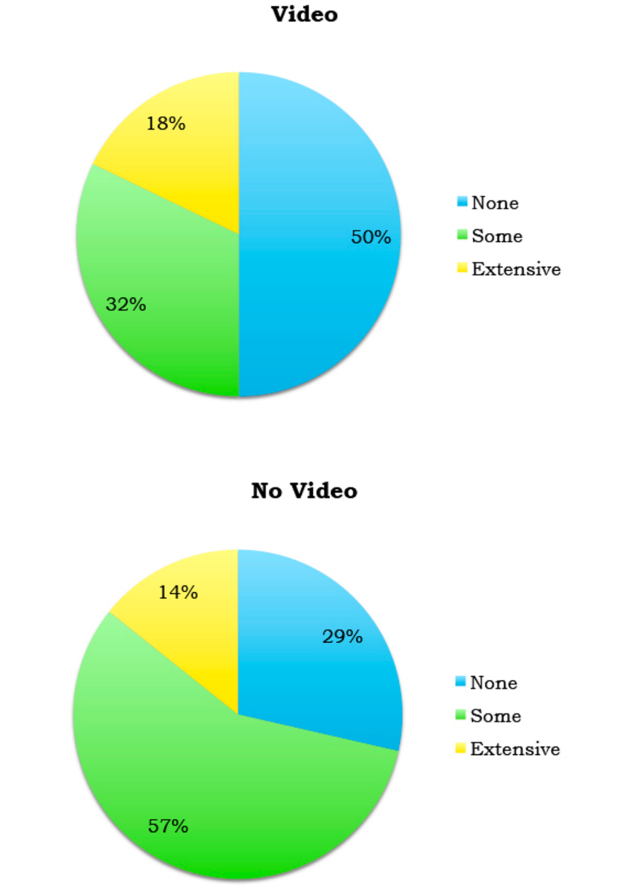

Figure 2. Distribution of students who required TA assistance during the lab period.

23% more likely to remember the correct set of commands for using the lab software as shown in Figure 1. This is significant because while the procedure for this experiment did not have any associated safety hazards, many organic chemistry experiments do. Thus, by use of multimedia instruction for experimental procedure, we can increase the level of student understanding and possibly reduce the number of laboratory accidents.

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From Figure 2, it is clear that students who did not receive video instruction generally required more TA assistance throughout the experiment. Although the percentage of students that required extensive assistance is slightly higher for the video group (18% vs 14% for the group that received TA instruction), the difference between the two is not statistically significant. It appears as if the video instruction largely benefitted those who required some assistance, allowing a much higher percentage of them to be independent. Likely, these students were able to revisit the video to find answers to simple questions, and some students did so using the lab computers as well as their smartphones as reported by the observers. The percentage of students that required no assistance was also greater for the video sections. Overall, students were 37% less likely to require TA assistance throughout the lab when presented with video instruction. This allows the TA to spend more time with those who are struggling and require extensive assistance; video instruction alone does not appear to significantly benefit these students. By allowing a larger portion of the students to perform the lab autonomously, the TA can identify those students who are struggling and provide extensive assistance to these individuals.

In this work students were empowered to generate a peer-to-peer communication tool that addressed the needs of the students enrolled in the organic laboratories in subsequent semesters. The videos generated in this manner may not work for other students in other universities, but the idea can be implemented anywhere, with low cost and measurable impacts. Moreover, there are reasonable concerns by undergraduate students about the quality of education from non-native English-speaking teaching assistants.[17] By providing students with multimedia instruction locally created or reviewed by native English-speaking students, these fears may be effectively quelled. Thus, all students will have access to homogeneous presentations regardless of a TA's language ability.

Students taking the organic laboratories are encouraged to provide feedback on their video user experience using the communication tools available in the course Web site. Since the videos are open to any YouTube user, comments on YouTube have been disabled but an e-mail address is provided for feedback.

CONCLUSION

Video instruction seems to be a promising tool to help students prepare for lab in a timely manner while providing uniform access to information; the literature reports many benefits of multimedia instruction. Upon reviewing relevant existing content, a group of undergraduate students at NC State University supervised by a faculty member set out to create a set of videos using the existing lab instrumentation and tested whether student-generated video instruction could be compared to TA instruction.

The videos that were shown were created by the students' peers, individuals with a student's perspective on the lab rather than an instructor's perspective. These videos were made publicly available on YouTube, accessible to students at their convenience. Students were able to replay hard to grasp topics or revisit forgotten concepts, learning at a self-set pace. This was found to benefit students who would normally require some assistance during the lab, as they now had a resource to visit for simple questions.

The video tested in this study was found both to effectively prepare students for the target lab and to be more effective than equivalent TA instruction. An average of 17% more students correctly answered questions about the laboratory procedure when exposed to the video as compared to the TA lecture, according to the results of the pre-experiment questionnaire summarized in Figure 1. Results from the lab observations show that while the video instruction does not benefit all students, it allows most students to become more independent throughout the lab (Figure 2), allowing TAs to dedicate more time to struggling students. Ultimately, video instruction was found to both increase student understanding of the experiment and student independence during the lab. Moreover, using this form of information distribution, all students have access to the same video instruction, mitigating any variance in language and teaching abilities across the various TAs who assist in the organic chemistry laboratories and providing uniform access to the material for all students. The use of an integrated approach combines the strengths of all available presentation opportunities. Students can access written instructions in the lab e-books with embedded links to the video content. TAs are trained and encouraged to offer a lab briefing before each lab, and QR codes are provided in the lab environment to make sure that videos can be accessed as the need arises.

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Notes

The authors declare no competing financial interest.

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