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Videotaping Experiments in an Analytical Chemistry Laboratory Course at Pace University

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Instructional videos for laboratory experiments performed in an analytical chemistry course were developed to show undergraduate students enrolled in the course how to conduct experiments. Students watched the videos before coming to the laboratory class. The effectiveness of using these videos was evaluated via a postlaboratory survey. The overall response to these videos was positive, with students reporting that the videos helped them to prepare beforehand and to understand the concepts covered in the experiment. The shortened discussion time at the beginning of class resulted in more laboratory time for the students to focus on performing the experiment and for the instructors to supervise, answer questions, make corrections to laboratory techniques, and ensure that the experiment is conducted in a safe manner.

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Introduction

The laboratory component of a course plays an important role in science education, particularly chemistry. The main purpose of this activity is to reinforce the core concepts discussed in lectures through performance of the experiment. The laboratory setting provides a way to present material in a format different from the lecture and to expose the students to new skills.[1] Typically, the laboratory component consists of a prelaboratory exercise/assignment, a laboratory lecture, and then conducting the experiment by following the written procedure in a laboratory manual. The laboratory activity is widely characterized as an essential part of the students' education in the chemical sciences, as this teaching component is often the only opportunity for students to gain practical skills.[2] Observational, problem-solving, inferential, technical (manipulative), and even social skills are usually developed during laboratory work. In addition, this component also gives students the chance to build their confidence, stimulate their interest in science, and develop positive attitudes toward the subject matter, all of which are indispensable for student success and course retention.[3]

However, the success of gaining these skills from laboratory work depends mostly on student participation. There is evidence that students are able to complete their laboratory work without acquiring these beneficial skills. One reason these skills might not be achieved is the cognitive overload that students usually encounter in a laboratory class. Among the sources of cognitive overload in a typical science laboratory class are the following: difficulty in following a detailed laboratory manual or verbal instructions, presentation of unfamiliar materials or equipment, unfamiliarity with the theoretical background, and inefficient time management.[4] One way to minimize this problem is to conduct a prelaboratory activity. This activity will allow students to collapse the information that they need to learn into smaller pieces, thus reducing the amount of new material that they will need to learn during the laboratory class and allowing the students to better absorb any new information discussed during the class. In this way, completing the prelaboratory activity will help to reduce cognitive overload and will enable deeper engagement with the material. A previous study has reported that a "prepared mind" will be more likely to separate important experimental observations from extraneous "noise" caused by the preoccupation with technical issues. However, to be successful, the prelaboratory activity should be required or grade mandated, as students will not perform the activity to prepare for the laboratory.[5]

Among the prelaboratory activities that have been proposed to reduce cognitive overload is the development of instructional videos. The use of videos in the educational context continues to gain popularity. Several studies have reported using instructional videos as a prelaboratory activity to prepare students for the laboratory class. Meador et al. suggest that new interventions that employ online prelaboratory videos hold significant potential for improving student performance in the general chemistry laboratory.[6] Another study found that videos helped to prepare students for the laboratory more effectively, with an average of 17% more students answering questions correctly after watching the video than after receiving instruction from a teaching assistant (TA).[7] Lastly, results from a study on videos that TAs could use at the start of the laboratory period showed that students in the treatment group had a greater learning experience and required less time to complete the experiments.[8]

In this chapter, we discuss how we developed instructional videos for students to watch prior to completing experiments conducted in an analytical chemistry laboratory course and how we determined the effectiveness of these videotaped experiments by surveying students enrolled in the course.

Course Content

The Department of Chemistry and Physical Sciences at Pace University offers an analytical chemistry course (CHE 221) to students majoring in chemistry, biochemistry, and forensic science. This one-semester course is called Analytical Methods and Techniques and is offered every fall semester. The course presents an integrated view of the theories and methods that can be employed in solving a variety of real problems in chemical analysis. The problem-oriented role of chemical analysis is emphasized throughout the student's experience. The course meets weekly for a three-hour lecture and for another three-hour laboratory component. The laboratory portion is included to teach students basic analytical methods and techniques that will enhance their skills in data gathering and conducting experiments. The laboratory component comprises 12 experiments (Table 1) that are performed throughout the semester, with the following student learning objectives:

1. Perform classical chemical analysis (qualitative and quantitative gravimetric and volumetric analysis) safely and accurately.
2. Perform qualitative and quantitative instrumental analysis safely and accurately.
3. Describe the theory and concepts underlining classical and instrumental chemical analysis correctly.

4. Maintain a laboratory notebook to record data while conducting experiments.
5. Communicate experimental findings concisely in a written laboratory report.
6. Plan, implement, and analyze the solution of a chemical problem.

Table 1. List of Laboratory Experiments in CHE 221

Experiment	*Laboratory experiment*
1	Tools of the trade
2	Introducing graphing techniques
3	Statistical evaluation of acid-base indicators
4	Determination of sodium by ion exchange
5	Stoichiometry: Analysis of zinc tablets
6	Analysis of a bicarbonate/carbonate mixture
7	Analysis of natural waters: EDTA titrations
8	Spectrophotometric determination of iron in dietary tablets and in an unknown
9	Spectrophotometric determination of nitrite
10	Analysis of natural waters using atomic absorption
11	Potentiometric determination of iron with dichromate
12	Determination of fluoride using an ion-selective electrode

Video Preparation and Survey Question

In the summer of 2013, Pace University funded the development of instructional videos to be used in the CHE 221 laboratory class. As a result, instructional videos for 10 experiments were prepared with the aid of two student assistants. Videos for Experiments 2 and 10 were not included, since Experiment 2 deals with the use of Microsoft Excel for graphing data and Experiment 10 employs the use of the atomic absorption spectroscopy instrument. A video for Experiment 10 was later developed in 2015. The lengths of the videos range from 4 to 10 min and focus on the procedure and equipment, technique to be used, and in the case of experiments employing titration, the change in color observed at the end point. The same videos were used throughout the course of this study and were not changed.

These videos were made available on Blackboard throughout the semester. Students enrolled in the course were required to watch the appropriate video before each laboratory class. This could be done by viewing the video directly on Blackboard or by downloading the video and watching it on their own time. The students were quizzed (quizzes constituted 10% of the overall laboratory grade) at the start of each laboratory session to encourage them to watch the videos.

The effectiveness of the videotaped experiments was determined by administering a survey by the end of the semester. For the inaugural year (2013) when two instructors team-taught the course (one during the first half of the semester and the other one during the second half), surveys were conducted both in the middle of the semester (after the first six experiments were completed) and at the end of the semester (after the last six experiments).

The survey consisted of 22 questions distributed as follows:

- Ten dichotomous (Yes or No) questions were aimed at assessing whether or not the students watched the videos as assigned.
- One open-ended question allowed students to report, if necessary, the reason they did not watch the videos.
- Six Likert-scale statements (1 = strongly disagree to 5 = strongly agree) were aimed at measuring the impact of the video on student preparation:
    1. The videos were helpful to me.
    2. The videos prepared me for the lab.
    3. I watched the video more than once.
    4. The videos helped me to understand the experimental protocol.
    5. After watching the video I felt that I did not need to read the protocol.
    6. The video helped me with report writing.
- The last five questions were open-ended questions that measured the students' reasons, motivations, and opinions about the learning resource (the videos):
    1. When before the lab would you watch the video (e.g., a few days before, the day before, on the day, a few minutes before, after the lab)?
    2. How many times would you watch each video, in general?
    3. Experiments 2 and 10 did not have a video. Would you have preferred one? Please explain.
    4. Would it make a difference to you if we did not have the videos?
    5. Are there any comments that you would like to make concerning the videos (or the lab in general)?

Survey Results

From fall 2013 to fall 2018, 103 students registered for the CHE 221 course with the class ranging from 10 to 26 students per semester. Out of this total enrollment, 94 students (91%) participated in the survey. The breakdown of the number of students who participated throughout the period is shown in Table 2. There are only two instances (fall 2014 and fall 2018) where 100% of those registered participated in the surveys. The main reason for nonparticipation of students is that they were absent when the survey was conducted. The survey was usually conducted within the last two weeks of the semester in lecture class after the last experiments in the laboratory class had been performed. In terms of the number of students who participated in the survey, 94 students and 91% participation of students is a somewhat large number of participants compared to those reported in the literature. In a study conducted on the use of instructional videos as a teaching tool in laboratory curricula at Simon Fraser University, only 11 out of 64 students enrolled in the analytical chemistry laboratory course completed the survey.[1] Studies performed at Marist College on the use of a presentation software (Prezi) that includes video clips to flip an analytical chemistry course and the inclusion of a forensic science problem-solving activity into an analytical chemistry laboratory course involved 24 and 11 respondents, respectively.[9,10] A study on the effectiveness of a student-generated video as a teaching tool in an organic chemistry laboratory involved 71 students, of which 41 students received instruction by video while the remaining 30 students were given a presentation by the TA.[7] Lastly, another study examining the use of video-based demonstrations to prepare students for an organic chemistry laboratory yielded data from an average of 82 students in the treatment group and 56 students in the control group (out of 172 enrolled students).[8]

Table 2. Number of Students Enrolled in the Course and Number of Students Who Participated in the Survey

Year	*Enrollment*	*Participated*	*% Participation*
Fall 2013	11	9	82
Fall 2014	15	15	100
Fall 2015	26	24	77
Fall 2016	21	18	86
Fall 2017	20	18	90
Fall 2018	10	10	100

Answers to the dichotomous questions along with the open-ended questions are summarized in Figure 1 for the different years. Students from fall 2015 and fall 2018 watched all videos, while in other periods some students missed watching one or two videos throughout the semester. There were three common reasons given by students as to why they failed to watch the video. The most common one was due to technical difficulties in accessing the videos. The other reasons reported were that the student forgot to watch the video or did not have time to watch it. The lowest percentage of students who watched the video occurred during fall 2013, when only two out of three students watched Experiment 5. Experiments 5 and 6 are usually performed during the middle of the semester when students are engaged in taking midterm exams in other courses.

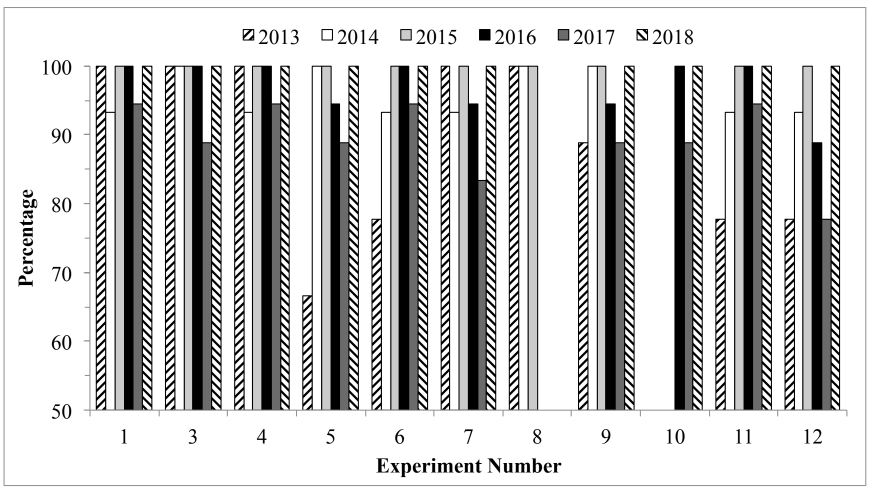


Figure 1. Percentage of students watching the videos.

The impact of the videos on student preparation throughout the period studied (N = 94) is summarized in Table 3. Here, the students were asked to rate the given statement (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). The ratings for the six statements varied from one another. The statement dealing with how helpful the videos are (Statement 1) showed the highest rating among all statements followed closely by how the videos helped the students to prepare for the experiment (Statement 2). Although the use of videos was also found to be helpful in understanding the experimental protocol (Statement 4), the students felt that they still needed to read the protocol (Statement 5), as shown by the low rating for this statement. In addition, based on the rating, watching the video was not helpful in writing laboratory reports

(Statement 6). The responses to the statement that the student watched the videos more than once (Statement 3) were variable.

The yearly ratings for each statement are shown in Figure 2. Just like the observed overall trend, the yearly rating shows consistently high ratings for Statements 1 and 2 followed by Statement 4. Consistently, the statement regarding the use of the experimental protocol in spite of watching the video (Statement 5) received the lowest rating.

Table 3. Results from the Survey Concerning the Effectiveness of Using Instructional Videos in the Laboratory Class

Statement	*Rating*
1. The videos were helpful to me.	4.59
2. The videos prepared me for the lab.	4.56
3. I watched the video more than once.	3.52
4. The videos helped me to understand the experimental protocol.	4.38
5. After watching the video I felt that I did not need to read the protocol.	2.50
6. The video helped me with report writing.	3.20

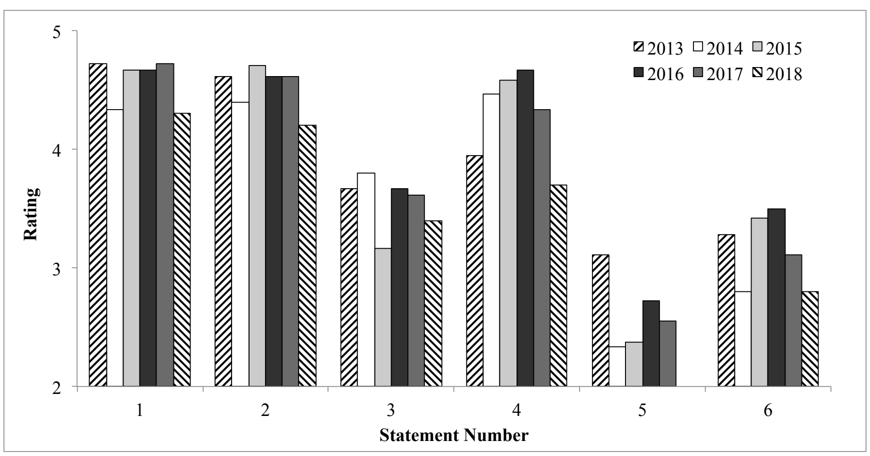


Figure 2. Yearly ratings for the questions/statements determining the effectiveness of using videos in the laboratory class.

In the next set of questions on the survey, the first two ask the students when and how often they watched the videos. With respect to when they watched the videos, almost half of students replied that they watched them on the day of the experiment (Figure 3). Although 49% of the students (46 out of 94 students) watched the videos on the day of experiment (usually an hour or hours before the experiment), 27% (25 out of 94 students) indicated that they watched them multiple times, ranging from days before the experiment to the day of the experiment. Of the 25 students who provided multiple times, 11 students watched the videos on the day of the experiment, 10 students watched them a day before, and 4 students watched them several days before the experiment (in addition to providing other times). Other times that students watched include the following: 8 students (9%) watched the videos days before, while 15 students (16%) watched them one day before the experiment.

For the question concerning how many times the videos were watched, the answers varied from only once to more than three times (Figure 3). Based on the results, approximately 86% of the students watched them at least once and, at most, twice. Breaking down this percentage, 31% of the students watched them only once, 26% of the students watched them twice, and 29% watched them one to two times. Some students indicated that they watched them only once, but twice if they found the experiment complicated (which is counted as one to two times).

The next question in the survey concerned the absence of videos for two experiments (2 and 10). For the first three years (2013–2015), these two experiments did not have accompanying videos. Based on the students' answers on the need for videos for these two experiments, most students replied that it was not necessary for Experiment 2, but that it would be helpful to have one for Experiment 10. Experiment 2 uses Microsoft Excel to graph data from common chemical analyses, while Experiment 10 utilizes an atomic absorption spectrometer to analyze the calcium and magnesium content in water samples. The students had not previously encountered the instrument employed in Experiment 10 and were unfamiliar with its use. For this reason, starting fall 2015, a video for Experiment 10 was included. Hence from fall 2016 onward, the question concerning the absence of videos concerned only Experiment 2.

With regard to the question "Would it make a difference to you if we did not have the videos?" 85% (80 out of 94 students) answered that it would make a difference, while 15% (14 students) said that it would not. Most of those with affirmative answers gave additional responses to this question, explaining why it would make a difference to them, in comparison to those who just replied that the use of videos did not make a difference. The following are representative comments provided by the students indicating that the videos did make a difference for them:

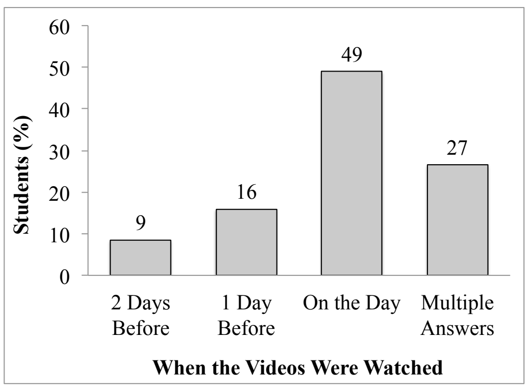
"I would have to consume more time to grasp the material and be prepared."

"The videos help me personally feel more prepared for the lab."

"Sometimes the protocols are bad at explaining, they are confusing at some points."

"I tend to be more of a visual learner. The video helped me to learn the steps of the experiments easier than actually reading it."

"The videos helped to understand each lab."



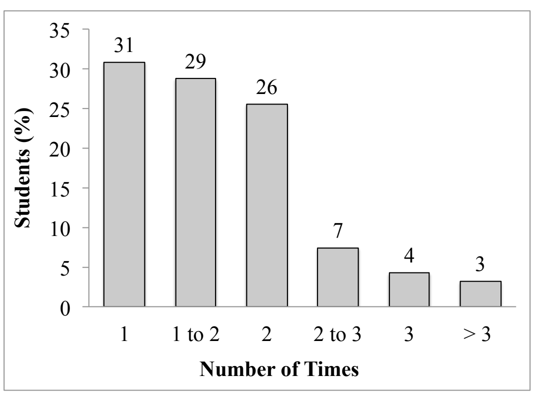


Figure 3. Results showing when the students watched the videos (above) and how many times they watched the videos (below) before conducting the experiment. The number above the bars in each graph indicates the percentage of students for each category.

Students who answered negatively saying that the use of videos made no difference in the laboratory class included the following additional comments:

"Each lab was pretty much the same procedure just different chemicals/ingredients."

"It was fine without them."

"It will just be less work to do, it wouldn't really make a difference."

"As long as the instructor would help make clear of any questions."

In the last item of the survey, students were asked to give any comments concerning the use of the videos, and more than half of the students provided comments. Among the representative comments written by the students are the following:

"*They are really helpful. Made procedure easier."*

"Videos are a good idea that other chem courses should adopt."

"Videos were great, they showed the equipment we needed to use plus the color change expected. I love the videos."

"The videos were helpful and I wish more science classes would have them."

"They are a great guide and tool."

"The videos were very helpful."

"I believed I would not have been as prepared for the lab without the videos."

"Videos helped us to visualize what we needed to do in the lab."

"They simplified the lab greatly and helped me narrow down the necessities of the lab as well as a time gauge to how long lab would take."

"I think the videos are helpful because they helped me think of them while doing the experiment like I can refer back to it."

"The videos helped with the more complex procedures."

Most of the students also commented that they would like some commentary to accompany the videos.

Based on the comments from the survey, most of the students thought that the videos were helpful and saved a lot of time. They were able to understand the procedure and to gain familiarity with the experiment before performing it. The videos helped them prepare for the experiment before it was performed. This is a big departure from the traditional laboratory class where students use the laboratory period to simply follow a recipe without giving much thought as to why they are performing a certain procedure or how the experiment relates to concepts discussed in the lecture.

On the other hand, the use of instructional videos has also helped instructors reduce the prelaboratory discussion time so that more time can be spent with the students. Typically, the common approach in a laboratory class before the use of video clips was implemented relied on the instructor to explain the details of the experimental work at the beginning of the class, telling the students what to do and what reagents and glassware to use, while also demonstrating the techniques to be performed. This approach was found to contribute to information overload, because a large amount of material was given to the students in such a short period of time. The development and introduction of the videos allow the instructors to have more time to focus on helping the students to master hands-on laboratory skills and techniques. Previously, students were assessed only in their written reports, but the additional time allows instructors to uncover the source of mistakes commonly encountered by students that might otherwise become incorporated into their reports. The students gain a significant understanding of laboratory techniques that are part of the experiments they are conducting, such as using a burette, volumetric flasks, and pipettes. The additional time allows instructors to correct improper techniques that students usually employ (e.g., reading a burette) despite instructions given in laboratory manuals and demonstrations that might be provided.

The results from our surveys concerning the use of instructional videos before laboratory classes reinforce what has been reported in previous studies about their effectiveness in helping students. One study reported that visual representations allow students to develop a mental picture of what they will be doing in laboratory classes, hence increasing student confidence.[4] Several studies have shown the positive effect of using videos in prelaboratory activities. For example, the introduction of web-accessible prelaboratory videos for a first-year university introductory chemistry course significantly enhanced the flow of the laboratory class.[10] The results from another study indicated that students who used videos at the start of the laboratory period showed greater learning and required less time to complete the experiment.[8] Lastly, another study reported that students using video preparation needed less support in an organic chemistry laboratory compared to students who received in-laboratory instruction from TAs.[7]

In terms of making the students more prepared and helping them understand the concepts behind every experiment, several studies have already reported these benefits when videos are used as a prelaboratory activity. For example, one study reported that videos help students to feel better prepared to conduct their laboratory experiments and help them to learn better the concepts presented in the experiment.[11] Another study demonstrated that the use of prelaboratory videos and e-quizzes improved the preparedness of students in an analytical chemistry laboratory class.[4]

Conclusion

The instructional videos helped the students to be more prepared and familiar with the experiments that they had to perform. The instructors spent less time instructing the students and more time monitoring the students' progress in acquiring skills. The students also had more time to perform the experiments and to develop the techniques and skills required for this laboratory course.

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