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Sandra Swenson
City University of New York - John Jay College …

Nathan H Lents
City University of New York - John Jay College …

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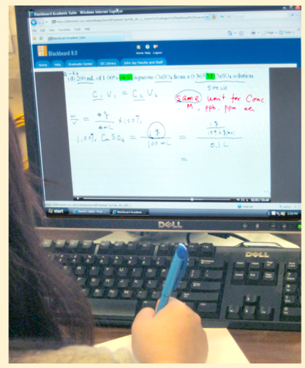
Online Video Tutorials Increase Learning of Difficult Concepts in an Undergraduate Analytical Chemistry Course

Yi He,* Sandra Swenson, and Nathan Lents

Department of Sciences, John Jay College of Criminal Justice, The City University of New York, New York, New York 10019, United States

ABSTRACT: Educational technology has enhanced, even revolutionized, pedagogy in many areas of higher education. This study examines the incorporation of video tutorials as a supplement to learning in an undergraduate analytical chemistry course. The concepts and problems in which students faced difficulty were first identified by assessing students' homework assignments and exam responses. Then, a tutorial video clip aimed at that specific knowledge point was designed by the instructor using the Camtasia software package and was uploaded to the course Web site portal (Blackboard). To assess the effectiveness of the tutorials, students' oral and written feedback, pre- and post-video-tutoring exam performance, and data from previous classes taught by the same instructor were examined. Results indicate that online video tutorials are a valuable, flexible, and cost-effective tool to improve student mastery of chemistry problem solving.



KEYWORDS: *Second-Year Undergraduate, Upper-Division Undergraduate, Analytical Chemistry, Curriculum, Internet/Web-Based Learning, Enrichment/Review Materials, Student-Centered Learning*

Tutoring has come to play an important role in student success in the STEM disciplines, and considerable efforts have been made to establish and disseminate best practices for learning gains through the use of tutoring.[1] Although most colleges have tutoring programs with live tutors or professors, the success of one-to-one tutoring, either with a peer or with a professor, is contingent upon availability, scheduling, time-commitment, and the learning experience necessary to facilitate procedural and conceptual changes in student learning. Although the benefits are clear, costs are high and logistics often inhibit students' taking full advantage of tutoring resources.

More than ever before, students get information from electronic devices such as computers, smartphones, tablets, and other portable devices, and the use of technologies in learning activities has become increasingly popular in curriculum and teaching. Online homework or tutoring are examples of sound pedagogical practice for courses at the university level. For example, an online chemistry-tutoring program, OWL Quick Prep, has been adapted as a method for helping students refresh basic chemistry concepts before entering a general chemistry sequence at the college level;[2] students using MCWeb Homework (Wiley Software) for practicing homework problems have shown significantly better results on test scores as compared with a control group that used traditional text-based homework;[3] chemistry students using the Web for homework and feedback with tutorial supplements are more motivated to learn;[4] and model-visualization tutorials in chemistry are useful to supplement laboratory curriculum.[5] In addition, online tutoring has also been demonstrated as effective in teaching other subjects such as language.[6]

There is nothing inherent in instructional technologies (IT) that will guarantee student success, but IT may help to increase learning by providing new approaches to teaching.[7] Although IT may never be an effective replacement for live classroom instruction, there are unique ways to use technology that can supplement live instruction and assist student learning. One of these ways is video tutoring, where *targeted* lessons are designed with one specific learning goal, as opposed to presenting students with broad course instruction or larger concepts that they must filter through without being able to ask questions.

The key strength of tutoring is that students receive individual attention in reaching given instructional objectives and the time can be effectively focused on only those concepts with which the student is struggling. Early comparative studies between one-to-one tutoring with an instructor and whole-class instruction have shown that one-to-one tutoring has a marked effect in student achievement.[8] Part of this achievement was attributed to corrective work: formative tests that allow for eventual feedback of corrective procedures by the tutor. Because individual live tutoring is not always practical, a very specific video-tutoring lesson was designed using formative evaluations and corrective feedback methods that could aid in student achievement.

Online access to tutoring videos may be an effective way to help students take control of their learning and foster independence. With instructional technology, students may work more independently and actively, self-adjust their study pace, and repeat the video when necessary. It is relatively easy with online tutoring to do things that are difficult from a

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traditional teaching perspective. For example, repeating the teaching materials multiple times until the key points are clearly understood.

Although premade instructional technologies were attractive, cost-effective, instructor-made video tutorials were desired that target specific student needs that may be unique to a given student population. For example, John Jay College is a large, public, urban college, and financial and technological resources are severely limited for both students and the institution. Thus, controlling costs for students is a paramount concern. In this study, online tutoring was introduced as a supplement to regular classroom and laboratory instruction in an analytical chemistry course. The method focused on instructor demonstration and improving student skills in critical thinking, problem analyzing, and problem solving. Not a platform for teaching new material or course content, the tutoring aims to facilitate students' mastery of knowledge already covered through instruction in solving the most challenging problems.

METHOD

Participants

The subjects of this study were students enrolled in a four-credit analytical chemistry course required of all forensic science students, typically taken in the second year. The prerequisite for this course is a two-semester general chemistry course. Students attend a 75-min lecture twice per week and a 5-h lab once per week. The tutoring in this study was focused solely on lecture content. The class began with 29 enrolled students, and two students dropped out during the semester, bringing the total number of participants to 27 in this study.

Procedure

The general procedure of the online tutoring approach included five steps: (i) identifying the difficult concept, (ii) preparing the tutorial video clips, (iii) delivering the tutorials, (iv) evaluating the method, and (v) improving the method based on student feedback.

The concept or word problem for which students could benefit from tutoring was identified through homework assignments and exam results. For example, students were given 15 questions in their first homework assignment. After grading the homework, it was observed that students had particular difficulty with four of the questions, in which nearly 50% of the students either gave a wrong answer or left the question blank. High error rates on exams were also noted. A tutoring video was provided by the instructor for the identified problems (noted above) and recorded as short video clips (details on how to make the video clip can be found below). Each video took 20−30 min to make. The tutoring was not limited to simply providing the solution to the question but specifically addressed key information provided by the question, how the problem is analyzed, and how this skill is applied to similar questions. The main goal was to help students grasp the knowledge point and also learn how to apply it.

The video tutorials, made with Camtasia and exported as Shockwave flash files (SWFs), were uploaded to the course Web site on Blackboard and made available to students. An example video is available online.[9] The tutorials usually were made available to students within five days after they handed in their homework, or took the exam.

Knowledge points identified via homework assignments and exam results were tested again on the next exam or quiz. To prevent students from mechanically memorizing the tutoring material and numbers, the questions given in the exam were similar to what the students had in their homework, but not identical. The percentages of the correctness of the pre- and post-intervention (video tutoring) on the specific exam question were compared. The students were asked to indicate on the exam paper whether they used the video tutoring or not. The students' performance was also compared with three previous classes that were taught by the same instructor using the same classroom teaching materials and strategies. The only difference was that the present group of students was provided with online tutoring, whereas the three previous classes were not. The results of six questions from the final exams were compared. The exact same questions were asked in final exams over several years because the final exams were always kept confidential and no students would have access to them beforehand. The correctness percentage of the study group (present class) and control group (previous three classes) on specific questions was compared. In addition, a survey was conducted at the end of the semester to seek in-depth feedback from the students. In addition to the information collected through the semester, the experience and knowledge gained through the assessments were summarized and applied to future offerings of the course to further improve the method.

Instrument

The style of video tutoring is based on voice and handwriting, which is similar to the traditional face-to-face and one-to-one tutoring using writing and explanation. The tutoring video was made using Microsoft Windows Journal running on a Lenovo Thinkpad X series PC tablet. The handwritings and voice audio were captured and edited by Camtasia software (Techsmith). The final product of the tutoring video was saved as a Shockwave flash file (SWF). Flash files can be viewed directly in any browser, without the need of special software, or directly embedded in Blackboard. Because each video focuses on one specific problem, each is under 10 min in length and the file size is 5−10 MB. The tutoring material is made available to all students, who can then decide whether they need the supplementary tutoring, which tutoring video they want to view, and when and where to view the video according to their own needs.

RESULTS

Data from Homework and Exam

Prior to the creation of the video tutorials, student mastery of key knowledge points ranged from 40−75%, as measured by the percentage correct and partial correct rate on homework assignments. (Partial correct is defined as correct understanding of the knowledge but failure to arrive at the fully correct answer, usually because of a minor problem such as calculation error.) However, following the introduction of the videos, the results from the first exam revealed that student mastery of all seven knowledge points covered by the tutoring materials had markedly improved (Figure 1). The improvement was especially substantial for questions that exhibited relatively low correctness rate in pre-video practice. For example, the rate for questions about preparing solution from dilution (question 5), concentration unit conversion (question 6), and preparing solution from solid reagent (question 7) improved from 46% to 75%, 46% to 79%, and 46% to 92%, respectively.

After the first exam, a low correctness rate was found in error propagation questions, which were not assigned as homework

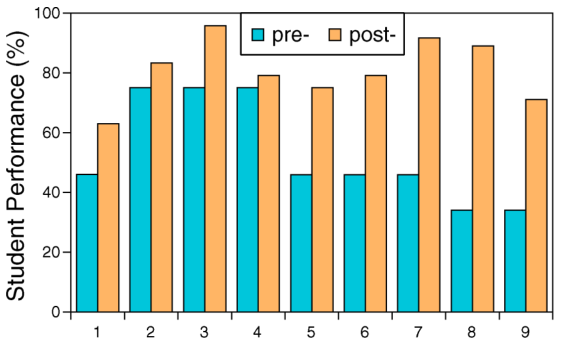

Figure 1. Comparison of student performance between pre- and post-online video tutoring on questions identified from homework: (1) converting w/w concentration to molarity; (2–4) prefix; (5) preparing solution from dilution; (6) concentration unit conversion; and (7) preparing solution from solid reagent. Comparison from exam questions: (8) error propagation—addition and subtraction; and (9) error propagation—multiplication and division.

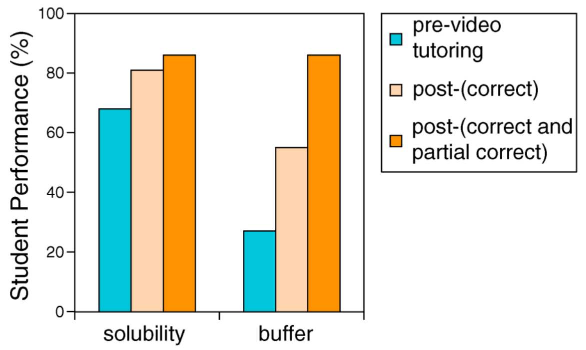

Figure 2. Comparison of the improvement with (buffer question) and without (solubility) online video tutoring. No student showed the ability to solve the problem partially pre-video tutoring.

and no tutoring video was provided before the exam. However, an example with the answer is available in the textbook and students had been instructed to study this problem by themselves after class. After identifying this weak point, a video demonstrating how to solve this type of question was produced and made available to students. A quiz on error propagation was given during the next lecture in the following week. The correctness percentage increased from 34% to 89% and 71%, respectively, for addition−subtraction and multiplication−division type of error propagation (Figure 1).

Before the second exam, two major weak points were identified from homework materials. They were (i) calculating the solubility of a solute using K_{sp} and (ii) preparing buffer solutions through different approaches (mixing salt with weak acid; mixing strong base with weak acid, and mixing strong acid with salt). For these two types of questions in their homework, students were either totally correct, totally incorrect, or just left the question blank. No student showed the ability to solve the problems partially.

To compare the effectiveness of the tutoring materials, online tutoring videos were purposefully not provided for calculating the solubility of a solute using K_{sp}, but they were provided to address the preparation of buffer solutions. A comparison of the results obtained before the video intervention (homework) and afterward (exam 2) revealed that the student correctness scores increased from 27% to 55% when the videos were introduced (the buffer question). However, when no video tutorial was provided, student performance decreased between the homework assignments and the exams from 68% to 55% (the solubility question).

If the partial correctness rate for post-video tutoring is also considered, the improvement was 68% to 86% for the untutored question (solubility) and 27% to 86% for the video-tutored question (buffer question). This gives an absolute improvement value for the untutored question of 18% and that for the tutored question of 59% (Figure 2).

Comparison with Previous Classes

Student performance was compared between classes with and without the video tutoring intervention by comparing performance on six common final exam questions. For three of the six questions, that is, preparing a solution from a liquid stock, calculating pH when a small amount of strong base is added to a weak acid, and calculating pH when the amount of acid and its conjugate base is same, the correctness rate of the experimental group was substantially higher than the three control groups. For the remaining three questions, the experimental group was the same or slightly higher than one class in the control group, but much higher than the other class (Table 1).

Table 1. Comparison of Students' Performance between Class with and without Online Tutoring

	Correctness Rate for the Control Group (%)			Correctness Rate for the Experimental Group (%)
Question	Fall 2009 (N = 24)	Spring 2010 (N = 24)	Fall 2010 (N = 24)	Spring 2011 (N = 27)
(1) Prepare solution from a liquid stock, with unit conversion	25	52	17	74
Titration of weak acid by a strong base:				
(2) Initial pH	21	52	N.A.	52
(3) pH after addition of small amount of base	17	20	N.A.	67
(4) pH when the amount of acid and its conjugate base is same	17	36	N.A.	70
(5) pH at equivalence point	8	40	N.A.	48
(6) pH when excess amount of acid is added	13	40	N.A.	41

The student cohort in this study was compared with the control cohort by examining performance on the ACS General Chemistry test. (General chemistry is a prerequisite course for quantitative analysis.) The overall performance of students involved in this study did not show significant difference in their ACS General Chemistry test. The class average of ACS final exam grade for general chemistry in years 2009 and 2010, which cover the control and experimental group in this study, was 71.21 ± 16.47 (N = 130) and 72.51 ± 15.72 (N = 119), respectively.

Student Survey Responses

In a survey administered at the end of the course, students reported positive feedback after viewing the video tutorials posted on Blackboard. An overwhelming majority, 88%, of the students agreed that video-based problem-solving tutoring was helpful to their study, with a bare majority, 56% *strongly*

Table 2. Students' Response to Questionnaire

Question	Response (%)				
	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree
1: I find that video based problem solving demonstration is helpful to my study.	0	0	12	32	56
2: The video based tutoring can replace the traditional classroom problem solving demonstration.	4	24	40	28	4
3: I want more traditional classroom problem-solving demonstration than the video.	4	8	56	16	16
4: I hope more videos can be provided to this class.	0	0	24	36	40
5: I hope we have video based tutoring available to other classes offered at John Jay College.	0	0	16	36	48

agreeing. Additional survey questions and responses are included in Table 2. The following are some specific comments given by students in the open-response question:

- Video tutoring is awesome! It helped a lot with problems we couldn't go over in class. It makes problems very clear when you show a general approach to a question that can be applied to other problems as well.
- It is posted in a timely manner and I love that it aids me in studying.
- It is perfect like that, just don't stop posting it.
- Just add more videos to the complex problems.
- The videos were very helpful and explained [the problems] well.

Interestingly, 56% of the students neither agree nor disagree with the survey question, "I want more traditional classroom problem-solving demonstration than video," (question 3), indicating that most students feel that the videos offer a supplement, but not a replacement, for in-class demonstrations. Thirty-two percent of the students agreed, with 16% strongly agreeing, that in-class demonstrations are still preferable to videos, and only 12% of students prefer online tutoring more than classroom tutoring. As one student indicated in his survey, "It is helpful. Do not try to replace lecture with video. The brain is a social device." Clearly, students value the social interaction provided by face-to-face teaching.

In summary, the results suggest that, although classroom knowledge delivery is still essential to the student experience, video tutorials can be a valuable supplement in the learning of difficult concepts in an upper-level chemistry course. Although there may be no substitute for the personal interactions available along with traditional teaching, contemporary students are open to online tutoring. As interactive technologies continue to develop, they can be successfully integrated into virtually any course for additional instruction. On the basis of our results, video tutoring is a suitable supplementary tool for the regular classroom teaching of upper-level chemistry courses.

■ DISCUSSION

Online video tutoring appears to have a positive effect on student mastery of knowledge. Because of the usefulness of this approach, most students (76%) agree or strongly agree (question 4 in Table 2) that they would like more videos to be provided in this chemistry class. An even larger majority, 84%, felt that this kind of help should be available to other classes offered at this college (question 5 in Table 2). This information indicates that it would be worth our time and effort to design and develop more video tutorials and perhaps to design a model that may be applicable to other courses at the college. An essential component to the success of these video-based tutorials is that front-end analysis is conducted before the tutorials are made. In this way, the supplements are better targeted and there is a close link between the student needs and the interventions given to address them.

To some, the process of making videos may seem like a daunting task on the part of the instructor. However, available technology has made creating a video a relatively simple process, demonstrated by this and other studies.[10,11] With Camtasi, as with other similar software packages, almost no pre-recording preparation is needed. Similarly, the variety of preset parameters requires minimal or no manipulation for the production of the videos after they have been recorded. For example, the 6−10 min videos featured in this study were produced and posted in as little as 20 min from start to finish, including the recording, and were made by a professor with no prior experience in digital video production. Additionally, once videos are made, they can be archived by the instructor for future use, gradually building a library of tutorials that can be drawn upon for years.

For tutoring to be successful, it should involve formative assessment, a skilled and knowledgeable individual, and a corrective process with follow-up evaluation.[8,12] Rather than taking a generalized prescriptive approach to assigning tutorials from the Internet, or using tutorials designed by a publishing company who may not target the correct skills, the instructor in this study thoroughly assessed her students' needs and designed specific video tutorials to meet those needs. Moreover, she was able to assess their learning with follow-up exams, given in class.

Live tutoring and e-tutors may offer students some aspects of the paradigm described by Bloom,[8] but the demands of time and cost are considerable. With a video tutorial that can be viewed and repeated, students may work at their own pace and at a time and place of their choosing. In one report on study skills of contemporary undergraduates, Kuo, Hagie, and Miller[13] found that, in general, students tend to prefer to work individually, at home, rather than in organized study or tutoring environments on campus. This may be especially true for commuter students who attend urban colleges and universities.

■ CONCLUSION AND EXPERIENCES LEARNED

The results from this study indicate that online video tutoring delivered to students through Blackboard effectively helps students master knowledge points and improve their performance in an upper-level chemistry course. This technique is especially beneficial to the average and lower-performing students in the class, as noted in a study by Milkent and Roth[14] on student achievement through computer-generated homework. During this investigation, it was found that the top students can master the knowledge well through classroom instruction and their own study, which were reflected by the homework results. While many top students chose not to use the videos, others viewed them anyway, as part of their study. The significant change occurred in average and lower-performing students, those that could not solve the problems correctly prior to video tutoring, but become able to do so following the video tutoring. Several students in this category approached the instructor and requested additional videos.

By using online video tutoring, students have more flexibility in terms of time and place of study.[15] The students can decide how much time they need to spend on a specific topic. For difficult points, they can view the tutorial material several times until they fully understand and for other points, they can skip the tutorial if they already feel comfortable with the knowledge point. Thus, video tutorials are student-controlled, need-based, and task-oriented learning aids.

■ FUTURE APPLICATIONS

This study was limited by the number of students assessed and by the fact that the videos made for this course are specific to analytical chemistry or quantitative analysis. It is our goal to scale up the online tutorials for additional chemistry courses and to serve as a model for other courses at our college. A recent six-year study on online homework and student achievement in large enrollment classes shows that this is possible.[16] It is our hope that success stories like ours will inspire other instructors to consider implementing these tools in their courses.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: yhe@jjay.cuny.edu.

Notes

The authors declare no competing financial interest.

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