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The use of digital technology in the class and laboratory

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Introduction

In this article I will share some digital tools that I have found to be highly effective in helping my students grasp course material. Incorporating digital technologies into my instruction provides students with more tools through which they can see, hear, or interact with course material. These tools have the potential to assist students who may not be best suited to learning in a traditional lecture environment.

Incorporation of technology into teaching should not be done because of its "wow factor", but instead because it fills a need or adds an instructional opportunity. Consequently, I always evaluate the digital tools and technologies that I bring into the classroom to determine if they are effective in enhancing student learning. I solicit feedback from my students on how well various tools helped their education, as I feel that they are the best judges of the effectiveness of a new teaching tool.

It is well known that students have different learning styles, which can be broadly segmented into visual, auditory, reading and writing, and kinesthetic learners [1]. Some of the digital tools that I use aid visual learners whereas others favor kinesthetic learners. Furthermore, the digital tools that I have incorporated are optional and students can make use of them as they wish. I will describe the use of lecture recordings, cell phone-based polling, a digital textbook, and laboratory demo videos. I have used these technologies in a range of class sizes and course levels. Most commonly I have taught a traditional quantitative analysis course that has up to 80 students per semester. I have also taught graduate level analytical chemistry courses with just over 20 students, and larger general chemistry classes with upwards of 200 students. So these tools can be used in just about any size of class and in fact may be most useful in some of the largest class sizes. For more information on the specific digital tools that I have used please consult the supplementary material accompanying this article.

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Lecture recordings

Recent published literature shows that lecture recordings do not consistently result in better student learning [1–4]. However, it is evident that some students benefit from the availability of lecture recordings. Lectures can be recorded in audio only or in video format. Of the two I prefer video recordings, as they provide a more engaging medium for the students; video recordings provide a better reflection of what transpired in the classroom. Independent of format, recorded lectures can be very helpful for students for whom the language of instruction is their second language. They now have the ability to review what was said, pausing and rewinding the recording as needed to ensure that they comprehend what was said. For other students, the challenge of taking notes while reading slides or material on a whiteboard, while listening to the instructor speak, may not result in clear or complete notes. Some students are too intimidated to ask instructors to repeat themselves, particularly in large classes. Recordings afford them the opportunity to get that repetition without having to interrupt the class. Recordings are also valuable to students who must miss class due to illness or other commitments.

A concern with lecture recordings is whether their availability will encourage students to skip classes. This can be a problem and some students in my classes have missed classes because of the availability of the recordings. I point out to my students that skipping a few lectures means that they have to listen to me for many hours of lecturing and they may fall too far behind. Surveys of students indicate that about 20 %

reported that they were tempted to skip some classes because of availability of the recordings; most students who reported skipping classes claimed to have skipped fewer than three classes during the semester. If done properly, students can get as much or more from the recordings. I had one student who never came to class, but watched the videos in 15-minute increments because it was easier for this individual to focus on and comprehend the material in this way. This student was one of the top students that semester. Clearly, lecture recordings can work well for those students who are willing to use them responsibly. Students who do not take the learning process seriously are likely to do poorly by skipping class and relying only on the recordings.

Audio recordings

There are a couple of methods that can be used to make audio recordings of your lectures. One option involves a portable digital audio recorder. You can place it on a lecture podium, in a breast pocket of a shirt, or possibly on a lanyard around your neck. The placement of the recorder is crucial to a good recording. Placing it on the podium or table should isolate it from the sounds of your movements; however, if you tend to wander around the classroom your voice will rise and fall in volume with your positioning relative to the recorder location. What might be a less obvious choice of recording device is your smartphone. Among the multitude of available applications available for iPhones, Androids, and Windows phones, there are plenty of free (and paid) audio recording applications. These essentially turn your smartphone into a digital recorder. There are a few advantages to using your smartphone as the recording device. First, I'm not likely to forget to bring my phone with me when I go to a lecture, I may very easily forget an audio recorder. Second, it is likely easier to export the recorded audio file from your smartphone to your computer, and ultimately your file sharing system. The smartphone will likely be able to do the transfer automatically and wirelessly, whereas a standard digital audio recorder will likely need to be physically plugged into the computer for the file transfer.

There is a final advantage to using a smartphone as a recorder for those who like to move around during a lecture. Many of the audio recording applications can be set to record from a linked Bluetooth device. This means that if you have a Bluetooth headset for hands-free calling, you can use this as your wireless microphone, ensuring consistent audio recording levels for your lectures. With all recordings of lectures it is a good idea to repeat any student questions so that they can be heard on the recording clearly; this is particularly true of recordings done with a headset.

Video recordings

I have tried a couple of methods of generating video recordings, with different degrees of success. One option that did not work as well as I would have liked was the use of a smartphone. I placed the smartphone on a table in front of the classroom so that the screen and whiteboard were in frame. While the recording did capture the audio and video of the lecture, the native format of the video resulted in overly large files (>1 GB) at the end of the 75-minute lecture period. Sharing of the recording and processing of the video was difficult and time consuming; however, with the right tools it is a viable option. For this type of recording it is advisable to purchase a small tripod and mount for the smartphone.

If the presentation is being given through PowerPoint or Keynote, which is Apple's equivalent to PowerPoint, a second and preferable option is to use the built in recording system that comes with the presentation software. From my experience, the recording and exporting processes are a little more difficult with PowerPoint than Keynote. There are also some third party applications that can allow you to do this as well (e.g. Camtasia). The software allows you to record the audio of the lecture in time with any slide transitions and animations, providing a "video" of the lecture slides. A drawback to this process is that it does not capture any video of work done on a whiteboard, although the audio recording will continue during these phases. If the recording is intended as a supplement to the actual lecture, it need not be all-encompassing.

When doing recordings of lectures through the presentation software, it is advisable to use your own laptop computer. The recorded file may be large and slow to save and/or transfer between the podium computer and a portable USB drive. It is advisable to bring a power cord for your laptop as recording will consume more power from the battery. The audio quality of this type of recording can suffer from computer fan noise and your physical proximity to the computer. These problems can be reduced with the use of an external USB or Bluetooth microphone. The latter gives you the freedom to move around the room and still be recorded clearly.

Lectures while away

Lecture recordings can also be used for times when you are away from campus. Recording lectures through the presentation software does not have to be done in the classroom, as it is not dependent on the projection of the slides. You can record a lecture at anytime and place. Consequently, I no longer have to trouble colleagues to cover lectures for me and I know exactly what my students will have been taught while I'm away.

I usually make pre-recorded lectures shorter than my regular lectures. This means that I go faster, but they can rewind

the recording if things go too quickly. To be effective, this requires that students watch the videos while you are away. I advise recording all the lectures prior to your departure to give them as much time as possible to watch them. For the truly adventurous, if the timing works out properly, you can use live video calling (e.g. Skype) to give your lecture from the road. The ability to do screen sharing that shows them your presentation rather than your face can be a good substitute for you being there in person. This approach requires an assistant to receive your call on a computer connected to the projector and audio system of the classroom. The assistant may also need to repeat questions from the students to you. Also, a sufficiently rapid and capable Internet connection is necessary. I attempted this once with a general chemistry class of ~200 students. Most students attended the lecture and were enthusiastic about the process for the lecture. However the Internet connection in the hotel was incapable of providing enough bandwidth and the audio and video were soon hopelessly out of sync.

Distribution

Most universities employ some form of on-line course management system; at San Diego State University we have been using Blackboard for many years. These tools can be used to upload the recordings that you have made and to allow the students to download them at their leisure. However, I have run into instances where the file that I wished to upload exceeded the limits imposed by Blackboard.

For that reason I have switched to using a cloud storage system, specifically Dropbox.com, to store and distribute my lecture materials, as well as for other file storage and transfer needs. This system, as well as many other cloud storage systems (e.g. Google Drive, Box, Skydrive), allows you to upload, store and share data with ease. Most systems provide a limited amount of free storage (~5 GB) with more storage available through subscription purchases or referral rewards. The free storage amounts should suffice for all but the most massive video recordings; my video recordings, captured from Keynote, for a semester of analytical chemistry typically total less than 2 GB. By providing your students with a URL link to your cloud storage site, or by sharing the folder with them through the cloud, they can easily download the recordings. Do check the terms of service for the cloud storage site you use, as not all sites will allow complete video streaming from the cloud. For example, Dropbox.com limits streaming to 15 minutes of video, but if the students download the video they can watch the entire length of the video. It should be noted that not all of these cloud storage services are secure, and the material that you upload may be able to be seen by individuals who are not part of your course. This may not be a concern for some, but it is important to be mindful of the level of privacy that any on-line materials may have.

Student opinion

Polls of students in my analytical chemistry classes indicate that 70 % of the students made use of the recordings at some point in time; with a preference for video over audio recordings. Fifty percent of the students felt that the recordings improved their grade (somewhat or greatly) whereas 6 % felt that it hindered their grade.

Classroom polling

The use of classroom response systems (e.g. clickers) continues to grow in chemistry education [5]. Rather than requiring students (and myself) to acquire additional equipment (clickers and a receiver) and the need to remember to bring them to each class, I opted for a simpler approach, cellphone-based polling. If you are wondering whether it is asking for trouble by letting students use their cellphones in class, I don't believe that it does. Students who are already inclined to play with their phones rather than pay attention to the lecture are likely to do so regardless of having them use their phones as a feedback tool.

The name "cellphone polling" is a bit of a misnomer, as students can respond to multiple-choice and open response questions through more than a cellphone. The system is web-based and can accept participant responses in the form of text messages, tweets, or through a dedicated web site. An advantage of this system is that, unlike clickers, students never forget their cell phones. The variety of response methods opens the system up to those who come to class with laptops or tablets and do not want to use text messaging. There are a few systems available for this type of polling, many with free options, for a limited number of respondents per question. The system that I have been using, first as a free account, then as a paid service through my university is Poll Everywhere. Other companies exist, and there is now even a custom in-house designed system, based on SMS messaging, that was recently published [6].

I mostly use the polling to gauge student comprehension of the material that I have covered or am about to cover. I typically ask 3 or 4 questions of the students throughout a 75-minute lecture period. The questions are included as slides in the lecture. Depending on the presentation software being used, the slides can include a live chart of the polling results through a software plugin. Alternately, the results are also viewable through a web browser; I embed the URL to the results in the slide for easy access. Most often the questions I use are multiple choice ones, though on occasion I have used the open response format to allow the students to enter text or numerical answers. Questions most often relate to the material that I have just covered, though occasionally I will ask the same question before and after I cover a subject to see how well they have understood the material. In either case, from

their responses I can quickly determine if I have been able to convey the information that I wanted them to grasp. The benefit is that if I find that I failed to convey the information properly, I can then alter my lecture plan to insure that they better understand the material before moving on to something new.

When the results of a poll indicate the students are confused, an effective tactic is to have the students take a few minutes to discuss the question with the students seated near them, rather than provide them with the answer. Without fail, after this discussion period, when asked to resubmit their answers to the question, the majority of the class has shifted to the correct answer.

I also use classroom polling at the beginning of each class. I arrive a few minutes early and post a more challenging question on the screen that relates to material from the previous class. This provides a way for me to gauge if the students have been able to retain material from the prior class. With all questions posed to the class, I take the time after the responses have been submitted to go over the calculations or theory that lead to the correct answer. It is rare for all the students in the class to get the right answer, and some may have just made lucky guesses. This process helps students confirm their approach to the problem.

It is possible to collect individual student results from the Poll Everywhere system and use this for assigning points for answering questions. I do not take polls for points towards grades, but for practice and feedback for the students and me. Being an optional tool, not all students respond to every question, about 50 % of the students typically respond per question. It is an effective tool for those who recognize they need practice with the problems in order to better understand the material.

Student opinion

From surveys, 70 % of students rate polling "always useful" and 23 % "sometimes useful". Eighty-seven percent of students reported that polling helped them become more engaged with the material and 77 % preferred cellphone polling over "clicker" polling.

Digital textbooks

I have been using David Harvey's Analytical Chemistry 2.0 [7], a free PDF textbook, in my analytical chemistry course for the past two years. In doing so, I was surprised at the inability of my "tech-savvy" students to effectively use a web-based text resource. The first year that I used the digital textbook half of my students principally accessed the textbook through a web browser. Consequently, they did not download the text and make use of the annotation, search, highlighting, and bookmarking features of a PDF textbook. I also learned that over 80 % of the students would have liked to have some list of software that would allow them to annotate PDF files. Overall, they were unaware that this was a possibility.

This past year I provided my students with instructional videos showing them how a downloaded PDF file can be manipulated [8]. Consequently, of the 28 students who responded to the survey this year, all but one student had downloaded the textbook. However, students as a whole were not very satisfied with the digital textbook as compared with the printed alternative. It should be noted that this dissatisfaction arose not from the content of the textbook, but rather the means of accessing the content. Overall the students reported using the digital textbook less than they would have used the printed textbook. The use of a digital textbook, on a platform with access to the Internet, also posed additional challenges to the students in the form of distractions (e.g. email, Facebook, games …) with 55 % of the respondents claiming an increase in the likelihood of being distracted when using the digital textbook as compared with a printed textbook.

In the future I intend to include an optional printed textbook to accompany the free digital textbook to help meet the needs of all the students. I will also share with the students the feedback and comments from the previous classes, warning them of the challenges of using a digital textbook.

Lab demo videos

Probably the most impactful digital technology that I have incorporated into my analytical chemistry course has been the inclusion of video demos of laboratory procedures and results in the lab manual. Lab manuals are still printed, and inclusion of videos in the manual is done via a shortened URL that students can type into a web browser. The use of URL shortening services allows you to automatically convert a long and complicated URL into a much shorter and easier to copy format, as seen below. The only text for the shortened URL that changes for each individual websites is the text after the final backslash (/). I have also used this technique with the cellphone-based polling questions, so that those using laptops can easily access the polling web page.

- Original URL: http://www.youtube.com/watch?v=6SQus2Ikqqs
- Bitly URL: http://bit.ly/1bsIvey
- Tiny URL: http://tinyurl.com/kgbxwhw
- Goo.gl URL: http://goo.gl/8gfwb

Even easier than typing in a URL is having your smartphone or tablet enter the URL for you. This can be done with QR codes, which are two-dimensional patterned codes that can be interpreted by a computer with a connected digital camera (e.g. smartphone, tablet, or laptop). The QR codes are able to convert any textual information, such as URLs, into a computer-readable image. The original URL for the lab demo video (above) can be converted into a simple QR code (Fig. 1). QR codes can be generated through a number of free web-based or downloadable programs. The resulting image file can then be easily inserted into the lab manual, just like any other figure. To read the QR codes the students must download and install an appropriate application on their smartphone, tablet, or laptop, many of which are available for free, such as Google's image based search feature called Google Goggles.

Visual information, particularly as it pertains to lab technique or equipment setup, is often more easily understood than text-based descriptions. Think of the essential task of pipetting. The textual description of all the things that need to be done to pipette properly can take several pages. Such a long series of instructions are less likely to be read and fully followed by students. Reading the entire set of instructions isn't likely to provide a beginner with a clear mental image of how to pipette. Often the instructor demonstrates the proper pipetting technique. However group viewing of a demonstration is a flawed process as you cannot ensure that all viewers have the right vantage point or are focused throughout the demonstration. With a video, proper framing of the individual shots can ensure that everyone has the perfect vantage point from which to observe the technique.

When watched before the labs the videos help students prepare for the work they will need to do. In the labs, videos can act as secondary teaching assistants, showing the students the proper setups, or the proper colors for endpoints of titrations; particularly if students have their smart phones or other devices with them and can watch the videos while in lab.

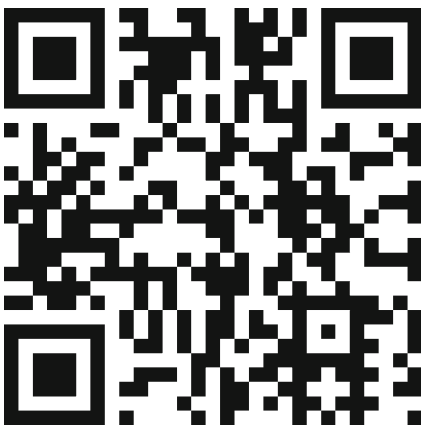

Fig. 1 The above QR code can be scanned by a smart phone application to direct the user to the desired website. In this instance the QR code translates to the following YouTube video URL: http://www.youtube.com/watch?v=6SQus2Ikqqs

The benefits of using videos for demonstrating laboratory techniques has already extended beyond the teaching lab to the research lab, with the peer reviewed Journal of Visualized Experiments (JoVE) publishing videos of research processes from chemistry, as well as other fields, in a video format [9].

Distribution

As with other course documents, lab videos can be distributed to your students through on-line course management systems or a cloud storage system. However, I opted to post my videos on YouTube, after creating my own channel (free with any YouTube/Google account) [10]. Videos posted on YouTube can be made available to the public or be restricted to those with whom you share the video URLs. I make my videos public and I was surprised by the public interest they generated. I have posted 20 videos to my channel, some for general chemistry, but most for analytical chemistry labs. In the past two years these videos have been viewed over 100,000 times. I have left the comment option open to the public and routinely get asked questions by viewers around the world about the chemistry or techniques being demonstrated.

Student opinion

Student response to the lab videos has been overwhelmingly positive. Over 60 % of the respondents always watched the videos and the remainder watched some of them. Over 80 % found the videos helpful in preparing for lab, and over 50 % watched the videos while in lab.

Concluding comments

I find it useful to inform my students that I am trying something new that I hope will facilitate their learning but may not work perfectly. I explain the specific reasons why I am using these digital tools and emphasize that the goal is to enhance their learning. Students seem to appreciate the experimental nature of the endeavor. I also emphasize the importance of receiving their honest feedback on the use of these new technologies. I have found that it often takes me a couple of tries to work out the kinks in these new techniques, but the students are willing participants in these experiments. Most importantly, the surveys I have conducted each year show that the majority of students feel that they benefit from the use of these digital technologies.

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