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Scientific Life

Video for Active and Remote Learning

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The outbreak of COVID-19 has caused the canceling of in-person lectures on a massive scale. Rapid movement of education to online platforms will eventually lead to innovations in remote education. At the moment, however, instructors lack guidance. This short article describes approaches for producing video for remote and active learning.

Video: A Versatile Tool in Science Education

When I was 5 years old, Santa brought me a gift that would change my life: a Fisher-Price PXL-2000, a ‘toy’ video camera that could capture 11 minutes of black-and-white video on each side of an audio cassette. At a time when I couldn’t even lift the weight of a grown-up’s full-size VHS camcorder, the PXL-2000 was a lightweight marvel of point-and-shoot simplicity. While my filmmaking ambitions rarely went beyond making my stuffed animals act out scenes from *Star Wars*, I somehow knew that communicating through video would be a defining feature of whatever it was that I would grow up to do.

Fast forward 20 years to graduate school, where I watched Professor Eric Mazur of the physics department at Harvard deliver a seminar on ‘peer instruction’ [1]. This method – which shares indistinct boundaries with similar teaching strategies variously referred to as the ‘flipped classroom’ or ‘active learning’ – relies on the students preparing for class by reading a chapter or watching a video and completing an assignment [2]. Class time is then used for problem solving in groups, with the professor behaving more as a ‘coach’

than a ‘performer’. The descriptor ‘flipped’ is thus twofold: problems ordinarily assigned as homework are done in class and peers do much of the teaching.

While there are many ways to incorporate elements of active learning into one’s teaching, it seems to me that it succeeds or fails by the type and quality of the pre-lecture material. In the original conception of peer instruction, the material was envisioned to be a selection from a textbook that the student was directed to ‘read before coming to class’. Some courses, however, are not amenable to prereading. For example, the textbook usually contains much more information than can be reasonably covered in one semester or quarter and animations are impossible to render on a printed page. Moreover, the level of writing in a textbook is often obscure and the usage is sometimes unsympathetic to new learners.

Videos, by contrast, address many of these problems. Humans evolved to understand the spoken word, not the written word [3]. Moreover, with the use of video it is possible to use gestures and facial expressions to communicate a level of subtlety that is impossible with writing alone. When a video is recorded in front of a live audience, expressions of confusion can cause an instructor to change their tack. Even when recording lectures in an empty classroom or office, an experienced instructor has often internalized the type of reaction an ill-formulated explanation is likely to elicit and can explain the concept again in a different way, in real time.

In 2017, I decided to start recording my lectures for use in future courses. I did this for three reasons. (i) I did not feel it was a good use of my time to give the same lectures year after year, semester after semester. Preparing for these lectures often involved memorizing derivations and other repetitive tasks that left little substrate for imagination. Why not record these lectures for my students (and myself) to learn from in future years? (ii) With the lectures recorded, I could use

them as a ‘video textbook’ for my courses. I would thus be free to ‘flip’ all of my classrooms, to transform class time from a traditional lecture – which the students have already seen – into a variety show comprising real-world applications, problem-solving strategies, and group design challenges. (iii) By putting these lectures online and making them freely available, it was possible to reach a vastly greater number of viewers than I could by delivering live, unrecorded lectures. As of this writing, my YouTube channel (‘Darren Lipomi’; Figure 1) has over 5000 subscribers with course material that has been viewed roughly 500 000 times. These statistics vastly outnumber my ‘impact’ as a researcher, at least by any citation metric. With the outbreak of COVID-19 in late 2019/early 2020, online course materials have taken on a new importance. Given the lack of time available to adjust, many instructors are understandably struggling to develop an approach. The default strategy emerging appears to be to mimic live lectures, but using an online platform. By contrast, I favor an approach that uses prerecorded lectures of the usual length (perhaps somewhat abbreviated) complemented by separate discussions involving the full class. These sections can take place at a set time, perhaps twice per week. This format preserves the strengths of the video lecture; namely, the ability of the students to watch it on their own schedule and to fast forward, pause, and rewind. It also preserves the type of interaction amenable to the flipped classroom, especially if the platform allows virtual ‘breakout’ rooms for peer-to-peer interaction. Furthermore, prerecorded lectures offer the opportunity to use somewhat higher production values than are available with webcams and on-board laptop microphones.

The Nuts and Bolts of Quality Amateur Video

I favor a minimalist style that emphasizes direct communication of the lecturer with

Figure 1. A still frame from one of my YouTube videos: 'Learning from Rejection in Academia' (<https://youtu.be/5zBoZzOgNts>).

the audience, in contrast to a style that uses extensive design components, transitions, and other technical 'eye candy'. A principle value of the instructor is the ability to serve as a learning coach and professional role model. While platforms such as Khan Academy are extraordinarily useful for teaching individual topics, their reliance on tablet-drawn diagrams and voice-over narration remove the instructor's face from the presentation; this distancing is to the detriment of empathy and inspiration that one might derive from interacting with a human instructor in a semester-long course.

A minimalist style does not mean bad production values – quite the opposite. The technology used in the video should be transparent to the viewer. A good video lecture requires not only rehearsal on the

part of the instructor, but also decent equipment. Blurry, shaky video and fuzzy, inaudible sound are a constant reminder of the presence of recording equipment (i.e., the opposite of a 'transparent' style). Depending on the budgetary constraints, a stand-alone 4K video camera should be used, along with a high-quality tripod. Sound should always be recorded in duplicate. An amateur creator such as myself inadvertently fails to record usable audio about 10% of the time and thus a backup source is critical. For recording in lecture halls, I recommend wearing two lapel ('lavalier') mics, one connected to a stand-alone recorder (e.g., the Zoom H1) and one connected to a wireless transmitter whose receiver is plugged into the camera. For recording in the office, I recommend plugging a lavalier mic with a

long cable directly into the input jack of the camcorder. The audio from the microphone embedded in the camcorder is usually of poor quality, although it is sometimes useful on editing as a fiducial mark to sync the higher-quality audio recorded independently. In offices, uncovered concrete, glass, and sheetrock walls produce reverb, which can be suppressed with a few slabs of acoustic foam. To avoid radio frequency (RF) interference, cell phones should also be kept away from audio equipment.

The quality of the image is determined by three things: resolution, stability, and lighting. It is best to record your source material as a 4K master. External hard drives can store many hours of ultrahigh-definition content at low cost. With most amateur camcorders, resolution degrades

with lack of stability. If you want someone to follow you around a lecture hall with the camera, a thick-legged tripod with smooth tracking is essential; a gimbal for stabilization is also helpful. With lighting, the goal is to reduce shadows on the performer's face. That is, light sources should be diffuse and behind the camera. If there is a window in the office, it should also be behind the camera. A good investment would be a pair of square LED arrays to eliminate shadows. It is not vanity: I have found from the analytics of my more amateurish uploads that they have poorer audience retention and fewer views than the ones in which I paid greater attention to quality.

For editing, I use iMovie for tasks such as combining audio and video, adjusting audio levels, cropping, inserting cutaways, and occasionally removing minor hiccups in my speech. Nevertheless, around half of my videos are uploaded with no processing. A helpful trick is to use a camcorder that can be started and stopped using a smartphone, and thus it is rarely necessary to clip the beginning and end from a video. This simple step saves potentially hours of resaving minimally edited videos.

Video is the natural medium for Millennial and Generation Z students. It is already ubiquitous in their lives and is underutilized in higher education. Amid the tragedy of the COVID-19 pandemic, one body of knowledge that is sure to be created is a trove of best practices in the area of remote coursework. It is my belief that this knowledge will ultimately improve the quality of higher education, long after the crisis has passed.

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Science & Society

Artificial Photosynthesis Beyond Water Splitting for Environmental Remediation

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Artificial photosynthesis potentially offers solutions to the world's looming energy and environmental crises. Here, we discuss the ongoing challenges of commercializing traditional artificial photosynthetic systems based on water splitting and highlight the advantages of replacing the water oxidation half-reaction with value-added alternatives, including biomass valorization and plastics upcycling.

Economic Challenges in Using Traditional Artificial Photosynthesis to Overcome the Energy Crisis

There is growing recognition that the world faces impending energy and environmental crises if we maintain the status quo of relying heavily on fossil fuels. The combustion of fossil fuels produces CO₂, a greenhouse gas that traps heat in the atmosphere, and is largely responsible for global climate change. Despite this, remarkably little progress has been made to wean the world off fossil fuels. Over a decade after the 2007 Nobel Peace Prize was awarded to the Intergovernmental Panel on Climate Change and Al

Gore for bringing the attention of the world to anthropogenic climate change, the demand for crude oil is still rising. In fact, the International Energy Agency expects oil demand to continue growing for the next two decades, owing to the population and economic growth of developing countries.

The need for renewable energy storage has spurred research in batteries, supercapacitors, and artificial photosynthesis, with the last being especially attractive since sunlight can be harvested to produce the same chemicals currently derived from fossil fuels. Drawing inspiration from natural photosynthesis, in which water is oxidized to O₂ and reduced to energetic hydride equivalents, research in artificial photosynthesis has been preoccupied by the development of photo- and electro-catalytic methods to split water into H₂ and O₂. However, only H₂ is a fuel, whereas O₂ is an innocuous by-product that already constitutes around 21% of the atmosphere, affecting the cost competitiveness of this process. In a recent technoeconomic analysis, the price of H₂ produced by using renewable resources to split water is currently around US \$3.50/kg and is projected to fall to around US\$2.60/kg by 2030 [1]. To put things in perspective, the price of H₂ produced from coal or natural gas is currently around US\$1.30–1.50 [1], and both coal and natural gas reserves are still being uncovered. In other words, if we used artificial photosynthesis to produce H₂ fuel solely for the cathodic half-reaction, with no additional value-added reaction for the anodic half-reaction, it would not be economically viable in the foreseeable future without collective action on introducing a sufficiently high carbon tax by governments worldwide.

Mitigating Climate Change and Overcoming Plastics Pollution Simultaneously

As a harbinger of the catastrophes to expect from global climate change, 2019 was a year when uncontrollable wildfires were