ONLINE VIDEOS: WHAT EVERY INSTRUCTOR SHOULD KNOW

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Introduction

Instructors in STEM fields are increasingly developing online videos for use in flipped courses or simply as supplementary resources for students. Although research interest in video predates the rise of massive open online courses (MOOCs) in the last few years, [11] the rapid proliferation of these courses with video at their core has helped reinvigorate interest in video as a medium for communication, learning, and research. This renewed attention opens up two significant opportunities for researchers and instructors. First, the scale with which researchers can now collect data not just on video usage, but also from video usage, opens up avenues for inquiry that were not feasible before. [7] Second, the experimentation that video producers, instructors, and researchers can now carry out is both faster and wider than before. [5] One byproduct of this creative opportunity, however, is the challenge faced by instructors in identifying practical insights and principles to apply when considering and/or developing videos.

In this paper, we aim to achieve two objectives: (1) summarize the research surrounding online educational videos, and (2) provide a list of seven recommendations for creating educational videos high in pedagogical value. We are writing this paper primarily for instructors and instructional designers, so we focus both objectives on creating online videos that then exist in the context of a wider educational endeavor (e.g., an online or blended course). In the first section, we address the issue of the best design model for educational videos. In the second section, we review various literatures to provide three different lenses for understanding online video. In the third section, we recommend practices for creating online video. Finally, we outline different avenues for future work based on both the reviews and the recommendations.

Choosing the Right Model

When thinking about the best design for educational videos, several authors draw a comparison between educational videos and commercial films, channels, and television. [4,25] The analogy makes sense on one level and especially drives home the point about the "appeal" of educational video content being nowhere near that of, say, the latest superhero movie. But, as Table 1 shows, if we compare a Hollywood blockbuster to a classroom instructional video along the lines of production, [7,12,23,24,31] purpose, [23,24,31] proliferation, [23,31] pedagogy, [1,23,24,31] and place/positioning, [24,25,31] then the analogy is both unfair and uninformative. Although these dimensions and the names for them are our own (we could not find a prior framework for this kind of analysis), the inspiration for each dimension comes from prior work, as indicated by the various citations for each. To say that instructors should strive for the level of appeal of studio-backed films because audiences pay to sit through them willingly and even enjoy them is unrealistic and also not the right guiding principle. The simple reason is that the viewer intention (e.g., I paid for this movie), mechanisms for engagement (e.g., special effects and fresh takes on familiar plots/themes), and pedagogical objectives (e.g., exposing or re-framing via a documentary) are completely different.

Depending on what an instructor aims to achieve with a particular video, a better model from which to draw lessons and inspiration might be either a TED talk, a YouTube educational video (e.g., Veritasium for conceptual scientific knowledge), or a Khan Academy instructional video. These tend to be much closer in terms of their pedagogical objectives and purpose and also their production. The choice of comparison is not trivial because it sets expectations for production budgets (e.g., studio costs) and student outcomes (e.g., dropout rates). Given the number of companies, universities, and other entities producing online educational videos today, there are enough good models within the education field to emulate rather than going outside of it.

Three Research-Based Lenses Through Which to View Online Video

Research into video does not belong to any one particular field. Video – and more widely visual

	Hollywood Movie	TED Talk	Veritasium	Khan Academy
Production	Massive, professional, well-funded endeavor	Well-organized, rehearsed, and planned presentations	Low-budget single-camera shoots and interviews	Tablet-style, low-budget procedural videos
Purpose	Entertainment product guaranteeing a financial return	Engaging product guaranteeing educational value	Pose intriguing scientific questions and then answer them	Detailed explanations and step-by-step videos for STEM topics
Proliferation	Months-long global marketing campaigns with celebrities	Via an in-person conference and also online	Via its own dedicated YouTube channel	Initially via YouTube, now via the Khan Academy platform
Pedagogy	At the level of theme and without assessment	Conceptual knowledge, usually with a narrative	Inquiry-based exploration of conceptual scientific topics	Primarily procedural STEM knowledge
Place/Positioning	A standalone film or sequel within a wider franchise	A standalone offline presentation captured digitally	Online sequences of videos	Online sequence of videos that can be used in formal settings

Table 1. A table outlining four kinds of video: a Hollywood movie, TED talk (http://www.ted.com), Veritasium video (https://www.youtube.com/user/1veritasium), and Khan Academy video (https://www.khanacademy.org), according to five elements: production, purpose, proliferation, pedagogy, and place/positioning.

representation – represents a medium that one can study from a variety of perspectives, including that of communication for advertising, [17,19] education for learning, [16,19,24] and computer science for data mining. [7,16] A given portion of video may therefore be analyzed using different frameworks. Each framework acts as a lens that reveals and emphasizes some information that another lens might conceal or de-emphasize.

Lens #1 – Learning Cognition Lens

The first lens – learning cognition – frames video as a cognitive tool. This frame introduces models that emphasize not so much what the visual representation is, but how the brain processes the visual representation.

Two models in particular inform this view. The first model, known as the limited capacity information-processing model, sees a human being as an information processor with a limited capacity to handle information. [6,19] The processing itself unfolds in three subprocesses, or stages: encoding (turning environmental stimuli into mental representations constructed by the viewer); storage (linking the new mental representations to existing ones in memory); and retrieval (searching for and reactivating a stored mental representation). [17] Because one's capacity for actively processing information is limited and one can consciously allocate some of that limited capacity, two possible scenarios exist for sub-optimal processing of information. A person may allocate fewer cognitive resources than a task requires, or the task may simply require more cognitive resources than a person is able to allocate. The shortfall in needed cognitive resources can occur within any one of the three subprocesses. [17] Research employing this model focuses primarily on studying the mechanisms for engaging the subprocesses, managing memory, and orienting attention.

The second model combines the limited-capacity model with a dual-channel information-processing model (Figure 1). [19] This model suggests that humans possess two information-processing channels, with one handling verbal information (spoken and written words) and the other handling nonverbal information (pictures and other visuals). [19] These two streams of information are then handled by two separate sensory channels: the ears and the eyes. The brain, in turn, handles these two streams separately before combining them together into a meaningful unit of information to store in long-term memory.

Lens #2 – Learning Environment Lens

The second lens – learning environment – frames video as an environmental support tool. This frame introduces models that emphasize (1) the holistic nature of the learning environment, which includes objects, people, and resources beyond the video, and (2) the function that a video plays specifically within this learning environment. In other words, the lens identifies how instructors set up whole ecosystems to facilitate learning and how learners interact with those ecosystems when learning.

Kurt Lewin advocated for the study of the learning ecology as a way to motivate the psychological study of everything that might be physically, socially, and psychologically influencing a person's psychological state at a given time. [18] Acknowledging that video exists in a wider learning context (e.g., with multiple learning goals and various assessments), Schwartz and Hartman provide a framework that classifies video according to: the video's learning outcomes (doing, seeing, saying, engaging); the video's learning targets; outcome- and target-matched learning assessments; and video genres corresponding to those learning outcomes (Figure 2). [24] For instance, if the learning outcome of the video is for students to be able to recount facts, then the appropriate learning assessment might be a recall task, facilitated via a chronicle video. This model recognizes that different videos in a learning environment can play different roles and that videos interact with other videos as well as non-video resources in that environment. The instructor's challenge is how to best deploy each video at the right place at the right time with the right learning task.

Thanks to online distribution of video, however, the likelihood of a single educational video being used in multiple contexts is higher than ever. In a given recorded lecture or uploaded video, an instructor might reference another learning resource or another happening in class that an outsider might not at all understand. This means that an instructor needs to decide not only how a video applies in his or her context, but also how a video might apply in a completely different context. This reusability of video is, in fact, one of the promises of recording lectures and creating online video archives. Turro, Cañero, and Busquets describe the set-up of the Polimedia system at Universidad Politecnica de Valencia that specifically encourages instructors to produce videos that are completely reusable in other contexts. [31] To achieve this reusability, the Polimedia process asks instructors to break down the content into the smallest bits of digital knowledge, labeled a Learning Object (LO). The idea is for an instructor to create multiple digital video-based LOs that require no additional context (acting as standalone learning materials). The LOs may then be bundled into learning modules, and sequences of modules put together into what would be considered

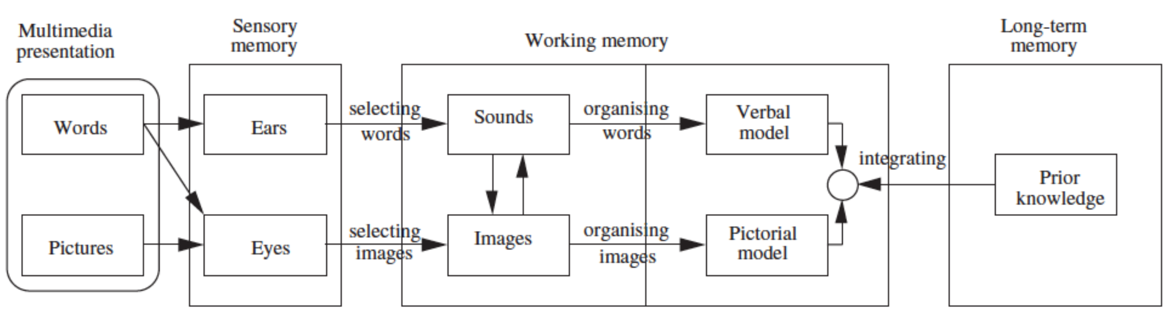

Figure 1. The multimedia learning model that integrates the dual-channel limited-capacity active-processing assumptions. Reprinted from Mayer. [19]

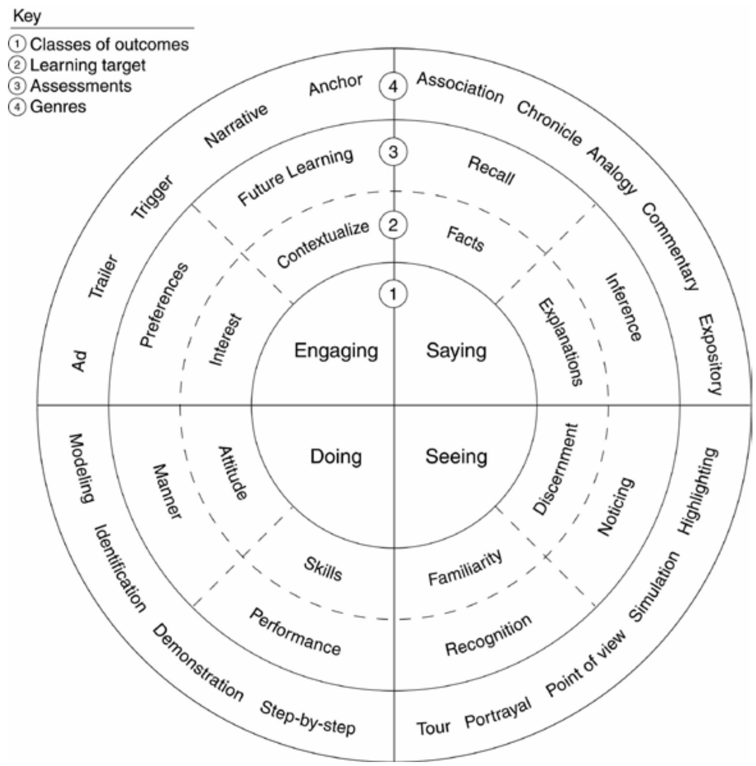

Figure 2. A framework for understanding the role of video within a wider learning context. Reprinted from Schwartz and Hartman. [24]

a traditional course. The choice of reusability as a guiding principle thereby influences the philosophy of production for instructors creating the content as well as the structure of pedagogy for instructors using the content. [31] In other words, these choices are not independent of or separate from each other; rather, they inform each other.

Lens #3 – Learning Data Lens

The third lens – learning data – frames video as a pedagogical researching/prototyping tool. Because a video is a standardized and replayable media artifact, researchers and instructors can use it multiple times without having to worry about variability in content or quality. [24] And because a single online video has the potential to reach a large number as well as a large variety of students, researchers and instructors can collect data to better understand that video's effect and value. The large scale makes it possible to separate signal from noise when analyzing student interactions with the video.

The focus is therefore on the video as a platform for collecting data to assist in understanding learners (habits, preferences), videos (content, style), and pedagogy (approach, assessment). Such analyses emphasize collecting data on viewing and interaction habits, identifying the influence of video production styles on those habits, and constructing learner profiles and histories from video and other data streams. The unit of analysis (and, therefore, scrutiny) tends to be clickstream data and, more specifically, when each user clicked on which button in the video player (e.g., pause, play, skip, rewind). [4-7,11,16,21-23,25,31] Because online learning platforms have access to learner data beyond the videos, analyses have also focused on the viewing habits of on-campus versus distance learners,[16] learners who drop out of the course and who do not, [8] and low- and high-performers on follow-up tasks, [10] to name a few dichotomies. With an increasing variety of courses and, in some cases, variety of video within courses, researchers can also investigate these learner behaviors across videos with low versus high production value, [7] procedural tablet-style videos versus conceptual lecture-style videos, [7,25] and videos with and without instructors as talking heads. [7,12] By analyzing these traces of learner behavior, researchers and instructors can draw conclusions about which segments of video to double-down on or re-design.

In addition to viewing a video as a platform for collecting data, this lens can also view a video as a platform for deploying data. Traditionally, television was a mass medium of communication that could neither target a particular audience nor adapt to an individual audience member's cognitive needs and preferences. In other words, a television ad could not guarantee that the people it wanted to reach would see the ad and, even if the ad reached the right audience, the ad could not modify itself to match each viewer best. The remedy is to assume and design content for an average viewer. Services such as YouTube and even Coursera have built recommendation engines that suggest the next video or ad or course that a viewer might be interested in. Constructing these viewer preferences and histories improves the targeting of content. The educational opportunity some researchers, instructors, and designers see now is in improving the adapting of content, specifically via the video player. Allowing the user to change the speed and direction of the video is only the beginning. What if we designed video players that show information on other viewers' interactions with the currently-playing video or that allow viewers to annotate the slides in real-time? These opportunities for designing more interactive, social, and adaptive video as well as learning interfaces are compelling because they take learning technology design beyond content recommendation and into learning personalization.

Recommendations

We include the recommendations below not as an exhaustive guide to all aspects of producing educational online videos, but rather as a starting primer to create such videos in line with robust findings and best practices.

Recommendation #1: Plan pedagogy before you produce video.

In the words of Mayer: "Decisions about how to design a multimedia message always reflect an underlying conception of how people learn - even when the underlying theory of learning is not stated" (p. 46). [19] Therefore, in line with the second and third lenses (learning environment and learning data), we highly recommend that before producing a video an instructor should clearly articulate the learning objectives of the video and identify how that video fits into the larger context of the learning environment. For high-level categorization of learning objectives, instructors can use the Schwartz and Hartman framework (Figure 2). [24] For low-level definition of learning objectives, instructors can use an adapted version of the learning objective framework from Ambrose, Bridges, DiPietro, Lovett, and Norman: "After watching this video, students will be able to _________." [1]

In other words, we are advocating for planning before producing at a pedagogical level. To our knowledge, no research study has yet robustly compared how a video with advance pedagogical planning differs from that without advance pedagogical planning. However, in their MOOC-scale video analysis, Guo, Kim, and Rubin used student viewing habits during their watching session as a proxy for measuring engagement and found that videos with extensive pre-planning were more engaging to viewers than those without. [7] The study compared recorded lectures from one course in which the instruction and production staff spent time outlining each lecture into discrete chunks and another course in which the instruction and production staff did not plan. A byproduct of advance planning is also less post-production efforts, especially less editing. [7] Taking the chunking method to its logical conclusion leads to the design and development of videos as fully reusable learning objects, as done in the Polimedia framework. [31] The advance planning can reveal which learning framework and corresponding production framework match the instructor's endeavor best.

Recommendation #2: If you are unsure how and where to start, start with procedural/problem-based videos.

Whether an instructor wants to create a few videos or a few hundred, every instructor needs to start somewhere. Research into video podcasts, [9] as well as other forms of digitally distributed video, suggest that students find online videos overall appealing and useful in their learning. [3,9,11] Summarizing the research into video podcasts from 2002 to 2011, Kay states that students tend to show "very positive attitudes toward video podcasts describing them as useful, helpful and effective, as well as enjoyable, motivating, and stimulating" (p. 825). [9] Furthermore, Kay points to several examples when the use of video podcasts has direct and positive impacts on test and skill performance. [9] Kay and Kletskin translated the principles of clear, step-by-step worked examples from paper into podcast form and showed that the clarity and step-by-step nature of the podcasts was one of the top reasons for driving the student appeal. [10] The appeal of these videos from the student side is understandable: students can practice procedures at their own pace and can see more problems worked in the manner the instructors wants. The appeal of these videos from the instructor side is also understandable: instructors already work through problems on homework assignments and in class anyway, so the content for these videos is already at the instructors' fingertips. In their initial analysis of MOOC videos, Guo, Kim, and Rubin found that tablet-style procedural (or tutorial) videos, such as those from the Khan Academy, showed longer student engagement than conceptual ones. [7]

Procedural/problem-based videos are therefore a promising starting point for an instructor producing online videos. This does not mean, however, that creating such videos is without its nuances. An extensive body of literature exists on written/paper-based worked examples [2] that can be of help in translating these learning exercises into video form. [10] We do not yet have an extensive body of video-based research to match the written medium, but we do have an extensive literature on multimedia learning that can provide an appropriate framework for producing these videos that we detail in the next recommendation. [20]

Recommendation #3: Use research-based multimedia learning principles in production.

Mayer summarizes decades of research into multimedia learning specifically for the purposes of producing medical education material, but the principles are generalizable beyond that context. [20] In fact, Kay and Kletskin used the outlined principles (summarized in Table 2) to craft pre-calculus mathematics video podcasts for first-year college students. [10] The principles fall into three categories: reducing extraneous processing (i.e., minimizing the impact of non-essential, seductive, and/or distracting information); managing essential processing (i.e., maximizing the impact of essential information); and fostering generative processing (i.e., facilitating making sense of information). While some of these principles make intuitive sense, others do not, and we highly recommend Mayer as an in-depth resource for more detailed and nuanced explanation of the principles and their respective mechanisms. [19] (As one example of a non-intuitive result: the argument is often made that because some students process words via narration better, while other students process words via reading better, both should be presented in a video or slide-show type of presentation. Research reveals, however, that showing written words along with narration tends to depress learning, due to cognitive interference effects. Thus the "modality principle": present words in spoken form for best results.)

Principles for reducing extraneous processing
Coherence principle: eliminate extraneous material
Signaling principle: highlight essential material
Contiguity principle: place printed words near corresponding graphics
Principles for managing essential processing
Pre-training principle: provide pre-training in names and characteristics of key concepts
Segmenting principle: break lessons into learner-controlled segments
Modality principle: present words in spoken form
Principles for fostering generative processing
Multimedia principle: present words and pictures rather than words alone
Personalization principle: present words in conversational or polite style
Voice principle: use a human voice rather than a machine voice

Table 2. Organizes and summarizes the key multimedia learning principles that can be applied, but are not limited, to video. Adapted from Mayer. [20]

Researchers who have studied MOOC videos have also found results that apply to non-MOOC contexts as well. First, high production value might not matter as much as often believed. What seems to matter more (in line with one of Mayer's principles) is personalization for the viewer. [7] Specifically, Guo, Kim, and Rubin found that viewer engagement was higher for videos with a professor speaking informally at his/her desk and making direct eye contact with the camera than for videos with a professor lecturing from behind a podium and looking around a large lecture hall. [7] Second, a video that includes lecture slides interspersed with the instructor at a desk or whiteboard (as opposed to videos that contain only slides or only a "talking head") showed higher median student viewing engagement and higher attempt rates of problems following the video. [7] An eye-tracking experiment of a video with and without the instructor's talking head revealed that viewers spend about 41% of their time watching the instructor's face. The viewers also strongly preferred the videos with the instructor's face despite no significant difference in performance on a post-video test. [12] Third, the content and order of the first videos in a sequence can substantially affect learner disengagement. [13] This last point is especially subtle and difficult to analyze without a culturally diverse and large-scale demographic – the takeaway is to be aware that the first few videos in a sequence can have lasting effects on a learner's psyche.

Recommendation #4: Choose the appropriate interactive activities for your video.

A variety of online education platforms – Udacity (https://www.udacity.com), Coursera (https://www.coursera.org), OpenEdX (https:// open.edx.org) – regularly interrupt their videos with interactive activities such as in-video quizzes (e.g., multiple-choice questions, text-input questions, and so on). The logic for including these in-video quizzes is understandable. First, filling out the in-video quizzes serves as a policing function to ensure that viewers are paying attention. Second, the quizzes can serve as an assessment for evaluating how well the viewer processed the information presented.

An additional reason to include in-video interactive activities is that educational videos can encourage overconfidence. When students watch video lectures, they tend to predict their performance on a post-video learning task will be much better than the actual result. [28] Szupnar, Jing, and Schacter split up 54 high school students into three groups: watching video and performing on a learning task (0-test condition); watching video, taking a single test after the video, and then performing on a learning task (1-test condition); and watching video interrupted with four tests and then performing a learning task (4-test condition). [28] The authors had students predict their performance on the post-video learning task and found that (a) students are in fact overconfident about their learning after watching video-recorded lectures, (b) in-video testing improves students' predictions about their actual performance on the learning task, and (c) a single post-video test also helps to adjust unrealistic expectations. [28] Therefore, some sort of in-video or post-video testing, or both, is recommended to check viewer expectations about their own learning.

Recommendation #5: When determining an appropriate video length, somewhere in the range of 5-15 minutes is recommended.

There is no conclusive body of literature on the optimal length of an educational video, but in general shorter is better. Guo, Kim, and Rubin point to a drop in student viewership and engagement at around the 6-minute mark in a variety of science, technology, engineering, and mathematics MOOC videos. [7] Using a similar procedure to analyze viewership patterns and engagement in online videos in two hybrid/flipped college-level computer sciences courses with on-campus as well as distance learners, Lagerstrom, Johanes, and Ponsukcharoen found that the critical loss in viewership and engagement occurs at approximately 15 to 18 minutes. [16]

It is therefore recommended that educational videos be designed to last between five and fifteen minutes. In addition, when at all possible it is recommended to create a first batch of videos as prototypes and then iterate, via testing and feedback, to more effective final versions. Shorter lengths also force the instructor to think carefully about what to include and what not to include, as well as allow for easier editing and re-recording, if necessary. Nevertheless, because every combination of video, instructor, environment, and viewer represent a unique context, the same premise might require a longer video in one context and a shorter one in another. The only way to find out for sure is to experiment.

Intuitively, it makes sense that students should find it easier to sit and watch shorter rather than longer videos. What is not clear is what these short timescales communicate. On one hand, it could be that viewers start engaged and lose engagement until they stop watching. This hypothesis frames viewer retention as a problem of sustaining engagement. On the other hand, it could be that these videos might not be engaging to begin with and are depleting viewer willpower or patience: viewers start un-engaged and gradually lose the will to continue watching until they finally stop. This hypothesis frames viewer retention as a problem of generating engagement and/or supporting willpower. Determining which hypothesis (or another one) may apply, is another reason for taking an iterative approach to online video development.

Recommendation #6: Make educational video production a team effort rather than a solo activity.

One of the takeaway messages from these recommendations is that producing educational videos high in pedagogical value is a complex activity with a lot of nuance to it. Every instructor cannot be expected to possess all of the knowledge and skills required to produce such videos, nor should every instructor have to produce them alone. In wanting to understand what kinds of knowledge one needs to teach, Shulman created a framework that delineates between teachers requiring subject-matter content knowledge (e.g., knowing mathematics) as well as pedagogical content knowledge (e.g., knowing how to teach mathematics). [26,27] In other words, even if one knows a lot of mathematics, that does not mean that one knows how to teach mathematics. More importantly, even if one knows a lot of mathematics and a lot about how to teach mathematics (say, at the college level), but does not know a lot about how to teach mathematics to the students in one's classroom (say, at the elementary school level), then one's teaching ability will most likely be diminished. Shulman's framework elucidates the idea that some threshold of knowledge (in these various areas) is necessary, but not sufficient – that a great teacher needs to have the right alignment/overlap of that knowledge to his/her particular context. [26,27]

Building on Shulman's framework, Koehler and Mishra created a framework called technology, pedagogy, and content knowledge (TPACK) to address the increasing use of complexity as well as of technology in the classroom. [15] The important contribution of this framework is that Koehler and Mishra explicitly communicate that teaching has become so interwoven with technology that instructors need to better understand educational technology and/or seek out support in those fields of knowledge (see Figure 3). [15] The framework communicates that there is a difference between technological knowledge (e.g., knowing how to create online videos) and technological pedagogical knowledge (e.g., knowing how to create online videos for teaching purposes) and technological pedagogical content knowledge (e.g., knowing how to create online videos for teaching mathematics in a specific educational setting). [15] As Shulman does, Koehler and Mishra communicate that quantity and variety of knowledge is not enough to produce a great technology-savvy educator – it is the overlap of enough quantity and variety of knowledge that matters. [15,26,27]

However, based on the above review of research, we would add to this framework two additional knowledge components when it comes to video: media knowledge and data knowledge. Media knowledge is distinct from technology knowledge in that media knowledge specifically encapsulates the process of pre-production, production, and post-production within a given medium such as video. After all, even if an instructor knows how to operate a camera and upload a video to YouTube (both of which can be considered technology knowledge), this does not mean that the instructor knows the ins and outs of video production and storytelling as a trained film producer might. Similarly, as the number of students and the nuance of the data increases, data knowledge will become increasingly important. Data knowledge not only includes simply operating an Excel spreadsheet and graphing a distribution (arguably contained within technology knowledge), but rather the knowledge and skill set to collect, analyze, and visualize data in meaningful and pedagogically actionable ways. Especially with the increasing scale of collected data, these data analysis endeavors more frequently require using and/or designing machine learning algorithms. [7] While some individuals exist who have the requisite expertise across these areas, and some institutions will specifically train individuals at the center of these knowledge areas (see Figure 4), the fact of the matter is that it is usually much easier and much more enriching to bring a team together. To that end, we highly recommend finding a team with pedagogical, content, technology, media, and data knowledge.

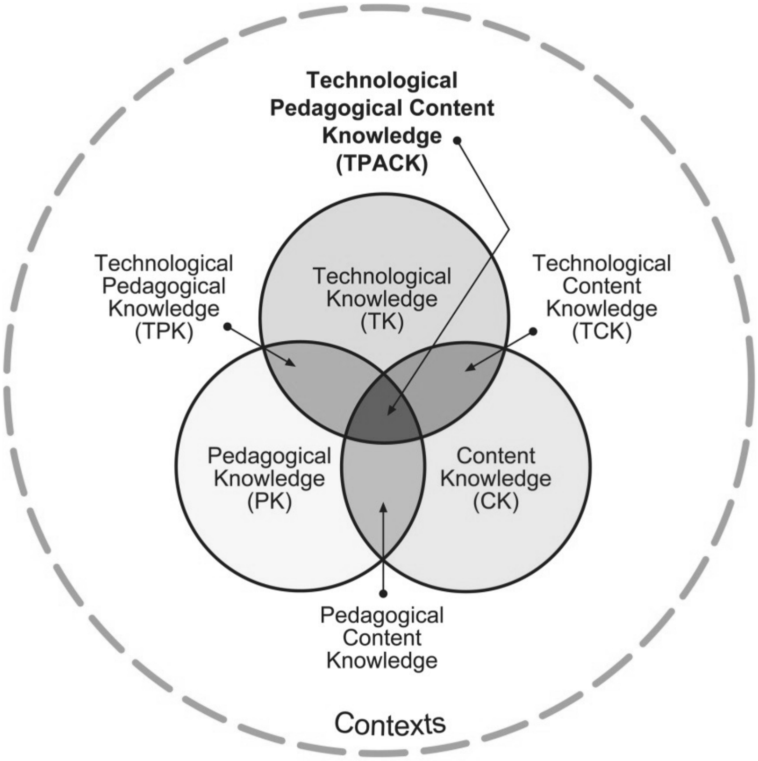

Figure 3. The TPACK framework. Reprinted from Koehler and Mishra. [15]

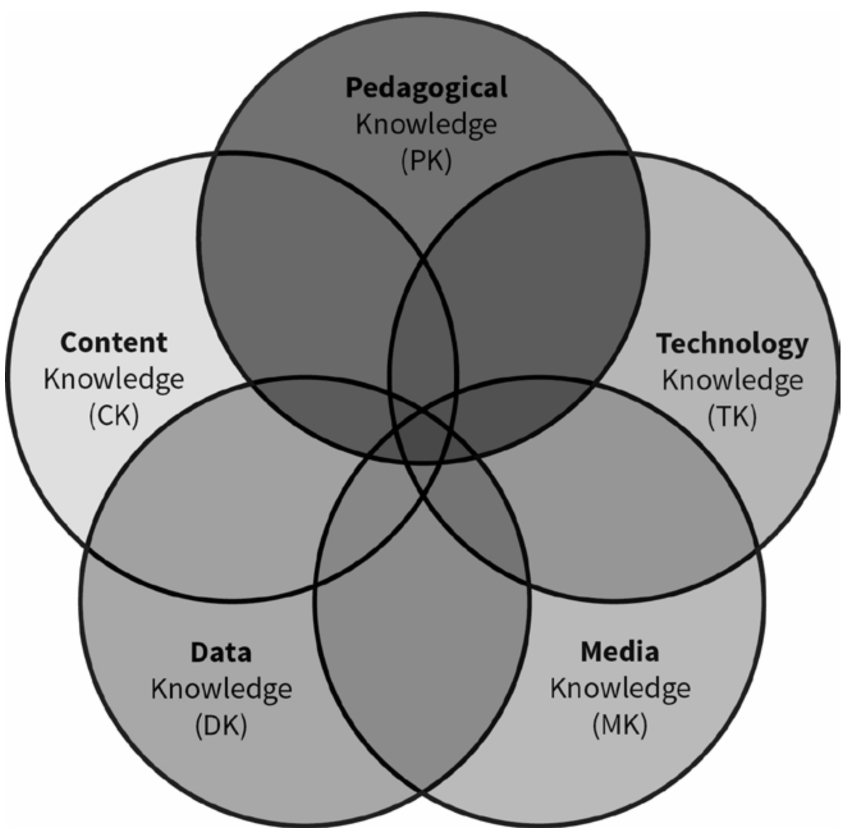

Figure 4. The TPACK framework [15] expanded to include media knowledge (MK) in green and data knowledge (DK) in orange, reflecting the new demands in educational video production.

Recommendation #7: Don't rely just on online videos.

While online videos can be an important part of an effective learning environment, don't overlook other online or computer-based tools. Online interactive simulations such as PhETs (https://phet. colorado.edu/) or interactive textbook, homework, and discussion platforms (e.g., Piazza (https://piazza.com), zyBooks (https://zybooks. zyante.com/#/zybooks), Sapling Learning (http:// www2.saplinglearning. com), or other learning management systems and publisher sites) can provide the "goal-directed practice with targeted feedback" [1] that is essential to deep student learning. Two excellent resources for STEM instructors seeking practical advice and examples of effective pedagogy are:

- Nancy Kober, *Reaching Students: What Research Says about Effective Instruction in Undergraduate Science and* Engineering [14] Available for free online reading or as free pdf download at http://www.nap.edu/catalog/ 18687/reaching-students-what-research-says-about-effective-instruction-in-undergraduate. Topics covered include active learning, formative and summative assessments, concept inventories, clickers, collaborative learning, scaffolding, flipped classes, just-in-time teaching, metacognition, peer instruction, problem-based learning, practice-based instruction, and animations and simulations. It also includes twenty "Designing Learning" case studies that highlight practical ways to implement many of these techniques.

- The Carl Wieman Science Education Initiative, *Evidence-based Science Education in Action* (videos demonstrating flipped classes, clickers, framework activities, worksheets and other strategies, available at http://blogs.ubc.ca/wpvc/). [29] From the website: "This collection of videos was inspired by the observation that instructors are most likely to consider trying new teaching strategies after watching a colleague or a video that demonstrates the strategy in action in a real setting." [29]

At a practical level, this recommendation serves as a reminder that video is not a panacea to all educational woes for all student learners. In combination with recommendation #1, let the choice of pedagogical practice and learning problems guide the choice to use video.

Future Work

One of the themes in this literature review is that much about online learning and especially the use of online video for learning remains unclear, unknown, and untested. Below, we propose future work based on the three lenses:

- *Conduct a content analysis of existing MOOC and hybrid/flipped courses based on the Schwartz and Hartman framework.* [24] We imagine a research endeavor that would map out the videos and assessments and learning goals to better understand which combinations are the most popular, the most successful, and the least prevalent. We expect that most videos will belong to the "do and say" learning outcome category.

- *Test out the interaction of different video formats in a learning environment.* Currently many online courses display a limited subset of video formats despite the wide number of possibilities (Figure 2 includes nineteen, for instance). It would be informative to see how learner viewing engagement, dropout rate, and learning performance change as the number of video formats in a course strategically increases. For instance, does a trailer for each course chapter cause a noticeable difference in learner engagement? By testing out different combinations of video, we might arrive at a more stable subset of video formats that create the most beneficial learning conditions.

- *Experiment with new video players and learner data integration.* With the resurgence of research interest in video analytics, researchers have begun creating a variety of new video players, each aimed at leveraging a different aspect of online learning. For instance, one video player creates an on-screen interactive learning "e-Partner" that evolves in terms of shape, size, and behavior to point out visually interesting and aurally salient features of the video. [4] Other video players include: Mudslide for experimenting with student annotation and reflection around confusing points, [6] ToolScape for experimenting with video timeline-based annotation, [23] LectureScape for experimenting with learner crowdsourced video interaction peaks/timelines, [11] and Crowdy for experimenting with summarization and self-explanation exercises. [31]

We expect that video production will remain a staple of online learning, which means that video analysis will also remain a staple of online learning. We do expect, however, that the role of video will change in online learning as video production becomes increasingly more strategic and as the video production and data production activities become more closely aligned.

Conclusion

Our purpose in writing this literature review is to provide those either producing their first set of online videos and/or re-visiting their last set of online videos with a foundation of useful frameworks and findings. Based on our review of the relevant literature along three lenses – learning cognition, learning environment, and learning data – we provide seven research-based recommendations for producing online educational videos, summarized in Table 3. We hope that this review will be of use to instructors, instructional designers, researchers, and anyone else involved in the increasingly collaborative effort to produce effective educational videos.

1. Plan pedagogy before you produce video.
2. If you need to start somewhere, start with procedural/problem-based videos.
3. Use research-based multimedia learning principles in production.
4. Choose the appropriate interactive activities for your video.
5. When determining an appropriate video length, somewhere in the range of 5-15 minutes is recommended.
6. Make educational video production a team effort rather than a solo activity.
7. Don't rely just on online videos.

Table 3. Re-statement of the seven research-based recommendations for producing online educational videos.

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