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Building Effective Online Education Video Lectures:
Recommendations from Research and Practice

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ABSTRACT

As universities continue to increase their online course offerings, faculty developing online course content may find that in-class practices do not always transfer effectively to the online environment. This paper focuses on how instructors can better design and develop video lectures to improve student learning outcomes. Incorporating multimedia principles as well as lessons from practice, it is shown that effective video lecture development requires the consideration of length, structure, interactivity, accessibility, and personalization.

KEYWORDS: Online Education, Video, Educational Design

INTRODUCTION

Universities face an increasing demand for online courses, a shift driven not only by technological developments but also by the changing nature of the student population and by the universities' aim to expand their enrollment by serving out-of-state and overseas students. (Eduventures, LLC., 2006) In addition to providing educational opportunities to remote students, online courses are also valuable to local students whose schedules do not accommodate regular class sessions. (Preston et al, 2010)

The development of online courses may require educators to rethink their approaches to educational design and development. The education community's early attempts at developing pedagogy for online education have proved "daunting," as existing educational theories needed to be applied to a broad variety of new and often untested teaching practices and tools. In addition, educators' initial online education efforts were commonly based on assumptions from the traditional classroom environment, resulting in limited pedagogical insights. (Knowlton, 2000) Since then, we have learned that both teaching and studying in a distance education environment can be more difficult than in a classroom setting. (Geri, 2012)

A common aspect of online course development is the creation of video content, often in the form of video lectures. Video lectures can be defined as "CD and web viewable files that present lecture materials and narrative instruction from a course's instructor." (Brecht & Ogilby, 2008) Research has not only shown that students prefer video lectures over text, but also that the combination of auditory and visual information is superior to text in enhancing the conceptual understanding of educational content. (Ibrahim et al., 2012)

The author has taught online courses for more than 10 years and in the process realized that the transition from delivering in-class lectures to developing online lectures requires an educator to consider both pedagogical modifications and technical solutions.

From a pedagogy standpoint, the author has found that the dynamics of an online lecture differ greatly from a traditional in-class lecture. In online lectures, which tend to be recorded as a

narration, direct interaction with students is absent: the students can't be queried about how well they've understood a particular concept, there are no student questions or requests for clarification, and the instructor can't work out a problem on the class whiteboard in real time. In online education, such direct interactions with students usually take place outside of the lecture. Due to the absence of this interaction, it often becomes necessary for the lectures to be rewritten before they are recorded. Based on in-class experience, clarifications and examples can be added to the lecture itself, as these can't be extemporaneously added as one might during an in-class lecture. The question arises whether these changes are all that is needed to create effective video lectures.

The objective of this paper therefore is to examine current state of research and development of video lecture development, particularly in higher education. What practices are most effective for engaging students and promoting learning? What does current research recommend regarding the design and development of online video content? What level of digital literacy should university faculty attain to develop effective lecture videos?

The technology to produce lecture videos is now affordable and quite easy to use. Using a web-cam and a microphone, faculty members can now record online lectures at their desks. A variety of software packages - such as Camtasia Studio (www.techsmith.com/camtasia.html) or Adobe Presenter (www.adobe.com/Presenter) - are available to capture the visuals and narration of a lecture and subsequently edit these into a complete online lecture.

Given the increasingly sophisticated features of these software tools, the challenge to instructors is to develop instructional videos which direct student attention to the relevant content in the most effective manner, while avoiding cognitive overload brought on by presenting too much complex information too quickly. (Ibrahim et al., 2012) This, then, requires instructors who develop lecture videos to comprehend what design characteristics will result in videos that are engaging, effective, and likely to be viewed by students. (Kim et al., 2014b) Such comprehension is at times lacking. For example, a study by (Preston et al, 2010) found that a substantial portion of faculty who had developed lecture videos often would not change their in-class lecture style, content, or structure. Yet what may be effective for in-class lectures may not necessarily be as effective in a video format. Indeed, (Koumi, 2015) argues that the requirements for the design of videos which both engage students and support student learning are greatly underestimated.

A better understanding of the use and effectiveness of online video lectures is now possible through the use of sophisticated tracking tools. Using video server logs which trace viewer activity, student viewing patterns and their interactions with the video content can now be analyzed in great detail, resulting in fresh insights for instructors and educational designers. (Guo et al, 2014; Kim et al., 2014a; Kim et al., 2014b) Tracking of student performance on quizzes and exercises which follow video lectures provides greater insights in the learning outcomes of various approaches to video lecture development. (Brecht & Ogilby, 2008; Merkt et al, 2011) When these insights are combined with educational theory developed to specifically address online lecture content, it becomes possible to provide specific and actionable recommendations for educators seeking to effectively deploy available technologies in order to transform their courses and create new learning opportunities for their students. (Chorianopoulos & Giannakos, 2013)

This paper will first examine the properties of video lectures, as well as the role of instructors developing these videos. A review of the principles of multimedia learning will provide a

theoretical foundation for lecture video design. This is followed by an overview of video lecture development practices, with a specific focus on ensuring video accessibility, examining proper video length, applying structure to a video's content, and incorporating interactive features. The paper will then review current research which examine these development features and finally concludes with some specific recommendations for lecture video development.

USES, BENEFITS, AND DRAWBACKS OF VIDEO LECTURES

The initial development of video lectures in higher education targeted their deployment in online education courses. As mentioned earlier, these courses no longer focus solely on attracting remotely located students, but are now also recognized as a convenient and flexible learning option for local and on-campus students who face other work and family commitments (Green et al., 2008; Preston et al, 2010)

Once a course's lectures have been recorded, their availability provides for some additional uses as digital course content can easily be distributed and shared. An instructor may provide these recordings to in-class students in case class-time has been cancelled or when individual students have been unable to attend. Recorded lectures can also be provided to students in other courses who need an introduction to or a review of a topic. An instructor can easily create a small set of lectures designed to bring auxiliary content to a course (such as a software tutorial), or to provide remedial instruction for students lacking some prerequisite knowledge. (Brecht & Ogilby, 2008; Pavel et al., 2014)

Video lectures also allow an instructor to redesign the overall educational process of a course and present it in a flipped-class format. In this design, the students watch the online lectures as homework so that limited in-class time can be used for active learning practices such as interactive tutorials, hands-on workshops, problem-solving sessions, class discussion, or answering student questions. (Brecht & Ogilby, 2008; Preston et al, 2010)

In addition to the above uses, the availability of soundly developed lecture videos provides some clear benefits to educational institutions, educators, and students. For an educational institution offering online courses and the instructors teaching these, the availability of lecture videos permits their use in multiples sections of a given course. Instructors other than the person who developed the lecture videos can more easily administer an online course section without having to invest additional development time and effort. Use of existing lecture videos in this way also ensures that all students enrolled in the various course sections receive consistent content of a known level of quality. (Green et al., 2008; Preston et al, 2010) The more existing course content is utilized in these ways, the more appealing it becomes to the educational institution to invest in its continued development.

The use of lecture videos also provides great potential benefits for students. A collection of lecture videos provides students with a digital vending machine of knowledge which students can access anytime and anywhere. (Brecht & Ogilby, 2008; Pavel et al., 2014) Students who lack some prerequisite knowledge for a course can fill this need outside of the classroom, studying at their own pace.

For complex course content, students are able to view digital lectures multiple times in order to help comprehend the material in order to prepare for assignments or exams. These videos can be paused and repeated as will, providing the student with substantial control over the learning

process. When students assert greater control over their own learning, this has been found to improve both student engagement and learning outcomes (Brecht & Ogilby, 2008; Brecht, 2012)

Video lectures also appear to appeal to student learning preferences in today's media culture, which is substantially video-based rather than text-based. As such, students may learn more effectively. (Brecht & Ogilby, 2008; O'Rourke et al, 2014; Preston et al, 2010) Moreover, (Geri, 2012) argues that video lectures may engage online education students better by enhancing social interaction in an online course. Video is a richer medium than written text for establishing a social connection between instructor and student, especially when the video lecture permits the instructor to include non-verbal cues such as tone of voice or facial expressions. (Jadin et al., 2009) In this way, the instructor's presence "resonates" more clearly than it could in text, which in turn may enhance both student learning outcomes and student retention. (Geri, 2012) An interesting example of this resonance was provided by (Green et al., 2008) who described how some lecturers would actually directly ask questions to students watching an online lecture, only to see students subsequently post answers to those questions on an online discussion forum.

Some drawbacks to the use of video lectures have been observed. First, (Preston et al, 2010) cite the concern of faculty that the availability of lecture videos for students enrolled in a traditional course may reduce student attendance at in-class lectures. Students were found to perceive this differently. They viewed lecture video availability as a positive to help them better comprehend complex content that was discussed in class and to help them study for examinations.

A more serious drawback is that in an online learning environment, lecture videos are not a complete replacement for the direct teacher-to-student and student-to-student interactions that occur in the classroom. Online students can't ask a lecture video to clarify a confusing explanation, which requires these students to have higher levels of intrinsic motivation and greater self-discipline when it comes to learning course content in order to be successful. (Jadin et al., 2009) While this drawback applies to online education in general rather than to lecture videos per se, it should encourage educators to not only develop lecture videos which provide clear and comprehensible explanations, but also to provide for effective communications options in online courses, such as e-mail, web-chats, or online forums.

ONLINE LECTURES AND THE CHANGING ROLE OF EDUCATORS

The increased usage of digital technology for both in-class and online education requires new layers of technical skills from educators. (Green et al., 2008) state that the popularity of online lecture videos in particular has changed the roles of educators to instructional designers, complicating the existing teaching efforts within this "technology rich environment." A study by Easton (2003) confirms that the skills and processes involved in teaching online courses are similar to teaching in-class courses, but stresses that the traditional approach to instructional design requires a fresh perspective. Instructional design requires not only the development of course content (such as lectures and readings) for online distribution, but must also consider the means by which other course mechanics (exams and quizzes, student presentations, responding to student questions about course content, etc.) are to be executed in the online environment.

(Berge, 1995) insists that "the ultimate technical goal for the instructor is to make the technology transparent" so that "the learner may concentrate on the academic task at hand." Two decades'

worth of progress and innovation in online communication and collaboration technologies have brought educators closer to achieving this transparency. These technologies are now more affordable, reliable, powerful, and usable than ever before, permitting educators to select those specific applications and platforms that will help them meet educational objectives. Moreover, these technologies are becoming ubiquitous in education, rather than being limited to online education efforts. As these technologies are being embedded in existing educational processes, technology usage is likely to disappear as a separate role altogether. Instead the focus of educators will be on the effective implementation of available technology options in various educational settings. (Van Vliet, 2015)

For many educators, this wave of technology-driven change has resulted in new and ongoing requirements for professional development. A survey by (Kaltura, Inc., 2015) found a clear need for educator training on the tools that permit them to independently create and edit video content. (Green et al., 2008) advocate that educators take a broader perspective in their development. Educators should obtain insights on how students use online learning technologies and how both broad curricula and individual units of study can be optimized to take advantage of these technologies. This paper aims to provide instructors with current insights in the most effective design of video lectures.

PRINCIPLES OF MULTIMEDIA LEARNING

The current research and development efforts in educational media have been greatly influenced by the work of Richard E. Mayer. Mayer's work focuses on connecting the science of learning (which is student-focused) with the science of instruction (which is educator-focused) as it relates to multimedia-based education. (Mayer, 2008) Based on extensive research, Mayer summarized his findings as a series of principles for educational multimedia development in his influential 2001 text "Multimedia Learning" (Mayer, 2001)

At the heart of Mayer's work is what he calls the **Multimedia Principle**, which states that "students learn better from words and pictures than from words alone." (Mayer, 2001) Mayer asserts that even when the information contained in an image and in a piece of text are practically identical, this information is represented in two different formats, resulting in two distinct mental representations. Mayer bases this on a key notion from the science of learning, which is that humans possess two distinct channels for processing verbal and visual information. Consequently, Mayer developed a cognitive theory of multimedia learning which posits that when students experience a multimedia presentation, the words and images of that presentation are processed into both a verbal model and a pictorial model in working memory. These models are subsequently integrated using the prior knowledge drawn from the student's long-term memory. The effectiveness of multimedia learning, then, is based on the appropriate balance of verbal and visual information presented to the student in a way that does not exceed the student's cognitive capacity. (Mayer, 2008; Mayer & Fiorella, 2014) This can most easily be achieved when the narration specifically supports the graphic that is on screen, so that concurrent learning can occur. The combination of on-screen graphics and a spoken narration permits students to effectively connect them. (Moreno, 2006)

Mayer subsequently organizes his theory into three categories of principles: those which reduce the inclusion of extraneous information, those which address the proper presentation of essential content, and those which address student comprehension of the content.

Mayer considers the inclusion of unnecessary or extraneous information to be one of the most important flaws of ineffective multimedia content. The extraneous content requires the student to process more information than is necessary – referred to as extraneous cognitive processing – which places an unnecessary burden on the student's cognitive capacity. (Mayer, 2008; Mayer & Fiorella, 2014) Mayer articulated five principles which aim to reduce extraneous processing: (Mayer & Fiorella, 2014)

- **Coherence Principle:** Learning improves when extraneous words, pictures and sounds are excluded. While the inclusion of embellishments or so-called "seductive details" may appear to spice up a presentation, this information places a needless burden on the student.
- **Signaling Principle:** Learning improves when the presentation includes cues about its organization. For example, a text may start with an organizational sentence which lists five main items, which is then followed with numbered descriptions of each item.
- **Redundancy Principle:** The combination of animation and narration is more effective than the combination of animation, narration, and on-screen text. The student will obtain the textual information from the narration so that the visual component of the presentation can focus on imagery alone.
- **Spatial Contiguity Principle:** Learning improves when related words and pictures are shown adjacent rather than apart. The student does not have to scan the entire display to make this connection.
- **Temporal Contiguity Principle:** Learning improves when related words and pictures are presented simultaneously rather than in succession. If the student needs to keep information from a previous display in working memory in order to relate it to a subsequent display, the student's cognitive capacity is needlessly taxed.

Once extraneous information has been removed from a multimedia presentation, the focus should shift to the proper presentation of the essential learning content. When this content is more complex than it needs to be or is presented too fast for the learner to absorb, the amount of essential cognitive processing required to understand the instruction exceeds the cognitive capacity of the Student. Reducing this essential cognitive overload should be a key activity in the instructional design of multimedia content. (Mayer, 2008; Mayer & Pilegard, 2014) Mayer articulated three principles which address the management of essential processing: (Mayer & Pilegard, 2014)

- **Segmenting Principle:** Learning improves when content is presented in learner-paced segments rather than a single continuous unit. Segmenting slows the pace of the presentation of materials, thereby enabling the learner to carry out essential processing. Segmenting is most effective when the student controls the pace at which these segments are presented.
- **Pre-Training Principle:** Learning improves when the names and characteristics of the main concepts are known. Pre-training equips the student with prior knowledge so that the student can process the subsequent lesson with less cognitive effort. For example, when discussing a complex model, a student should first be taught about its individual components, before these are subsequently integrated into the larger model. Without such pre-training, the student would need to comprehend each component and the connections among them simultaneously.
- **Modality Principle:** The combination of graphics and narration is more effective than the combination of graphics and on-screen text. The combination of graphics and on-screen text may overload the student's visual channel; providing the text as audio reduces the load on the student's visual processing. This principle reinforces the earlier stated Redundancy Principle

Once the multimedia content has been presented, students engage in generative processing, which is a cognitive process aimed at making sense of the content, organizing it, and integrating it with the student's existing knowledge. Such generative processing is strengthened when the multimedia presentation includes social cues for the student to respond to, as these tend to increase the student's motivational commitment to the learning process. (Mayer, 2008; Mayer, 2014) Mayer articulated four principles which aim to enhance generative processing: (Mayer, 2014)

- **Personalization Principle:** Learning improves when the narration is conversational rather than formal. The personalization of a narration creates what Mayer refers to a "social partnership" of the student with the narrator, in which the student makes a greater effort to comprehend the narrator.
- **Voice Principle:** Learning improves when the narration is in a standard-accented voice, rather than in a machine-generated voice or a voice with a strong foreign accent.
- **Image Principle:** Learning does not necessarily improve when the speaker's image is included in the video, especially when the image is of an animated character. Still images or animated characters generate few, if any, social cues for the students to interpret.
- **Embodiment Principle:** Learning improves when an on-screen narrator displays humanlike gestures, movement, eye contact, and facial expressions. While animated characters could be developed for this purpose, the inclusion of video of the actual instructor is the easiest way to accomplish this.

Mayer's multimedia principles have clear practical implications for educational designers. It must be kept in mind, of course, that Mayer's principles apply to multimedia presentations in general, not to lecture videos in particular. However, there is an obvious and intuitive overlap of these two areas of digital educational content. Subsequent sections will demonstrate how these multimedia principles have been incorporated into lecture video design, following an examination of the general video lecture development process.

DEVELOPMENT OPTIONS FOR VIDEO LECTURES

Video lectures were previously defined as "CD and web viewable files that present lecture materials and narrative instruction from a course's instructor." (Brecht & Ogilby, 2008) This makes video lectures a subset of a broader range of educational video content available to instructors. Video options for instructors also include commercially developed training videos, free online content such as open courseware and creative commons stock video, documentaries, feature films, television programs, and more. This paper, however, limits its discussion to the types of educational video which instructors can develop themselves, usually referred to as lecture videos.

There is not a single type or format for lecture videos; instructors can consider quite a variety from which to choose the most appropriate format for a specific course or educational objective. (Caspi et al., 2005; Chorianopoulos & Giannakos, 2013; Guo et al, 2014; Ilioudi et al., 2013 Tunku Ahmad & Doheny, 2014), mention the following lecture video format options:

- **Capture of classroom lecture**: This requires that a camera pointed be at the blackboard or whiteboard in a classroom and that the instructor wear a microphone. This option removes the need for the instructor to spend time recording a separate narration for the lecture video.

- **Talking head lecture:** This is a video in which an instructor recites a lecture directly to the camera. These recordings can be made in the instructor's office or in a specific recording studio.
- **Voice-over-PowerPoint**: This is the common term for a video produced from presentation slides accompanied by an instructor voice-over. The Microsoft PowerPoint application permits users to record a narration for each presentation slide and export the full presentation as a video file. For instructors who already use PowerPoint to produce in-class lecture slides, this is a simple and affordable option.
- **Screencast:** This refers to a video tutorial which captures an instructor's on-screen activity, accompanied by an instructor voice-over or other audio commentary. Screencasts are quite effective for demonstrations of software usage.
- **Digital tablet drawing:** This format captures the instructor's notes or drawings on a digital tablet, resulting in an on-screen animation, and is often accompanied by an instructor voice-over. Khan Academy videos popularized this format.
- **Hybrid Format:** This combines the voice-over-PowerPoint, screencast, or digital tablet drawing formats with a video insert of the instructor providing the narration. This permits the students to see the instructor, which adds personalization to the lecture video. It is also possible to combine presentation slides, screencasts, and digital tablet usage within a single lecture video if the subject matter calls for it.

The development for any of the above lecture video formats consists of four key phases: planning, recording, editing, (Pappas, 2015b) and distribution (Green et al., 2008).

During the planning phase, the instructor designs the online lecture, based on the learning objectives it needs to achieve. The instructor may gather existing content (such as images and diagrams) or develop original content to include in the video lecture. The content of the video lecture should also be considered from the perspective of the assignments or assessments it needs to support: what specific learning needs should be addressed? (Koumi, 2015) recommends that educational videos are most effective when they have a clear narrative structure; the video's story should capture the student's attention, continuously engage the student, enable the construction of knowledge, reinforce its main concepts throughout, and conclude with a summary of key ideas. This is most readily achieved with a carefully designed, planned, and scripted video lecture. (Pappas, 2015b)

The second phase is the recording of the lecture video's original content. Current software options permit instructors to do this with a minimal investment in resources. To record a Voice-over-PowerPoint style video lecture, an instructor only needs a copy of the presentation software and a microphone to record the lecture. An investment in more fully featured recording software (such as Camtasia Studio or Adobe Presenter) allows an instructor to easily manage a greater set of recording features - such as the combination of images, video, and audio which permit the narrative to be paired with appropriate visual elements. (Guo et al, 2014; Pappas, 2015b; Sanchez-Gonzalez et al., 2013) In addition to these general development environment, specialized tools are being developed, such as the AMELIE authoring tool for the creation of multimedia educational content in medical areas such as nursing and surgery. (Sanchez-Gonzalez et al., 2013)

The use of fully featured recording software usually also permits the instructor to subsequently edit the video recordings. (Pappas, 2015b) Such editing operations could include:

- Correcting errors in narration or presentation, without having to re-record the full lecture video.

- Adjusting audio levels to provide a consistent volume-level throughout.
- Adding captions to portions of the video.
- Including break-points or interactive exercises.
- Closed-captioning the video for accessibility purposes.
- Rearranging content to produce a more effective narrative sequence.

Once the editing is complete, the final video file needs to be produced for students to see. Most video recording software applications allow the instructor to produce the video lecture in a variety of formats and compression sizes in order to serve multiple viewing platforms. For students watching the lecture video on a desktop or laptop computer, a high-resolution video file is commonly produced, while for efficient access on mobile devices – a platform which has recently experienced rapid growth in video distribution and viewing – a lower-quality version can be provided. (Clothier, 2013; Pappas, 2015b)

Finally, the lecture videos need to be made available to the students. Distribution options include the use of a university's learning management system (Van Vliet, 2015), a commercial video distribution platform (Kaltura, Inc., 2015), or the use of a dedicated web server for streaming, podcasting, or download purposes. (Green et al., 2008) The choice among these options are usually made at an institutional level, not by individual instructors.

The following sections examine lecture video development in more detail regarding four significant video characteristics: accessibility, length, structure, and interactivity.

LECTURE VIDEO ACCESSIBILITY CONSIDERATIONS – PROVIDING ACCESS FOR ALL

Lecture video development should address the inclusion of accessibility features for students with disabilities. Disabled students are those who have a sensory, cognitive, physical or psychological impairment and hence may experience difficulties in accessing educational experiences. Such difficulties may be overcome through the application of assistive technologies and services, such as adapted keyboards, Braille embossers, screen magnification applications, screen reading software, transcription services, interpreters, etc. (Seale, 2014)

Within the United States, legal requirements for accessibility come from two distinct pieces of legislation. First, Sections 504 and 508 of the Rehabilitation Act require that federal agencies ensure all electronic information is accessible to people with disabilities and that individual accommodations are provided as needed. Universities receiving federal funding are covered by this act. Second, the Americans with Disabilities Act (ADA) prohibits any discrimination against people with disabilities by either public entities, commercial entities, or public accommodations. Initially, "public accommodations" referred to public buildings such as hotels, entertainment venues, and hospitals for which physical accessibility features were required. In recent years, any organization's web-based content and processes have gained consideration as "places of public accommodation." (3PlayMedia, 2106) That this includes online education programs was made clear when in early 2015 both Harvard University and the Massachusetts Institute of Technology were sued by advocates for the deaf for failing to provide closed-captioning for online course materials such as lecture videos and podcasts. (Lewin, 2105)

Online education requires that universities take a fundamentally different approach to dealing with accessibility issues than they have in the past. For many years, accessibility issues were mostly handled by a university's disability services office, which would provide disabled students with services and equipment as needed. However, the growth of online education has moved

quite a few accessibility responsibilities to the educators themselves. Faculty developing online courses are now obligated to make these courses and their content fully accessible to all students. (Ingeno, 2013)

Moreover, online education expands the availability requirements for accessibility accommodations. In traditional classroom settings, some student accommodations - such as a sign language interpreter - are only needed at the moment a lecture occurs. In online education, disabled students should have access to educational content at any time and any location, just as all other students have, requiring the continuous availability of accommodations. (Rose, 2014) This would suggest that accessibility features should be fully incorporated in all online education development efforts as part of the original development process, rather than be added later when doing so requires additional effort and expense. (Moore, 2014)

Accessibility needs in online education cover both the online learning environment which students navigate and the educational content itself. Within a learning environment, educational developers must ensure that disabled students have the ability to navigate its interface in order to access course materials online, participate in online discussions, and complete exams and assignments. (Kelly, 2008) Web Content Accessibility Guidelines play a big role here, and recommendations include the use of text alternatives for graphical elements, providing clear and simple navigation through the content, ensuring proper contrast in text and diagrams, and setting clear standards which make use of online resources more predictable. (3PlayMedia, 2106) In addition, the learning environment should support alternative modes of input and interaction to accommodate students with mobility impairments who may have difficulty operating input devices such as a computer keyboard, mouse, or touchpad. Assistive technologies such as adaptive keyboards and screen-reading software are available for these students but these require that the learning environment supports their usage. (Phipps et al, 2002)

The educational content itself, both video lectures and other types of multimedia content, presents an additional set of accessibility challenges. The controls of on-screen audio and video players may be inaccessible to blind or mobility-impaired students. Poorly tagged or titled multimedia content may be difficult to specifically identify and locate by screen-reading software. Deaf or hard-of-hearing students may be unable to access audio content. Finally, blind and visually-impaired students may be unable to access visual content. (CANnect, 2016; Moore, 2014; Phipps et al, 2002; Rose, 2014)

Each of these accessibility challenges should be addressed as part of the educational design process. The controls for on-screen audio and video should be made accessible through keyboard interaction or by screen readers. This permits students with mobility or visual impairments with playability, the first step in access to the content. (CANnect, 2016)

The proper identification of lecture videos within a learning environment can easily be improved by providing them with clear titles that reflect their content, rather than a nondescript title such as “Week 12 video,” as well as representative tags if needed. (Moore, 2014)

Accessibility to audio and video files is provided by including additional representations of their educational content, which can be achieved through transcriptions of audio files and closed-captioning of video files. Transcription is word-for-word translation of audio content into a text file. Transcripts permit deaf students to read a lecture and enable blind students to access the content using a braille printer or screen reader. Closed-captioning involves the synchronization

of text captions with the audio content of a video presentation. (3PlayMedia, 2106; Burgstahler, 2014; Rose, 2014)

The time and effort required to closed-caption a lecture video is usually substantial, especially considering the total amount of video a university-level course can contain. Consequently it is usually infeasible to quickly add captions to a course's video content when a disabled student requires it. It is for this reason that (Ingeno, 2013) recommends that this accessibility feature be included in the original video development process.

The closed-captioning effort can be eased somewhat by deploying additional technology. First, common digital video formats increasingly permit the easy insertion of captions. While these captioning features were originally intended to display foreign language subtitles, they can also be used for closed-captioning. (CANnect, 2016) In addition, captioning features are now included in video recording applications such as Camtasia and Captivate. The video hosting site YouTube has introduced an automatic video captioning feature which relies on speech recognition technology to caption its videos. (Moore, 2014)

In addition to captions of the instructor's audio, online lectures should also make available spoken descriptions (with closed-captioning) of important visual content that is not included in the instructor's main narration. This may include titles, diagrams, images, scenery, objects, and any other visual information. (3PlayMedia, 2106; Burgstahler, 2014; CANnect, 2016; Phipps et al, 2002)

By incorporating these accommodations in all aspects of online course development, educators can apply the concept of "universal design" into their course materials. Universal design refers to the design of products and environments which are "usable by all people, to the greatest extent possible, without the need for adaptation or specialized design," thereby removing or at least minimizing the need for special assistive technologies. (Burgstahler, 2014) For lecture videos, a universal design approach would mean that when retrieving a specific video, a student could enable or disable any of the above accessibility features as needed, rather than the instructor having to provide multiple versions of each lecture video and a student having to decide which version to retrieve. (3PlayMedia, 2106)

Finally, the inclusion of accessibility features – particularly the use of closed-captioning and transcripts – provides some interesting benefits beyond the accommodation of hearing-impaired students. Non-native English speakers may benefit from seeing the narrative in writing; students whose learning preferences tend towards text can read the captions or full transcripts; captions of full names, complex terms, and technical terms provide greater clarity; and students can access the content when an audio narration is not as useful, such as in noisy environments like buses and trains or quiet environments like libraries and offices. (3PlayMedia, 2106; Pappas, 2015a)

LECTURE VIDEO LENGTH – DOES BREVITY MATTER?

An interesting discussion among educators and educational designers concerns the recommended length of video lectures. When classroom lectures were filmed to be used of early online education efforts, the video lecture would be the length of the original lecture, which could be up to 60 or 90 minutes. (Caspi et al., 2005) The subsequent availability of affordable personal computer-based video capture and editing tools permitted experimentation with video lectures of varying lengths, and arguments were made that video lectures needed to be shorter.

Many educational designers point to a study by (Ruedlinger, 2012) which shows a drop-off in viewing as videos lengthen. The study recommends that shorter videos encourage viewers to watch the complete video. However, this study did not specifically address educational content; instead it examined viewership of business videos, mostly for the purposes of promotion. One might argue there is a substantial difference between the attention span of a motivated audience (such as online students) and the general audience for Internet-based videos. Nevertheless, proponents of short lecture videos argue that student attention will wane after 10 or 15 minutes, and hence video lectures ought to be kept short. (Linden, 2012) This stance was supported in a study on student viewing behavior by (Guo et al, 2014), who found video length to be the greatest indicator of student engagement.

Similar results were obtained by (Kim et al., 2014b), who found that students are more likely to stop watching video lectures as the videos become longer, possibly because they become bored or due to interruptions. Quitting rates went up even more when students re-watched a previously seen video, possibly because they were looking for very specific information in the video and stopped watching once that information was obtained.

Finally, (Ibrahim et al., 2012) make the argument that presenting longer videos to students requires them to process the educational content for longer periods of time, which may tax the limits of the student's working memory, resulting in cognitive overload.

The notion that educational videos should be kept short appears to be widely accepted by educators. A survey performed by video platform provider Kaltura generally found that a majority of respondents felt that video lectures should be no longer than 10 minutes. However, the study did find a distinction between instructional designers and educators: instructional designers strongly agreed video lectures should be kept under 10 minutes while a substantial portion of educators felt videos lectures could be up to 30 minutes in length. (Kaltura, Inc., 2015)

The educators' most common argument is that the additional time is needed to convey the complete content of a particular lesson, as they are used to doing in a classroom setting. (Guo et al, 2014) counter this by insisting that when video lectures are carefully planned and scripted, the result should be a concise, high-quality deliverable which more consistently engages students in a short amount of time. (Gallo, 2014) notes that the same motivation is behind the 18 minute limit for TED talks: when speakers have to pare down a longer presentation to fit a shorter time slot, they have to carefully consider what key ideas to communicate and how to present them. This application of discipline to overall content is expected to result in an improved presentation and greater impact on the audience.

A strong case for longer lecture videos was made by (Reich, 2014), who argues that studies which focus on student attention or student engagement are measuring the wrong outcome, they should be considering student learning outcomes instead. This view echoes an analysis by (Wilson & Korn, 2007) which examined a series of studies that evaluated student attention during in-class lectures. It found that while many such studies argue that student attention wanes after 10 or 15 minutes (usually as evidenced by a decline in student note-taking activity), the length of the lectures did not actually affect student retention of the educational content. Observed student attention, therefore, is not necessarily an indicator of learning achievement.

The case for longer video lectures is also supported by a study which examined the effectiveness of full video lectures – up to 75 minutes in length – on student comprehension of complex course content. (Brecht & Ogilby, 2008) The study particularly credited the video lectures with giving instructors the opportunity to present complex course content using clear and unhurried step-by-step explanations.

Brecht & Ogilby (2008) make a strong argument that students can obtain a tremendous benefit from the availability of longer online lecture videos. Complex subject matter, which is often found in higher education courses, benefits from calm, clear, precise, and comprehensive explanations. Online lecture videos provide a good opportunity for instructors to develop, capture and distribute such explanations, without having to worry about time limitations that may be imposed by classroom schedules. Students can then access these videos, review them as needed to build their comprehension of the subject matter, and master the contents at their own pace. Challenging university courses may cause students to experience great difficulty in integrating complex concepts and methods. This in turn may increase student frustration and result in reduced learning outcomes. The availability of lecture videos is one way by which these students can be supported in their learning process. (Brecht, 2012)

(Brecht, 2012) recommends that in longer lecture videos, the instructor includes graphics and sounds that liven up the video, and introduces occasional change-of-pace elements to help keep a student's attention. However, such elements may run counter to Mayer's recommendation to avoid the inclusion of extraneous content. (Mayer & Fiorella, 2014)

When the nature of a video lecture's subject matter requires a lengthy explanation of the material, greater student engagement may be obtained through the application of some of the multimedia learning principles expressed by Mayer (2008). The subsequent section examines the use of two key principles which might be quite useful in this context: signaling and segmenting.

APPLYING STRUCTURE TO LECTURE VIDEOS – SIGNALING & SEGMENTING

As discussed earlier, Mayer's Principles of Multimedia Learning recommend the clear and careful organization of educational content. Two key methods suggested here are Signaling and Segmenting. Signaling occurs when a presentation includes cues about its structure or organization, such as when an outline or list if key items is provided at the outset. (Mayer, 2001) Signaling identifies for a student the main ideas within a lesson. (Ibrahim et al., 2012) argue that signaling helps focus student attention and reduces the likelihood of students paying attention to extraneous or irrelevant information.

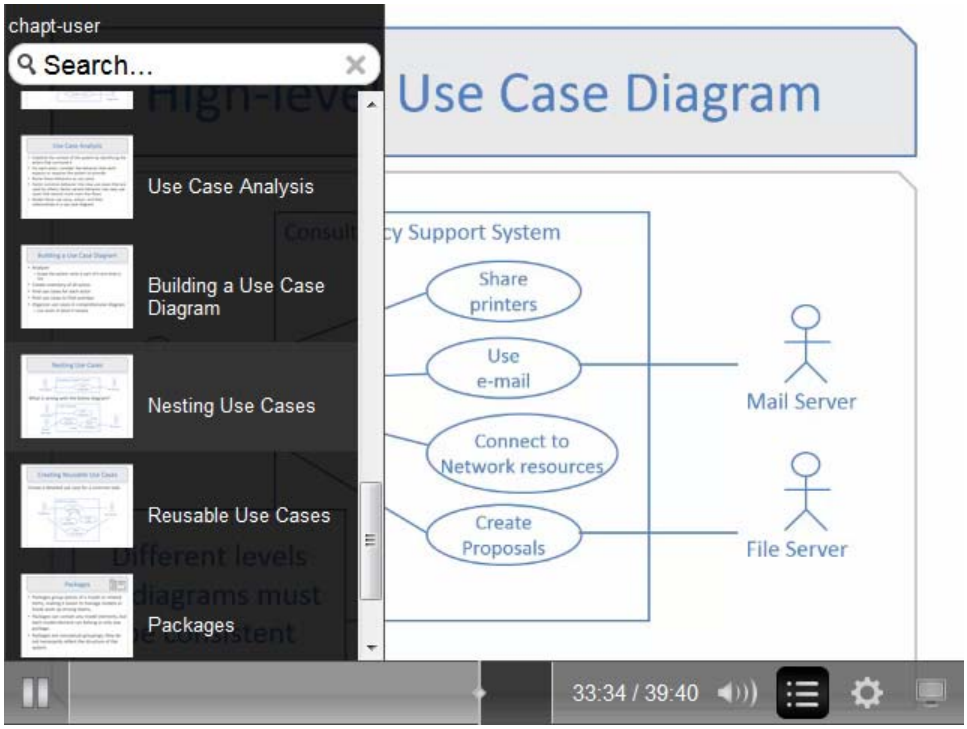
Segmenting is the process of subdividing content into distinct segments rather than a single continuous unit. This principle is further strengthened by the use of Mayer's Pre-Training principle, which suggests the deliberate sequencing of content by introducing individual components first before combining these into a more complex configuration. (Mayer, 2001) In practice, signaling and segmenting are commonly applied together; the structure that is signaled at the outset of a lesson is reflected in the segments that make up its full educational content.

Used this way, signaling and segmenting can actually provide an effective solution to a practical problem with lecture videos: the efficient locating of specific content a student wishes to see. (Pavel et al., 2014) point out that as a format, video itself provides viewers with little help to browse or skim the content. To navigate through a video, viewers must "scrub" back and forth

through the video presentation to get an idea of the overall content or to locate a specific section. This can be especially annoying or time-consuming when students want to re-watch a relevant portion of a lecture video in order to complete a specific assignment. (Kim et al., 2014b) found that students tend to be quite selective which videos (or portions of videos) they watch and re-watch. They encourage the inclusion of easy in-video navigation so that students can find the content they wish to watch more quickly and accurately.

Signaling can be deployed in lecture video development in multiple ways. (Ibrahim et al., 2012) suggest that the instructor verbally establishes the main structure of a lesson at the outset of the video and subsequently reinforces this structure through reiteration of key ideas at the lesson's conclusion. Even more effective, however, is the display of a video lecture's structure as a navigable table of contents, which would permit the student to select a specific topic and navigate to it directly. (Jadin et al., 2009) For example, the video capture and editing software package Camtasia Studio allows for specific points in a video to be marked and named, which then automatically produces a table of contents in the resulting lecture video. The screen-capture shown in Figure 1 shows a Camtasia Studio video as presented to students. On the left of the screen is the table of contents.

Figure 1. Table of Contents in Lecture Video Developed Using Camtasia Studio Software.



As seen in Figure 1, signaling practices need not be purely text-based. (Kim et al., 2014a) recommend the use of clear and well-chosen thumbnail images which students can navigate to easily in addition to clear and searchable section titles for video portions.

Finally, (Pavel et al., 2014) suggest the inclusion of more detailed information in a signaling approach referred to as a "video digest." In this approach, a clickable table of contents is augmented with a summarization of each video section's content or basic idea. In addition to

direct section access, these section summaries provide the student with the basic ideas of the overall video lecture before it is even watched. Developing such summaries does require additional development effort, and care must be taken that the summaries are accurate and appropriately representative of the video content.

The inclusion of a clickable table of contents for signaling purposes has the additional benefit of also effectively segmenting the video lecture from a student's point of view, even if the video itself is only a single file. However, additional segmenting approaches have been proposed. For example, (Breslow et al., 2013) subdivided a long lesson into a sequence of multiple 10-minute videos. These segments were interspersed with online exercises designed to permit students to put concepts from the videos into practice. Developing these shorter videos may make the content more readily reusable across multiple courses and disciplines, especially for tutoring purposes.

(Mayer & Pilegard, 2014) mention that segmenting is most effective when the student controls the pace at which video segments are presented. The signaling techniques described above are an effective implementation of this concept, especially given that the video lecture controls also permit students to pause, re-view, or fast-forward through the video.

INTERACTIVITY AND THE PROMOTION OF ACTIVE LEARNING

It has been mentioned several times now that the on-screen buttons on video players permit the students watching an online lecture an affordance of control over the learning process. Students can use these controls to pause, repeat, or fast-forward through a lecture video in order to personalize the pace of their learning. In addition, when the practices of signaling and segmenting are incorporated in a video lecture, the students can quickly identify and navigate to a specific portion of content. Such learner control is an essential component of effective learning. It allows a student to take the initiative in viewing and reviewing course materials, which more actively engages them with the course content rather than when they passively observe it. (Moreno, 2006; Nicholson et al, 2008)

Watching lecture videos without any control or interactivity was found to be less cognitively captivating or challenging, and is therefore less effective for learning. (Geri, 2012) This realization has encouraged educational designers to add additional interactive features to lecture videos. Some interactive ideas require very little technology: (Green et al., 2008) describe how an instructor inserted direct questions to students in an online lecture's narration, which students subsequently answered in an online discussion forum. Other easily included interactive features may include encouraging students to take notes, inserting online quizzes, relating a narration directly to an assignment, or providing suggestions for additional content students may seek out if interested. (Chorianopoulos & Giannakos, 2013; Geri, 2012)

New approaches to enhancing the interactivity of lecture videos are now being explored. (Kim et al., 2014a) suggest that lecture video navigation can be enhanced by examining student viewing behavior. First, based on video server logs, analysis of previous students' viewing activities can highlight those sections of a video that were most often watched and re-watched; such sections can be highlighted as being most useful to new students. Second, if the lecture video environment permits individual students to place personal bookmarks to mark video portions of special interest, the most commonly bookmarked portions can subsequently be shared with new students.

Until recently, interactivity options such as quizzes or connections to additional content required a student to navigate through multiple videos and applications in the online learning environment. This may soon be a thing of the past. (Clothier, 2013) shows the increasing use of interactive video technologies which use in-video buttons to steer the video narrative to related content, to an in-depth feature, or a simpler explanation. The inclusion of in-video quizzes and questions – the results of which can be made available to the instructor – provide an additional layer of in-video interactivity. (Meyer, 2015) The result of these developments is not only an efficient and continuous viewing experience, but also an opportunity for the viewer to engage with and explore the content in a more immersive way. (Zhang et al, 2006) view the emergence of this type of non-linear, interactive digital video technology as a key development in building learner engagement and learning effectiveness.

VIDEO LECTURES AND STUDENT LEARNING – SOME EVIDENCE

Lecture video development takes a considerable amount of time, effort, and money, especially when sophisticated video capture, custom animation, and interactive features are to be included. (O'Rourke et al, 2014) The question then becomes whether all this effort is actually worth it. (Moreno, 2006) notes that educators tend to assume that the use of new technologies will enhance student learning, even though only limited research exists that proves this is so. She also notes that educators often assume that embedding proven teaching methods in new media technologies will not affect the effectiveness of these methods.

Early studies which compared the effectiveness of video versus print for educational purposes found print materials to better support student learning. However, these studies focused on the use of broadcast video, in which the students had no control over the video stream. (Merkt et al, 2011) More recent studies on the efficacy of lecture videos show that these videos have greater promise to support student learning objectives; however this evidence is quite fragmentary and at times anecdotal. Many of these studies focus on the use of one or a few lecture videos in a short term-setting. Large-scale longitudinal studies which cover a complete online curriculum as completed by a body of students are not yet available. Still, an examination of the more limited research currently available does offer some evidence for the previously discussed principles and guidelines for more effective lecture video development.

General Reviews of Lecture Video Usage

In the most general terms, students appear to be quite receptive to the usage of video lectures as an educational strategy for universities. (Brecht & Ogilby, 2008) Results by (Jadin et al., 2009) indicate that students primarily use video lectures for knowledge acquisition purposes and that the subsequent phase of knowledge construction derives mainly from the students interacting with the course content in order to complete assignments.

As mentioned earlier, the use of lecture videos need not be limited to online education. (Preston et al., 2010) found that students respond positively to the availability of lecture videos as an augmentation to and reinforcement of in-class lectures. Moreover, (Brecht & Ogilby, 2008) found that the use of supplemental video lectures in an in-class course enhanced student performance on exams. In a more detailed study, (Woo et al., 2008) examined the usefulness of video lectures for both in-class students (for whom the video lectures were an accompaniment to classroom lectures) and online-only students enrolled in online courses. The usage patterns of the two student groups differed significantly, with the online-only students using the video lectures more often and more extensively. However, the in-class students found the video

lectures quite useful for learning content they missed in class, preparing for exams, and revisiting complex course content at their own pace.

Examining the Multimedia Principle

Mayer based his Multimedia Principle - "students learn better from words and pictures than from words alone" - on a substantial amount of early research in educational media. (Mayer, 2001) More recent studies have found continued support for this principle. (Nicholson et al, 2008) note that students learn from both visual and verbal stimuli, and that they readily connect these mentally. Consequently when educational material includes both visual and verbal information, the material increases student interest and hence will have greater impact. However, both (Caspi et al., 2005) and (Nicholson et al, 2008) note the potential for cognitive overload when the audio and visual portions of an educational video present too much simultaneous information. (Moreno, 2006) agrees that a common pitfall of online lecture design is to present too much simultaneous information, some extraneous, which results in students not being able to properly process all the information provided. (Jadin et al., 2009) recommend that online lectures carefully balance audio and visual information provided to students. For example, when in a lecture the on-screen text is also spoken verbatim by the instructor, the resulting redundancy (with the same information provided visually and via audio) needlessly taxes the student's cognitive capacity. These recommendations clearly echo Mayer's principles aimed at reducing extraneous cognitive processing, as well as the Modality Principle. (Mayer & Fiorella, 2014; Mayer & Pilegard, 2014)

Examining Lecture Video Types

It was mentioned earlier that instructors can consider from a variety of lecture video formats. Some researchers have examined the effectiveness of some of the most popular lecture video formats.

A key finding is the importance of students being able to see the video's instructor. A study by (Wang et al, 2015) compared the effectiveness of three video lecture formats: the capture of an in-class lecture, a voice-over-presentation slides video, and a voice-over-presentation slides video with an additional video insert of the instructor providing the narration. The researchers studied student attention, cognitive load, and learning outcomes. They found that while the simple voice-over-presentation slides video generated the highest level of sustained student attention, the other two video types (which both showed the instructor) resulted in both a reduced cognitive load and greater learning for the students. While these two types of lecture videos can be more expensive and time-consuming to produce, they are recommended for improved learning outcomes. A study by (Guo et al, 2014) examined the difference between video lectures specifically recorded by instructors for online delivery and those which mostly show a recording of an in-class lecture by an instructor. It was found that students were more engaged by the video lectures specifically prepared for online delivery, especially once these lectures lasted longer than 6 minutes.

Adding additional video features generally was found to have a positive effect on student learning. (Guo et al, 2014) found that providing students with more diverse video productions – those which mix video of the instructor with images, slides, animations, and video – tend engage students more effectively. (Tunku Ahmad & Doheny, 2014) studied the use of screencasts, which display the instructor's computer screen activity accompanied by a voice-over narration, and found this dynamic display to be more effective than written materials

covering the same content. Finally, as suggested by the Redundancy Principle (Mayer & Fiorella, 2014), a study by (Jadin et al., 2009) found that the addition of an on-screen text transcript of the narration does not improve the effectiveness of a lecture video.

Examining Lecture Video Personalization

The previous section showed that a strong instructor presence in lecture videos has a positive effect on student learning. This conforms with Mayer's argument that a student's motivation to learn can be strengthened through the use of social cues in a lecture video, particularly when the instructor narrating the video adopts a conversational rather than formal tone. (Mayer 2014; Nielsen, 2014) (Moreno, 2006) adds that adopting this Personalization Principle may heighten student attention and thus promote greater learning. This notion was supported in studies by (Ilioudi et al., 2013) and (Wang et al, 2015), who found that a video recording of the instructor (either recorded in-class or specifically for the online lecture) provided greater student learning outcomes than presentations which merely featured a voice-over narration. (Ilioudi et al., 2013) hypothesize that having grown up with in-class instruction, students are simply used to being able to see and hear an instructor explain course content.

Examining Signaling and Segmentation

Student navigation of lecture video content can be further enhanced through the principles of signaling and segmentation. As discussed above, signaling displays the structure or key points of a lesson. Segmentation divides a large lesson into short, distinct portions. The application of these two principles in lecture videos usually results in a navigable table of contents from which students can directly access specific video segments. (Zhang et al, 2006) specifically noted the benefits of signaling when students are provided with direct access to content using a clickable table-of-contents feature. Looking specifically at segmentation, (Ibrahim et al., 2012) found that subdividing a longer video lesson into shorter segments (approximately 6 minutes long) helped reduce students' perception of the difficulty of the content. A study by (Mayer & Pilegard, 2014) found the combination of signaling and segmentation to be quite effective as the direct access to the video segments allows the student control over the pace at which video segments are presented. This combination was also examined by (O'Rourke et al, 2014), who built an "interactive wall" of on-screen clickable tiles. Each tile provided access to some form of course content: a video lecture, an image, an internet link, etc. Students consistently found this interactive online learning environment more engaging than a traditional in-class lecture. Key to the students' preference once again turned out to be self-paced learning: in the interactive environment students were able to absorb the content at their own pace, pausing or re-watching content at will.

Examining Control and Interactivity

It was mentioned above that digital video permits a student to exert some control over the medium Video lectures can be paused and sections can be directly accessed, skipped, or re-watched at will, allowing a student to learn the material at his or her own pace. (Caspi et al., 2005) found that students watching lecture videos did indeed attempt to transfer existing learning strategies from reading textbooks to watching video. The students would go forward and backward through the videos as if using a textbook, although this is sometimes more difficult in practice as videos do not always have clear markers to jump to. Studies which examined the use of video controls found that students not only preferred this type of video

environment, but also that it resulted in higher levels of learning achievement when compared to videos over which students had no control. (Merkt et al, 2011; Zhang et al, 2006)

CONCLUSION – RECOMMENDATIONS FOR ONLINE LECTURE DEVELOPMENT

Instructors planning to develop video lectures may be disheartened when they consider the well-published video development efforts for Massive Open Online Courses (MOOCs). The creation of video content for MOOCs is commonly reported to require tens of thousands of dollars, with much of it spent on recording studios, audiovisual equipment, graphics and animation development, and a video production team, in addition to actual curriculum design. (Hollands & Tirthali, 2014) The recommendations and findings discussed in this paper demonstrate that effective lecture video development can actually be achieved by individual instructors, even on a limited budget. As (Nielsen, 2014) points out, "you don't need a full movie studio and video editing team to create great educational content." What is needed instead is a careful and methodical approach to video lecture design.

A key responsibility for the instructor is the organization of the video content. Extraneous materials should be removed, and the remaining content should be carefully organized, structured, and sequenced. Of course, curriculum design and educational development are not new; instructors have long performed these tasks for in-class courses. However, online lectures do require some adaptations. In particular, the instructor should take the time to develop clear and careful explanations which permit the students to more easily understand the material, a requirement that is vital outside of the immediacy of an interactive classroom setting. Then, applying the principles of signaling and segmenting, the instructor should provide the video lecture content in a structured and easily navigable format which permits students to quickly locate specific content and thereby encourages multiple viewings of complex or important portions. Finally, the instructor should ensure that the lecture videos are accessible to all potential students that might enroll in a course.

The inclusion of multimedia materials – diagrams, photographs, animations, video, etc. – was shown to engage students and positively affect the learning effects of a lecture video. Fortunately video capture, drawing, and screen-casting software packages has become more affordable even as their feature set and ease of use have increased. (Marquis, 2012) However, just as significant as the on-screen visuals is the instructor's presence. A lively and enthusiastic narration by the instructor – especially when augmented with video – can provide students with social cues, personalize the instruction for the students, and strengthen the student-instructor relationship, even in fully online courses. The ubiquity of webcams enables instructors to accomplish this at relatively low cost.

An important finding in the study of lecture video usage is the importance of a student being able to affect the manner in which the educational content is viewed and learned. Video player controls which permit students to pause, repeat, and forward a video permit a student to personalize the pace of learning. When the lecture video includes a clickable table of contents which provides direct access to specific video segments, students are able to actively seek out specific content quickly. This level of interactivity resembles the online experience in general and should therefore be easy to grasp by students.

As mentioned early in this paper, once they have been carefully developed, online lectures have multiple uses outside of a single, specific course. An investment in the development of high-quality lecture videos can therefore pay off in many ways for both individual instructors and the

educational institution as a whole. While there is still a lack of large-scale longitudinal research on the learning outcomes of lecture videos, the principles and findings stated in this paper can inform instructors as they aim to improve the quality and effectiveness of their online teaching efforts.

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