

AN INTRODUCTION TO PRODUCING MATHEMATICS INSTRUCTIONAL VIDEOS: TOOLS AND TRICKS

Clayton N. Kitchings
Assistant Professor of Mathematics
University of North Georgia Oconee Campus
Department of Mathematics
Watkinsville, GA 30677 USA
clayton.kitchings@ung.edu

Thomas Hartfield
Associate Professor of Mathematics
University of North Georgia Gainesville Campus
Department of Mathematics
Oakwood, GA 30566 USA
Thomas.Hartfield@ung.edu

Abstract

There is increased interest in creating mathematics instructional videos especially due to recent pandemic impacts on traditional classroom instruction. How many mathematics instructors view the creation of their own supplemental video instruction as a viable option to assist students in the learning of crucial mathematical content? How many mathematics instructors are confident in their knowledge of how to produce and share instructional videos? What can instructors do to try to improve the quality of the videos they create?

Introduction

This paper contains a practical, suggested framework for creating mathematics instructional videos as well as improving the production quality of videos. The focus on the first part of the paper is on that of acquiring the equipment required to create videos as well as how to use that equipment. The focus on the second part of the paper concerns suggested practices to enhance an instructor's videos beyond the entry level. The purpose of this paper is to document ways that an instructor may begin to create mathematics instructional videos.

Many instructors who utilize video instruction may choose to do so to accomplish a variety of goals including the following: flipping the classroom, teaching additional content, remediation or acceleration, extending content beyond the published syllabus, providing additional examples, or virtual office hours.

YouTube, Vimeo, and other sites are littered with tips and tricks for helping students with homework in mathematics. Additionally, many eText options available with various online platforms often contain publisher-produced instructional video content. Although the content is valid, instructors may prefer to demonstrate methods and strategies that differ from those demonstrated in the publisher videos. The current technological landscape makes it much easier and more affordable than ever for instructors to produce and share their own lectures, examples, and demonstrations with their students. Times of pandemic crisis required instructors to move to online and virtual means of instruction.

Both authors have been involved in commercial video and audio production as well as mathematics education for more than 20 years. Any references to commercial products in the paper should not be interpreted as endorsements, but rather examples used by the authors in the past as suggestions that may assist the reader to produce his or her own instructional videos.

The Need for Instructional Videos

Anecdotal evidence suggests instructors of mathematics were increasingly interested in creating their own mathematics and instructional videos prior to the pandemic of 2020. After the pandemic, the need for instructional videos increased exponentially. The requirement of digital and distance learning in the spring of 2020 created the need for complete implementation of video instruction for mathematics classes. Video instruction allows instructors to maintain and improve engagement with their students. Various technologies such as Zoom, WebEx, GoToMeeting, Blackboard Collaborate Ultra, GoBoard, Microsoft teams, and others can assist instructors with transitioning to online learning.

Equipment Requirements

We introduce four basic requirements for creating one's own mathematics and instructional videos. The four requirements for creating instructional videos on a desktop or laptop computer are: 1) a USB writing tablet, 2) writing software, 3) screen capturing software, and 4) an audio acquisition tool or microphone. These four components can be inexpensive and budget-friendly.

1) Writing Tablet:

A search of the Internet would yield many results for a USB writing tablet. The writing tablet will not display text on the tablet itself, but it behaves very much like an extremely large trackpad with a stylus. In the same manner that one will not see feedback on a laptop's trackpad, one will not see feedback on a USB writing or drawing tablet. As such, most who began using a writing tablet will experience a learning curve of approximately 30 to 60 minutes because the user must focus his or her eyes on the computer screen rather than the tip of the stylus in order to view the feedback of the writing. Most users will initially report an embarrassing version of their own handwriting until they move beyond the learning curve of the writing tablet, stylus, and computer screen. It is possible

to find USB writing or drawing tablets online for purchase as low as \$40 USD. Occasionally, some of the less expensive models may have a slight lag in keeping up with the drivers necessary to operate on various operating systems.

2) Writing Software:

In addition to a writing tablet, some sort of writing software is required in order to create mathematics instructional videos. Writing software will provide an electronic surface on which to display the handwritten text. One free Internet version is from goboard.com. Users may use this Internet site to draw and right mathematics examples so that others may join the session to watch and listen to you provide mathematics instruction. Many Microsoft office products such as Microsoft Word, Microsoft Excel, Microsoft PowerPoint, Microsoft One Note, and Microsoft Teams allow users to transcribe written notes into documents using a USB tablet and stylus. Institutions with access to Blackboard may use something called Blackboard Collaborate Ultra with its interactive whiteboard as well.

Smart Notebook is also a popular choice with many educators at the pre- and post-secondary institutions. Many institutions carry their own institutional licenses for this product. Some faculty occasionally purchase their own renewable license each year for around \$100, with additional renewals typically occurring around the \$50 range. Smart notebook has an interface similar to PowerPoint, but it is designed with the expectation that the user will transcribe a written text into the slides. This functionality allows instructors to preplan instruction for presentations. A basic version of smart notebook is available for free, but it will contain a watermark.

3) Screen-Capturing Software:

The third requirement for creating mathematics instructional videos is the screen-capturing software. Users need a method to prompt the computer to create a video to preserve the movements of the computer screen on the computer monitor. Microsoft PowerPoint even has the capability to record the presentation of the screen while drawing or writing into a slide as illustrated in Figure 1.

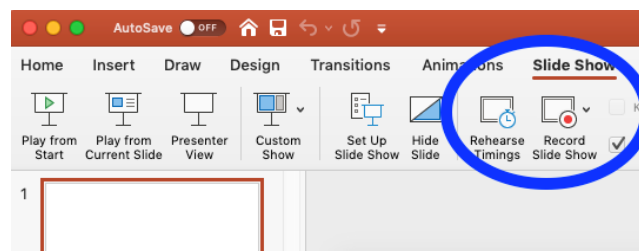


Figure 1. PowerPoint Recording

Microsoft Teams allows users to start a meeting (even if the instructor is the only attendee), share the users screen, and then record the meeting as a means by which to obtain a video recording of the screen. Instructors or institutions on a tight budget may wish to use Microsoft Teams as the means by which to implement video captures of

computer screens. Skype also offers the ability to share one's screen and record the meeting as well. Skype, Teams, and Blackboard Collaborate Ultra afford instructors the ability to create online meetings that students may attend virtually and video-record on-screen activity. Many other options also exist and new options may appear online via Internet searches in the future. Internet searches may also reveal newer companies that offer free video capturing a videos less than a certain length (e.g., less than 10 minutes), and paid versions for videos of longer lengths.

The TechSmith company offers Snagit (less expensive) and Camtasia (more expensive) software with video editing capabilities that allow the user to capture the activity on the computer screen to a video file. It is important to note that the software used to capture the video may require you to carefully select your microphone or audio input. If you use a web cam, these programs will often default to using the microphone embedded on the web cam itself (which is often not ideal).

4) Audio Acquisition Tool (Microphone):

The final tool required to produce mathematics instructional videos is a microphone. A detailed analysis of the types of microphone technology is beyond the scope of this paper, but a few suggestions may help instructors improve the audio of their instructional videos. Students are unlikely to listen to videos with poor audio.

Types of Microphones:

Webcams or microphones embedded in computers or laptops typically provide the worst audio, but they will suffice if budgets do not allow additional microphone purchases. If possible, instructors should purchase a stand-alone microphone in order to maximize the quality of the audio paired with the video. Microphone placement is crucial as well. If possible place the microphone as close as possible to the speaker's mouth but not directly in front of the mouth in order to avoid unnecessary "plosives" (which are "p" sounds that create less-than-desirable sounds for the listener). If a video contains excellent visual content but poor or annoying sounds, students will be unlikely to watch or finish the video as it was intended. Microphones may be purchased from one of two categories: 1) USB microphones (including headset microphones) and 2) XLR microphones with the purchase of a USB "audio interface."

USB microphones are popular due to their "plug-and-play" ease of use. Numerous USB headset microphones are available for purchase at numerous online and in-person retailers. An advantage of headset microphones is the microphone is placed in close proximity to the mouth, which strengthens the signal of the audio and lessens other environmental noises that may enter the video. Microphones of better quality include desktop microphone "podcast" kits such as the examples in Figure 2 below. Other less expensive USB microphones are available from less-known brands. Other microphones require what is known as "XLR" connections. Microphones with XLR connections are considered professional-level microphones. These kinds of microphones are found in movie studios, musical applications, and even in courthouses and other facilities.

USB Microphone	Price Range (USD)
Audio Technica ATR2100x	\$100
Audio Technica AT2005USB	\$80
Audio Technica AT2020USB+	\$150
Samson Q2U	\$80

Figure 2. Popular USB Podcasting Microphone Examples

Figure 3 contains an example of the ends of the XLR cable. XLR cables are often used in professional production environments. The advantage of using the XLR-type microphone is the freedom to use a range of professional microphones ranging in price from \$20 well into the thousands of dollars. These microphones require the purchase of an XLR cable (priced within the \$20 range as a conservative estimate). These cables exist in a variety of lengths to suit the needs of the user. The XLR option provides the user with much more flexibility, but few (if any) computers contain equipment that will accept the XLR as an audio input.



Figure 3. The XLR Cable

To compensate, the use of an XLR audio interface is required for XLR microphones. The XLR interface is a device that accepts the XLR input. The device then routes the audio signal into a USB cable that connects to the computer as an audio input. Most popular audio interfaces contain one or two XLR inputs. Figure 4 contains examples of XLR interfaces and their approximate price ranges in 2020.

Audio Interface	Price Range (USD)
Zoom U-22	\$100
Zoom U-24	\$150
Zoom U-44	\$175
Zoom H6	\$300
Zoom Podtrak P4	\$200
Tascam DR-40x	\$170
Focusrite Scarlet Solo (one XLR input)	\$110
Focusrite Scarlet 2i2 (two XLR inputs)	\$160
PreSonus AudioBox USB 96 2i2	\$100
Zoom H1n (accepts XLR input with adapter)	\$100-120

Figure 4. Examples of Popular XLR Audio Interfaces

There are numerous options available when selecting an XLR microphone. One of the most popular and most robust quality microphones in the industry is the Shure SM-58 dynamic microphone (typically \$100 USD). The reader may search the Internet for additional reviews of podcasting microphones to compare characteristics and make selections. Microphones that are “dynamic” do not require external power, but “condenser” microphones do require external power. Be sure to confirm the audio interface contains a “phantom power” option if using a condenser microphone.

Regardless of the quality of microphone selected, the video creator can improve audio quality by checking the quality of the recording environment. If possible, take a moment and listen to the recording environment with a critical ear. Try to silence any fans or other electronic devices or appliances with running motors. Microphones capture many sounds from the recording environment, even if unintended. Additional room noise can cause unwanted distractions for listeners. If recording on a laptop, moving into a closet to create a recording will improve sound quality (even if it seems odd). Clothes can absorb sound and reduce extra noise or unwanted echo in the video. Consider draping or hanging a blanket from the wall just behind the microphone to absorb sound and minimize echo bouncing back to the microphone. Finally, position the microphone closer to the speaker’s mouth in order to maximize the signal of the sound and reduce the amount of ambient room noise. Position the microphone slightly to the side of the speaker’s lips in order to prevent unwanted “plosive” sounds in the recording.

Summary of Production Elements:

The first author uses Camtasia screen-capturing software, a Monoprice USB Writing tablet or XP Pen USB writing tablet, the Shure SM-58 microphone (and the Focusrite Scarlet 2i2 Audio Interface) and Smart Notebook as a writing space. Microsoft Teams is used each day during virtual learning so students can gather virtually, ask questions, and view demonstrations. For recording, Microsoft Teams or Camtasia is used depending on the perceived need. Videos are shared via Microsoft Teams or Kaltura with capturing.

Climbing the Learning Curve: Improving Video Production

The most important step in creating mathematics instructional videos is to get started. Instructors with no experience in video production may need to fight away initial concerns about inadequate experience or concerns about producing videos with low quality. The only way to improve is to begin. Instructors who never begin will never create quality instructional videos.

How do instructors climb the learning curve once they possess the necessary technical components required to create instructional videos? The remaining discussion contains strategies for preparing and planning instructional videos, addressing American’s With Disabilities Act (ADA) concerns, and other best practices to improve the quality of mathematics instructional videos. Instructors who take the steps to begin producing video content can learn to produce high quality, reusable materials that they may share with pride.

Preparation Strategies

The pedagogy of delivery is important, but we focus our discussion on how to deliver mathematics content through the medium of videos. Consider building some notes with framework. Create notes (in software such as PowerPoint or Smart Notebook) that contain space with problems to work as well as space to work out the problems. Some experimentation is required and experience is a good guide. Keep notes as simple as possible. Use mostly black writing on a white background. For contrast on the same slide, create an inverted scheme using a black background with white writing. Make sure type content is large enough to read in the video. Provide plenty of space for writing out problems presented on the screen.

It is wise to make notes about the outline of your presentation before recording even though content is well known. Use precise vocabulary of the desired results and minimize slang or euphemistic language. For example, when discussing a factoring exercise such as "Factor $6x^3 + 15x^2 - 9x$," use the command, "Factor $3x$ out of the expression" rather than, "Take out $3x$."

Consider incorporating coordinate grids for graphing problems since you already have an area to sketch graphs by hand. For where having an image is an essential part of the problem, place the image into the notes as best as possible so students can see it while reading the problem. Clearly articulate any dimensions of the figure using directions such as left, right, up, and down as necessary.

Prepare any desired software that will be used in conjunction with the video lesson, including calculator emulators or websites such as GeoGebra or Desmos. Scale such windows or tabs and place them behind the main writing space to make them easily accessible during the presentation. Effective switching between the main writing space and other windows with unedited videos creates smooth transitions and better flow. If the instructor chooses to edit the video such effective switching minimizes the required editing time in post-production.

ADA Concerns

By federal law primary content must be accessible to all students. Ideally, the video hosting site (such as Kaltura) will address captioning automatically. Instructors should confirm the presence of captioning with their hosting site or with their institution's technology specialists. Aside from captioning, be mindful of students with visual impairments or audio challenges. Be aware of the size and color of anything typed or written on the screen. Typed content should be based on a minimum 24-point font relative to the size of the space of the recording. A good practice is to avoid Serif fonts such as TIMES NEW ROMAN, which may not display well when compressed into a video file. Fonts such as CALIBRI, Arial, Helvetica, and Tahoma are also good choices.

Use a contrast checker (www.contrastchecker.com) to be sure that colors can be seen by students with issues related to color blindness or color displacement.

Refrain from referring to texts or graphs by color. Instead, read the words themselves or label the graph such that it cannot be misinterpreted by mistaking or misinterpreting colors. Read most, if not all, of the written content on the page. Give students time to read a problem displayed with several sentences and read the problem aloud as well. Reading a problem aloud provides students with the opportunity to process it with both their eyes and ears. Read the problem as it is written. For example, consider the above prompt, "Factor $6x^3 + 15x^2 - 9x$." Read the text in its entirety as, "Factor Six x-cubed, plus 15 x-squared, minus 9x." Fully verbalize any hand-written data as well. Students may not always have access to text-to-speech converters. Instructors should aim to ensure any hand-written text is understood by the viewer regardless of any impairments that may be present.

Avoid positioning ambiguous words such as "over here" or "in this corner" (while referring to a particular location on the screen). Reference and identify specific points clearly as opposed to saying, "this point." Make a strong attempt to clearly describe any figure or graphic that is not in words, numbers, or symbols. Try to identify with a student who may not be able to decipher that which appears on the screen. Provide enough of a description so that everyone can understand what they should see on the screen, but it may not be necessary to provide immense details.

Other Miscellaneous Suggestions

Fight the temptation to hurry the video creation process. Work at a pace that students can understand. Expect to explain some things more via video than in a typical classroom setting because students cannot ask questions while watching the video. Try to also achieve a balance with explanations so they do not become unnecessarily verbose. If possible, try to create unique examples rather than those copied out of a book as doing so makes the video reusable in the future if you change books. If it is desirable to connect to a specific textbook, section, or problem, consider doing so at the beginning of the video on the title screen.

Finally, choose to make multiple short videos instead of a few long videos. The length of the video is directly proportional to the potential for making small mistakes in the video. Perhaps more importantly, realize students will not consume the video the same way they would a typical classroom lecture. Many students wish to digest the material in smaller bites and tie into particular examples and homework. Shorter video segments make it easier for students to locate content in the future if they encounter perplexing material.

Some may fear that students will choose to not watch all of the posted videos, but students are just as likely to mentally disengage from a long video. Additionally, students may find it is not worth their trouble to re-enter a long video, even if it is just a question

of jumping ahead to a particular point. Shorter-length videos are also easier to re-use in other courses that may correspond to other similar units.

Conclusion

Producing videos for students is a never-ending learning process. Those who practice always look to improve their production process. Educators know the value in aiming for a target and adjust as necessary over time to strengthen their ability to hit the target.