Production of long-term usable academic learning/teaching videos and their incorporation into lecture series

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Abstract

Die Erstellung von Lern-/Lehrvideos zum Ersatz von Präsenzvorlesungen und Übungen ist aus Anlass der Schließung der Universitäten im Jahr 2020 vielerorts in den Fokus gerückt. Derartige Videos können jedoch auch abseits derartiger Ereignisse einen wertvollen Beitrag zur universitären Lehre leisten. Im vorliegenden Beitrag zum *Lessons Learned* Journal werden Erfahrungen zur Produktion von langfristig nutzbaren digitalen Formaten dargestellt. Dazu wird ein Überblick über die Schritte der Erstellung von Lern-/Lehrvideos und Vorlesungsvideos gegeben. Dies beinhaltet Beispiele für Hardware und Software sowie Details zu Vor- und Nachbereitungsschritten. Des Weiteren wird auf die Integration der Videos in Lehrveranstaltungen eingegangen und ein Ausblick auf die Nutzung der Produktionen im Kontext des maschinellen Lernens gegeben.

The production of teaching/learning videos as a replacement for lectures and tutorials has come into focus in 2020 due to the close-down of the universities. However, this kind of video productions can also add value to university teaching when the usual presence teaching is resumed. In the current contribution to the *Lessons Learned* Journal, we share experiences about the sustainable production of teaching videos that can be used long-term. We give insights about the production steps, the hardware and software requirements and the integration into university courses. Finally, we give an outlook of the usage of the videos as a database for machine learning applications.

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1. Introduction and purpose of the learning videos

The creation of digital formats to replace classroom lectures and exercises has come into the focus of attention in many places due to the avoidance of classroom teaching in the summer semester of 2020. However, particularly learning/teaching videos, i.e., videos in which the content of science and engineering courses is presented, can also make a valuable contribution to university teaching beyond this singular event.

Screencast videos, in which a computer screen is recorded and the depicted steps are supplemented with verbal explanations, are known in particular from software training [1]. In the academic context, however, the recording and provision of lectures in the form of image recordings was already used in times before the home computer, for example in the University of Iowa's 1955 televised lecture series "The secret of flight" (republished [2]). Especially for the explanation of mathematical relationships, there are now plenty of materials available online that can contribute significantly to the learning success of students [3], [4].

Since 2019, a framework for the efficient creation of learning videos in the engineering sciences has been created in cooperation between teachers at TU Dresden and Wilhelm-Büchner-Hochschule Darmstadt. The experience gained in the process was successfully transferred for the spontaneous switch to digital distance learning at the Institute of Solid Mechanics at TU Dresden, which was necessary in the summer semester of 2020.

In this contribution to the *Lessons Learned* publication, the experiences of efficient production of high-quality learning videos are to be shared. Special attention is given to long-term usability. In doing so, the learner-centred form "learning videos" rather than "teaching videos" is used in this paper in accordance with the constructivist understanding of teaching - in which teachers take on a more supportive and facilitating role [5], [6].

The present publication is structured as follows: After the current chapter that deals with the definition of the purpose and different types of videos, chapter 2 follows with the prerequisites and the technical basis that is necessary for the creation of learning videos. Chapter 3 presents the stages in the creation of a learning video. Chapter 4 is dedicated to the integration of learning videos in hybrid courses. Chapter 5 broadens the view towards new digital opportunities in the context of using learning videos as a database for machine learning, before summary and outlook are drawn in Chapter 6.

Types of learning videos - Before creating a video, its purpose must be clearly defined. For example, a distinction can be made between the following four types:

1. In "lecture videos", frontal lectures are transferred into the digital space. They thus serve to shift the passive consumption of knowledge units into students' independent work phases. This opens up the possibility for more interactive use of face-to-face lecture times. However, in the current situation with the widespread standstill of face-to-face teaching at universities, lecture videos must completely take over the role of lectures.

2. If the video serves to highlight a specific, narrowly defined aspect of a subject area, e.g., a short, animated video can fulfil this purpose. Topics can be, for example, in Engineering Mechanics the calculation of the centre of gravity or the definition of tension. Videos of this type can be called "crucial point videos".

3. If the video is to be used to demonstrate a laboratory set-up or a manufacturing process, the video must be recorded on site under real conditions. In the case of a video that is intended to demonstrate various production steps, these individual steps are shown in detail and include all the materials used.

4. If the intention is to record a "mathematical derivation video" in which students are to learn a task type - for example, in preparation for an examination - the video should be oriented towards what has been defined as the learning objective and will be asked in the examination (according to *constructive alignment* [7], [8]). Since

the final examinations in STEM subjects usually have a character in which mathematical tasks are solved with handwritten derivations, the written presentation of tasks of the same level offers a great advantage for students. In these derivation tasks, the specific crucial points are then brought together in a calculation chain. Also, different calculation chains can be compared and different *dos and don'ts* for the task type can be highlighted.

In the present work, we focus on learning videos according to type (4), which present a calculation chain for a task in writing, supported by the spoken word. For this purpose, 49 learning videos of this type were created for Engineering Mechanics (Statics and Strength of Materials) at the Wilhelm-Büchner-Hochschule. Since lectures in basic courses of mechanical engineering and in mathematically specialised courses in "Simulation Methods of Mechanical Engineering" often have a similar character, many of the findings can be transferred to lecture videos according to type (1). For this purpose, 48 videos were produced for the course "Mechanics of Beams and Shells" (summer semester 2020) and 20 videos in the course "Continuum Mechanics and Fluid-Structure-Interaction" (Part 1: Structure, winter semester 2020/2021) at the TU Dresden, cf. table 1.

Table 1: *Videos produced with number N, total time ΣT and average duration of videos $\varnothing T$.*

Type	N	ΣT	ØT
Engineering Mechanics	49	525min	10.7min
Mechanics of Beams and Shells	48	517min	10.8min
Continuum Mechanics and Fluid-Structure-Interaction	20	277min	13.9min

The following chapter presents the findings on the individual steps in the production process with regard to the long-term usability of these videos.

2. Prerequisites and technical basis

For the creation of learning videos in which mathematical-technical relationships are to be derived step by step, the use of tablet computers and screen capturing is highly suitable. In the current chapter, examples of hardware and software will be shown. Subsequently, the use of visual material and the planned duration of use of the videos will be discussed. The section on "Other preparations" deals with vocal and manual preparation.

Hardware - In principle, any tablet computer or convertible with a built-in or externally connected digitizer is suitable as a technical basis. However, it is important to ensure that the screen resolution, which is also the maximum achievable resolution of the recording for screen capturing, is high enough for the purpose of the application.
If possible, an external headset should be used for the audio recording, as otherwise scratching noises from the pen or - in the case of a desktop microphone - losses in sound quality occur depending on the direction of speech. For an adequate quality of the recording, the extensive knowledge of the pod-casting scene can be used [9]. For noise-free recording, e.g., condenser microphones connected via an audio interface and USB, are a good choice.

Table 2: Hardware used in the present case.

Type	Product
Tablet/PC	MS Surface Book Gen.1
Pencil	Microsoft Surface Pen
Microphone	Beyerdynamic DT-297-PV/80 MKII
Audio interface	Focusrite Scarlett 2i2 3rd Gen
External hard disk	Western Digital WDBC3C0020BBL-WESN 2TB

In the case at hand, the technique according to Table 2 was used. The recording of handwritten derivations can also be realised with the help of a visualiser, however, the occlusion of the writing with the hand must be heeded.

Software - Many software solutions are available on the market for recording the screen (screen capturing). Commercial solutions can be chosen that allow not only the recording but also the editing of the videos. In this case,

the *Screencast-o-matic* software was used. Another variant is *Camtasia*. Alternatively, a combination of programmes for recording and editing can be used (e.g. *Open Broadcaster Software (OBS)-Studio* combined with *DaVinci Resolve*), for which a suitable workflow should then be defined. For videos based on slide sets, for example, the recording function integrated in *Microsoft PowerPoint* can be used.

Any software tool with a whiteboard function can be used to create the notes. Depending on personal inclination and practice in writing on tablets, graph lines/ruled paper can be used. However, these lines make post-processing more difficult, especially when using overlays. It is a good idea to use the same software to write the script. In the current case, Microsoft OneNote was used.

Table 2 also refers to an external hard drive, as large amounts of data can be generated in the course of a lecture series. In raw format, the aforementioned *Screencast-o-matic* software results in an average of 1-2 GB storage space requirement for an educational video, which can, however, be significantly reduced with simple compression. The data size of the videos exported in MP4 format (HD videos 1920 x 1080 pixels) is particularly relevant for transmitting and publishing. An educational video with a duration of 15-20 minutes can have a size of 60 MB. With graphic elements such as intro and outro as well as sound editing, this results in up to 250 MB. The servers for providing and archiving the files should therefore have sufficient storage capacity.

Graphics and images - The use of graphics, images, drawings and tables lighten up the video and give an additional impression of the learning content. In order to ensure the smooth use of copyrighted material outside of the academic context, one should make sure that these are under a free licence (e.g. Creative Commons https://creativecommons.org/licenses) or that a corresponding licence has been acquired for use (e.g. from archive/stock material). The easiest way is to use a self-made graphic and to indicate this clearly. When reusing and sharing the video, it is important to consider the licence or to re-license accordingly. The use includes the published environment, duration of use and the owner.

Ageing of learning videos - The question of the life span of learning videos should be discussed before production. On the one hand, the topicality of the topics covered and, on the other hand, the technical side must be taken into account. In the present case of learning videos and lectures in Engineering Mechanics, no major change in the technical content can be assumed in the foreseeable future. Thus, special attention must be paid to creating the technical prerequisites for the longevity of the material. This concerns both the image format and the resolution of the videos.

Many images are usually in a pixel-based format, such as .jpg or .png, and their enlargement is limited because they quickly look *rasterised/pixelated.* In contrast, an .svg format is vector-based and can be enlarged and reduced without loss. It is recommended to use the largest possible image size and not to enlarge it later by more than 15%-20%.

Since a screencast is naturally pixel-based, care must be taken to use the appropriate resolution. In this case, the videos were used and made available in HD format (1920 x 1080 pixels). However, it is foreseeable that development will continue and higher resolutions will become necessary. In order to plan for the long term and to be prepared for future format changes in video production, for example to the image resolution 4K (3840 x 2160 pixels), it is advisable to record at the next higher quality level (HD 4K→; 4K 8k→) as far as technically possible and to downscale to the lower resolution format in editing and rendering. If it becomes necessary, the material can be used again later and rendered at a higher resolution.

It is possible that current developments in the subsequent increase of resolution with the help of neural networks (*super-resolution* [10], [11]) will make these steps superfluous in the future.

Other preparations - In addition to expenditures for technical equipment, investments in one's own preparation are equally necessary. This concerns, on the one hand, getting used to writing on a digitizer. It is advisable to use basic writing exercises (e.g. the alphabet line by line), as *on-the-fly* practice does not lead to satisfactory results in most cases. At this point,

you should also consider which stroke width is suitable for the intended use (e.g. display on a smartphone or display on a PC screen), as this has a great influence on getting used to writing on a digitizer.

The general preparations should also be extended to the way of speaking. It is possible to practise speaking slowly and clearly [12] and to optimise one's own performance with the help of self-recordings. Further details on speech and voice are given in the section "Implementation" in chapter 3. This chapter also deals with the preparation and follow-up of the recordings.

3. Stages of the creation of learning videos

In this section, the stages of production and their share in the total time required are briefly discussed. The individual steps are then explained in more detail.

The steps to create a learning video are as usual (1) preparation, (2) execution and (3) post-processing, see Figure 1. In addition, there is another step of (4) distribution/dissemination.
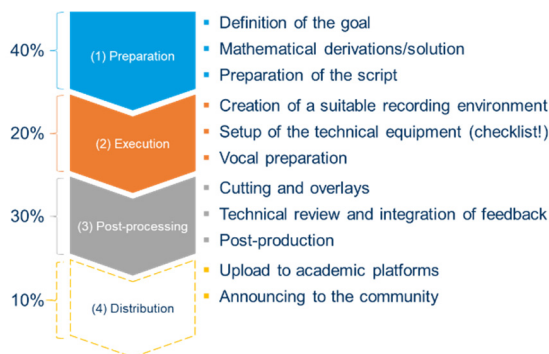

Fig. 1: Steps and corresponding percentage of the total time needed to create the video. In the present work, the proportions (40-20-30-10) resulted.

In the overall production time of a video, the percentages between the first three steps (here as an example 40%, 20% and 30%) can be shifted according to personal preference, but the fourth step of distribution is generally constant.

If, for example, a great deal of effort is invested in preparation (e.g. verbatim formulation of the script), fewer recording attempts (takes) are necessary. In most cases, this also reduces the amount of post-production work (50-20-10-10). If, on the other hand, very little effort is invested in preparation, entire mental paragraphs must occasionally be reformulated during the recording in order to achieve the same quality. The incomplete sentences or pronunciation mishaps must in turn be cut out in post-production (10-40-40-10).
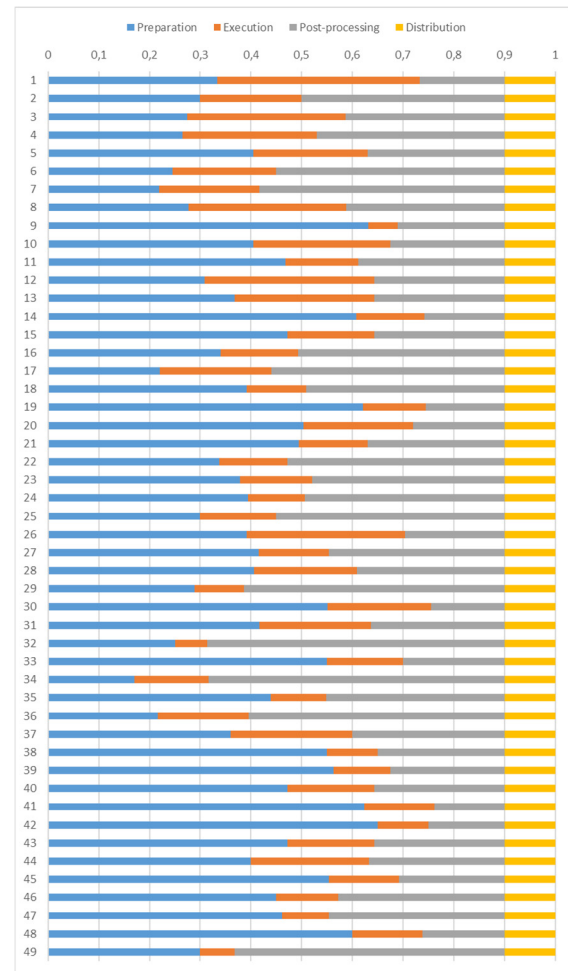

Fig. 2: Percentage of the phases (1) preparation, (2) implementation, (3) post-processing and (4) distribution in 49 produced learning videos (Engineering Mechanics).

Figure 2 shows the percentage shares of the individual stages for 49 learning videos of Engineering Mechanics. By shifting the proportions from (50-30-10-10) to (10-40-40-10), no global time saving could be realised that could not be explained by the individual improvement of each step. However, this was only true insofar as a minimal script (specific text, calculations, intro and outro) was used. A spontaneous calculation/improvisation always proved to be too error-prone.

It is advisable to keep a record of the times for the individual steps for a better understanding of one's own efficiency in production and for optimisation. From this, similar to the principle of pipeline optimisation known from software technology, it can be identified in which process step the greatest efficiency gains can be achieved with the least effort.

(1) Preparation - The first step is to define the goal of the video. For learning videos in which a single exercise/problem is to be solved, this is the task; for lecture videos it is a clearly defined section (topic). From the solution of the task or the writing down of the topic, a script can be created in which the texts and equations to be written are listed. This can be supplemented by additional instructions in bullet point form (reminders for extemporising) up to fully formulated text passages. Instructions can also include the occasional reference to slow and clear speech and consistent use of colour. It is also helpful to formulate a consistent introduction and conclusion.

(2) Execution - The actual recording begins with the creation of a suitable recording environment and a technical check. Ideal video recording conditions occur in a quiet environment, in an insulated room with little external noise (construction work, car or aircraft traffic, children's noise). Recording in the evening/night hours can help if certain noise sources are otherwise difficult to control. An increase in the quality of the recording is achieved by using partitions covered with soft, damping material and placed close to the person. A thick, sound-absorbing curtain or acoustic foam panels on the walls and ceiling elevate the room to the next professional level (recording studio).
The microphone position of the headset should be at lip level if possible and give the impression of speaking upwards. Speakers should adopt a standing posture, whether in the "on" (in the picture) or the "off" (not visible in the picture) position. This straight posture has a positive effect on good speech performance, but the effect varies from person to person.
A "bad day" can also be recognised in the voice. It is often better to postpone the recording or to take a longer break, because even with great effort not all shortcomings of badly recorded videos can be corrected: "You cannot force *a good video*". For a good voice and to avoid "smacking noises", a sip of water can be drunk occasionally.
During longer paragraphs and explanations, it is recommended to lower the voice at the end of the sentence to make it easier for the listener to listen. The interplay of clear voice, slow speech and structured language result in a pleasant learning and listening experience.
Establishing ideal recording conditions and setting up the technical equipment can be ritualised by using a checklist. A short test recording also enables to identify further environmental noises and to be able to assess one's own current condition.

(3) Post-processing - The recording should be followed by individual post-processing. It is advisable not to do this immediately after the recording, as this would not allow sufficient mental distance from the work. With the help of the script, the complete video can now be checked and - where necessary - corrected by cuts, partially new recordings and fade-ins/overlays.
The raw version of the videos should be technically reviewed (e.g. as a peer review) for quality assurance. The aim here is to provide well-founded independent feedback. In the case of the learning videos in Engineering Mechanics described above, particular attention was paid in the approval process to ensuring that

- The title fits the content,
- The calculation steps/instructions are comprehensible. A distinction must be made as to whether the calculation steps are of a subordinate category, such as solving a system of equations, or whether they are core points that belong to the learning video and must therefore not be omitted.
- The contents are correctly calculated.
- The notation/symbols from the lecture are used.
- The explanations are purposeful and complete.
- The author's pronunciation is understandable.
- A conclusion or summary may be drawn at the end.

The feedback must be inserted in a further post-processing step. The same type of feedback loop must be followed for feedback throughout the learning video lifetime.

Professional post-production - To create high-quality videos that will be useful for the longer term, a further step of professional post-production can be carried out.

The first step after reviewing the content is to create the repeating elements, such as visual intro, title, introduction of the creator and outro/credits (conclusion of the video). These can be created as templates in a graphics programme (e.g. *Adobe After Effects*) and integrated into the editing of each video. It is not absolutely necessary to use animated templates for a good video. A simpler graphic with the appropriate information can also be created at this point. An overlayed permanent logo in one corner and the inclusion of the title serves as orientation and creates a professional impression. The editing of music and sound can be done in a sound editing software that allows for cuts, fades and stereo sampling. It is advisable to use music for the intro, because it increases attention. The type of music also serves to set the mood for the content and creates the pleasant feeling that "*you know what to expect*". Once you have found a piece of music, you should check where it is registered. The associated label administers the performance rights and GEMA. Music is usually not free of charge and can, on the contrary, be very expensive, depending on the work and its popularity. If the author has been dead for more than 70 years, on the other hand, it is possible that the music is *GEMA-free.* If it is intended to show the video publicly, special attention should be paid to whether the licence allows this; the GVL (Gesellschaft zur Verwertung von Leistungsschutzrechten) is responsible for this.

Many music publishers offer a wide range of GEMA-free background music (e.g. Sonoton, Epicmusic, Audiohub, allesgemafrei.de), in other places the licence can be purchased to suit the use.

In professional post-production, small noises can also be removed, such as clearing of the throat, *ehms*, inhalations, scratching noises of the pen or clattering of the keyboard. However, it is not necessary to remove all minor oversights; "*some things are lost* in transmission", i.e. they are not consciously perceived by the listener. For example, a brief image slip, a blinking cursor or a manually corrected drawing may well remain in the video, especially if the correction in post-production takes a disproportionate amount of time.

(4) Distribution - In order to make the videos available to the user community, the appropriate channels of the university or college should be used, such as academic online platforms. The processes of uploading, linking, tagging and, if necessary, announcing the videos can be simplified and professionalised by using checklists, just like the other steps.

Now that some aspects in the steps of the recording have been dealt with, the following chapter will focus on the integration of the recordings in courses.

4. Integration in hybrid courses

The videos created according to the rules of art described above are to be used sustainably as part of academic courses.

Lecture videos - A complete replacement of the classroom lecture by online lectures or lecture videos is not recommended - mainly due to the lack of interaction between teachers and students. Mullamphy et al [13] describe a high level of acceptance as a means of supplementing teaching as the result of a survey of students on the use of screencasts. However, it was found that excessive use did not meet their expectations of a face-to-face university. This could also be seen in feedback from students at the TU Dresden.

Nevertheless, lecture videos can make an important contribution to the transition from lecturer-centred teaching to learner-centred teaching. Lectures, which are often very one-sided due to the large amount of material to be taught, can be transferred to the students' own preparation in this way. The time in which personal interaction between students and teachers is possible (e.g. lectures and exercises) can instead be used for interactive formats such as discussions or joint project work. However, particular care must be taken to ensure that an appropriate overall effort for the course (according to the credit points in the study regulations) is maintained.

A key point for the long-lasting use of high-quality produced lecture videos is updating. In order to be able to use the videos or parts of them again in the following semester, videos should be reviewed at the beginning of each semester and updated if necessary. If only minor changes or updates are necessary, the video from the previous semester can be adopted or used as a basis. However, the effort required varies depending on the method chosen: If a set of slides was used, as described in chapter 1, only the affected slides or the associated text need to be modified. In the case of handwritten lecture and learning videos, in the event of major errors, the corresponding sequences - regardless of whether there are changes on the transcript or in the text (sound) - must be completely recreated in each case. However, small changes can also be inserted in the editing software as an overlay. In any case, it should be made clear within the video that updates are available, as it is difficult to exclude the parallel use of different video versions.

Another important point is the possibility, occasionally requested by students, to print out the contents of a video. A set of slides or a manuscript offers students the opportunity to add their own points, which is a great advantage in terms of follow-up and preparation for the exam. A conscientiously prepared recording script can provide a useful basis for this.

Overall, it has been shown that the development of equations or the step-by-step explanation of calculation steps is absolutely necessary in the lectures of Engineering Mechanics.

Learning videos - For videos in which sample exercises are calculated, they can be used as a bridge between lectures and exercises. In this way, the introduction to exercises can also be shifted to the preparation of the students in favour of interaction during the attendance time.

5. Instructional videos as a data source

The widespread shift to digital formats opens up an exciting new field of application from the perspective of *data science* [1], [14]. For example, various machine learning methods from different application areas (OCR, speech-to-text, natural language processing) can be combined to make entire lecture video series searchable [14]. If this technology is applied to the entirety of the lecture and learning videos of a university degree programme, a wide range of possible applications arise, ranging from the harmonisation of the characters/symbols/abbreviations used within a field of study to the automated design of examination tasks (based on keywords from Bloom's Taxonomy [15]).

On the other hand, the self-produced videos can form a database for machine learning for lecturers themselves. This opens up the possibility, for example, of training a *"deep fake"* model of one's own voice and thus making it easier, for example, to add additions to videos [16]. However, the authors of videos must be aware that this data set is also available to others (*bad actors*) when it is published [17].

6. Summary and outlook

The current paper provides an insight into the production of lecture and learning videos that are intended to be usable in the longer term. The prerequisites and specific steps for the production of high-quality videos are discussed. Furthermore, aspects of the integration of video recordings in lecture series are presented and a brief outlook on the use of videos as a database for machine learning is given.

While some of the details mentioned here are not helpful for the current shift from face-to-face to distance learning, addressing them can contribute to a better understanding of the complexity of the process and help professionalise video production by teachers in universities and colleges.

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