Video material for self-study in mathematics and physics courses: from design to evaluation

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***Abstract*—This Innovative Practice Work-In-Progress article describes the implementation of video material in undergraduate mathematics and physics courses for engineering and computer science students. The COVID-19 pandemic has highlighted the need to provide online material to which students can return whenever their technical and temporal resources allow. A similar need has long existed among students who support themselves by working part- or even full-time while studying towards a degree. This student group is well represented at our institution as access and outreach initiatives target professionals with vocational training in a technical field. The didactic concept of the videos as well as didactic opportunities for face-to-face lecturing in combination with online video material will be described. Students' responses to the innovative practice were surveyed in two ways: first, through an online questionnaire administered to students of an introductory physics course. The questionnaire data is subjected to quantitative and qualitative analysis in this article, with results leading to an indication of high student satisfaction. Second, students' experience as gathered from group interviews with students from a first-year mathematics course will be analysed. Collectively, this information sheds light on the advantages of the practice presented as well as on further improvements.**

***Index Terms*—blended learning, student perception, higher education**

I. Introduction

Within higher education and beyond, the question of how to best use the technological resources available for creating blended learning settings is vividly debated [1] [2] [3]. This question has become even more pressing with the COVID-19 pandemic. Existing blended learning resources for higher education have been put to a test by constraints on face-to-face teaching [4]. This was also the case for the implementation of video material presented in this article. In 2019, a process to move from traditional lectures and classes to blended learning was initiated at our institution, the University of Applied Sciences Technikum Wien. So was the process of producing videos in order to make them part of blended learning units that consist of different types of learning material and complement face-to-face teaching. During campus closures caused by the COVID-19 pandemic, online live lecturing replaced face-to-face teaching. Thus, the videos at all times retained their purpose as material that accompanies, and does not replace, synchronous lecturing. In this article, the process of producing the videos and their implementation into maths and physics courses for engineering and computer science students will be described. Based on student feedback, the effects of video material on student learning at our institution will be discussed. Student feedback was gathered in two ways that complement each other: in one first-year physics course, students were asked to fill in a short questionnaire on the material provided for each blended learning unit, i.e. weekly over the course of 8 units in total. This feedback was collected for two academic years. In order to learn more about how students study with the videos provided, group interviews were conducted with students from a first-year mathematics course. The authors of this article also reflect on the opportunities provided by videos in blended learning settings from their perspective as both video makers and lecturers. It is our intention to continue research on the video material, especially as production and implementation of additional videos is ongoing.

II. Background

Video has long been an integral part of open educational settings and distance learning [5]. Higher education's turn to video as part of blended learning settings is more recent, intricately intertwined with attempts to individualise student learning in order to cater adequately for the needs of a diverse student body [6]. To the benefit of practitioners wishing to create their own educational videos, findings from previous

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research are often combined with recommendations for video design [7] [8] [9]. One persistent recommendation is to keep videos short, corroborated once more recently in a controlled experiment in a setting similar to the one under scrutiny in this article [10]. Brevity was thus a guiding principle for the production of videos at our institution. The decision to produce videos specifically adapted to our course content was informed by a study that found a preference among students for 'instructor-developed videos' [11]. A recent finding from a study attributing clickstream data to students' activities when engaging with videos ties in with a concern at the forefront of video production and integration at our institution [12]: helping students navigate through a single video and a video collection, both by providing hints in the videos themselves and by the learning environment into which they are integrated.

III. Implementation of the learning material

A. Blended Learning at our institution

Mathematics and physics courses at our institution are offered across multiple *bachelor-of-science* degree programmes. All of these courses have the same blended learning setup: each weekly unit of a course is split up into three study phases: self-study, face-to-face lecture, self-study. On Moodle, students will find a wide array of learning materials already attributed to a specific unit and to one of the three study phases within this unit. Examples of the learning material provided are: videos, applets, textbooks, scripts, fact sheets (compact summaries of topics), checklists (compact list of the learning objectives for a topic), quizzes, etc. Each topic has a *learning path*, i.e. a list of operationalised tasks that gives students guidance on how to use the suggested material. Our institution turned to blended learning in order to give students more flexibility with regard to when and where to study new content or revise prerequisite knowledge.

B. Video design and production

With the specific aim of providing support for the production of online learning material, our institution has equipped a studio room with high-quality audio and video infrastructure. A 75" Smartboard touch monitor with SMART Meeting Pro® software serves as the whiteboard background in videos. Header video lights are used in a sophisticated lighting setup for professional illumination. The whiteboard monitor can be controlled by the presenter or from the control room, enabling the use of complex video-editing techniques such as video-on-video and to enrich our instruction material with multimedia content.

C. Didactic concept of the videos

The aim is to present the whole content of all first-year mathematics and physics courses in a kaleidoscope of short videos (5–10 minutes). More complex concepts are explained in a series of videos that refer to each other, but each video can be watched on its own. We distinguish between theoretical and practical content. Typically, in one video the theory of a concept is explained and in another one an example is presented. In videos addressing more advanced content, basic concepts are not explained in detail, but the video in which the basics are explained is referred to. Complex calculations need basic calculations. This is important to make our videos work when watched as a series. In videos dealing with basic calculations, we aim to use exactly the ones we need for more complex calculations in other videos. Thus, we can keep our videos short, while being able to provide students with entire complex calculations on video.

D. Implementation of the videos in the courses

The videos are hosted on YouTube and implemented into Moodle courses via links to single videos or entire playlists in the *learning paths*. It is advisable to give links to two playlists, one called 'recommended', the other 'optional'. Thus, while the 'recommended' playlist focuses on the topic of the respective unit, students have videos covering common questions concerning prerequisite knowledge for this topic directly at hand in the 'optional' playlist. Another way of organising the playlists is by dividing videos on the topic of a unit into videos 'to be watched before' and 'videos to be watched after' the lecture. In lectures, it is clearly communicated to students that they can and should use the videos for studying and rehearsing at any time deemed sensible to them, that is, beyond the specific unit, and possibly lecture, to which the videos are assigned. The number of videos provided per unit varies. The two courses for which we gathered feedback can be seen as representative: In the course *Grundlagen der Physik für Ingenieurswissenschaften* ('Fundamentals of Physics for Engineering Science'), the median of videos provided per unit is 10. The unit with the lowest number has 3 videos; the unit with the highest number has 19. Numbers are comparable for the course *Mathematik für Engineering Science 2* ('Mathematics for Engineering Science 2'): the average of videos provided per unit is 8, with a minimum of 2 and a maximum of 19 videos. These big ranges are due to the fact that some of the self-study phases to which the videos are assigned require students to repeat content from previous units or even courses.

IV. Preliminary Results

A. Online survey

In the academic years 20/21 and 21/22 students of the lecture *Grundlagen der Physik für Ingenieurswissenschaften* were asked to give feedback on the videos. This physics course is particularly apt for surveying student opinion as it is offered to roughly 250 first-year students, i.e. 1/4 of our yearly student intake. All students were asked to fill in an online questionnaire for each of the 8 units of the course. During previous evaluations at our institution, we observed that students' motivation to give feedback decreases when asked to do so multiple times. We perceive feedback as a rare resource. Therefore, when designing the questionnaire, we were sensitive of students' time. The questionnaire was identical for each unit. The question read 'How do you perceive the videos provided for this unit?'. The response options were: 'helpful'; 'not helpful'; 'not used'. With our students' convenience in mind, the response options were always presented in the same order, although we recognise that changing the order may lead to more accurate results [13]. Table I shows the achieved response rates of roughly 50% for both years. In absolute numbers, approximately 500 students completed more than 2000 feedback forms. This should suffice to draw a representative picture of student satisfaction with videos at our institution.

TABLE I
DATA SUMMARY FOR THE LECTURE
Grundlagen der Physik für Ingenieurswissenschaften

Year	Students	Possible Feedbacks	Completed Feedbacks	Response rate
20/21	232	1856	1040	56%
21/22	261	2088	1023	49%

Fig. 1 and Table II show a generally positive perception of the videos. As reported in Table II, the approval rate rose between the academic years 20/21 and 21/22. It may be presumptuous to speak of a positive trend with only two data points. However, a possible explanation for the increase in approval may be that a number of videos were produced in 2021 and added to the course. Thus, the students attending the course in 21/22 had more video material at their disposal, which may have led to higher approval. In order to gather more data to support this interpretation, the online survey will be conducted again in the academic year 22/23.

TABLE II
DATA SUMMARY FOR THE FEEDBACK ON VIDEOS FOR THE LECTURE
Grundlagen der Physik für Ingenieurswissenschaften

Year	Completed Feedbacks	Helpful	Not Helpful Not Used No Comment	Approval rate
20/21	1040	661	379	64%
21/22	1023	728	295	71%

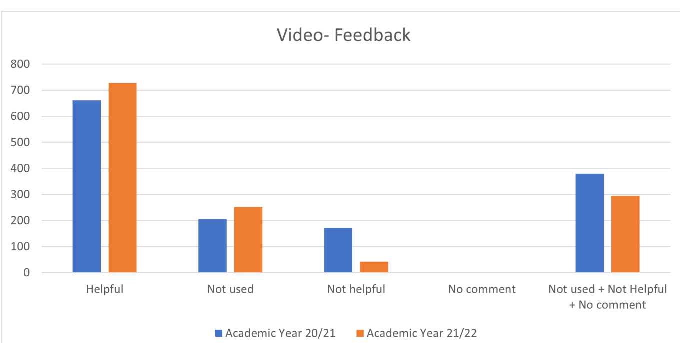

Fig. 1. Histogram of the feedback data, showing the total of students' responses for different categories of possible answers.

Text comments from the two previous surveys already suggest a possible correlation between higher number of videos provided and approval rate. The online questionnaire includes a field that allows respondents to add a text comment, to more freely and extensively elaborate on their perception of the course. A total of 118 students explicitly mention the videos in the open comment field. Often, they express their appreciation for the mix of textbook chapters, videos and fact sheets, and for the fact that they can use the videos to study at their own pace. Several students stated that this was their preferred part of the course. Moreover, they felt that they would benefit in the future from an even increased amount of videos and increased share of video-based learning, with an even more in-depth insight into the different topics to facilitate their knowledge acquisition. Many students felt additional videos could further help with the explanation of important laws and relationships, and especially could provide examples of calculations and guidance on the solving of specific equations and practical, hands-on exercises (e.g., also including real-world applications). In response to these student comments, video production and implementation is ongoing, as is the evaluation process.

B. *Student experience as gathered from group interviews*

One of the authors, who both lectures and is responsible for video content, conducted mid-term evaluations in her course *Mathematik für Engineering Science 2*, a second-semester blended learning course. She teaches the course to five different groups of students. The evaluation was carried out in all groups in the form of a semi-structured interview. At the day of the interview 18, 19, 21, 22 and 16 students respectively were present in class. We acknowledge that the participants of the interviews were a convenience sample and that there are advantages and disadvantages attributed to the teacher acting as facilitator of student group interviews [14]. Nevertheless, as student answers from all five groups overlap, we are confident that they can shed some light on student learning with video. The interview questions were:

- 'Do you use the videos for studying?'
- 'What do you like/dislike about the videos?'
- 'Why do/don't you use the videos for studying?'
- 'What would you do if we did not provide videos?'

Most of the students use the videos for studying, in each group approximately 80% of students. Students like about the videos that they are short. This answer was the one most frequently given to the question 'What do you like about the videos?'. Students explained that the advantage of short videos is that every single video is easy to follow, because it makes them focus on one specific aspect. After finishing one video, it is very likely for them to watch the next video: the first video makes them feel confident that they will understand the following one, too. This feeling leads students to watching the whole playlist, exactly as recommended in the Moodle course. In addition, students said that they are motivated to watch the whole playlist on a certain topic because they perceive a 'story line' that runs through different videos on one topic, sometimes expanding to videos on different topics, too. Student answers to the question 'Why do you use the videos for studying?' focused on the following aspects: students stated that, in the videos, the most important content is pointed out. Moreover, connections between the mathematical objects are drawn, which they find difficult to discover by themselves. As an important aspect of video-based learning, students mentioned that they can pause the video, in order to reflect on the content that was explained. Students reported that they watch difficult sections multiple times – perceived as a great advantage of video, as it is obviously impossible to watch repeatedly the explanation of a lecturer when given in the classroom. Another argument from students was that video supports their learning type. Knowing that the concept of learning types is discussed controversially [15], we may conclude that students appreciate multi-medial learning material. An important aspect for mathematics is language, which has to be exact and which students perceive as difficult. Students argued during the group discussions that the videos translate the mathematical content from a written mathematical language to an every-day spoken language. These student observations tie in with an advantage of learning with video material that has been theorised by R.E. Mayer as the 'personalization principle' [16]. Last but not least, students addressed the various possibilities of giving explanations that a video offers in contrast to learning material in a written form: presenting graphical solutions, going forward and backward, switching between the calculation and the graphical interpretation, as well as the fact that a solution is not encountered in its final written version at first, but that it is developed step by step in the course of the video. There was agreement in all student groups that, if videos were not provided, they would watch videos on the internet that cover the same content. The problem, however, that students observed with regard to videos from other sources is that they are not perfectly shaped for their coursework. It is important to note here that students state to use videos for studying regardless of whether these are provided by an institution. In our view, this strongly supports providing videos in a blended learning setting, preferably produced specifically for this purpose, in order to prevent students from turning to more dubious sources. The students who do not watch the videos gave as reasons that they generally do not study a lot on their own or that they find that the playlist on the private YouTube-channel has no structure. The first reason highlights the general need to adapt the mode of face-to-face-teaching alongside implementing material for self-study in order to make this material more compelling to students. The second comment has more of an internal value. Since students who choose to watch the videos reported to perceive a structure in the playlists provided, we need to work towards making this structure more apparent at first glance.

C. Teachers' perspectives

Three of the authors of this article were involved in producing the video material and in teaching the respective courses. In this subsection, they provide their perspectives. Maths and physics courses for first-year engineering and computer science students cover introductory topics by nature. This created the wish among lecturers to record explanations of common topics, with a focus on the conceptual difficulties that typically arise for students. From the start, the aim of recording content was not to replace lectures, but to gain more didactic options for shaping lectures. There are basic concepts that need to be introduced, but typically do not raise many student questions. With videos, we can shift the introduction of these concepts to self-study. In the lecture, based on students' video-supported preparation of the introductory content, we can move on to applications and more complex concepts. Gaining time for complex content is crucial, as from our teaching experience, students rarely understand more complex concepts just from listening to an explanation once. This is especially true if the explanation is placed at the end of a lecture, when student attention is already reduced, which is almost inevitable in a more traditional lecture setup. Videos addressing these more complex concepts are also provided, for students to watch after the lecture. This has two advantages: students can return to these more complex concepts when they feel ready to process them and they can split these concepts into small pieces, thus making them easier to understand. Taking account of the fact that videos are provided, lecturers have the possibility to adapt didactic concepts even spontaneously during lessons. The time reserved in a lesson for a complex concept can be used to give students an overview of its most central ideas and applications.

Each student, and each teacher who used to be a student, will remember at least one situation in which a good and compact explanation by a peer or teacher suddenly cleared up all the questions left unanswered after hours of study with a book. To emphasize this we want to share a recent personal experience of one of the authors. After discussing Gauss's law and the Electric Flux with students, a student expressed appreciation: 'It would be great if you could make a video of this explanation!' Of course, it will never be possible to cover all student questions in videos and it will always be advantageous to have face-to-face lectures to tackle more complex problems interactively. Nevertheless, in order to have the time during lectures to do so, the videos are a powerful tool to clear up easier problems.

V. Future Work

All evaluations of the practice presented in this article were conducted with an eye to improving the ongoing video production and implementation. In addition, students' attitudes towards the videos in the academic years surveyed may have been affected by the constraints imposed by the COVID-19 pandemic. Once implementation is completed, it is the authors' intention to repeat and optimise their surveying of students' perception of the videos in order to gain a more robust data sample. A particular future research interest will be to look more closely into the relationship between an 'inverted classroom' teaching mode and students' video use. We may hypothesise that students engage more deeply with the video material in a self-study phase if they know that they have to apply their knowledge actively in the following lesson. The data already collected promises to provide interesting points of comparison with a follow-up study focused on a student sample from a course that consistently applies an 'inverted classroom' teaching mode.

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