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Usage of prerecorded mathematics video-lectures – Comparison of the intentions of an instructor with students' usage

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Video-recorded lectures have become a common element in many university mathematics courses. Hence, it is important to explore how students at tertiary level use such video-recorded lectures for learning mathematical content. We, therefore, conducted a study in which we investigated how students of a linear algebra course used prerecorded mathematics lectures for getting acquainted with the content presented in these. In addition, we compared their reported behavior with the intended usage as provided by the instructor. The results show that there might be discrepancies between these two – in particular regarding the usage of the pause and rewind features. While the instructor hoped that the students would use these mainly for gaining an understanding of certain pieces of content, several of our participants mostly paused or rewound for taking neat notes.

Keywords: Video-recorded lectures, students' practices, linear algebra, learning with media.

Introduction and embedding of the research

Video-recorded lectures have become a common element in tertiary mathematics education. In traditional courses with lectures, these often cover the same content as the live lectures, and provide students with additional learning opportunities (e.g., Howard et al., 2018 or Yoon and Sneddon, 2011). Furthermore, during the Covid-19 pandemic, several instructors replaced their live lectures by prerecorded lectures (Ní Fhloinn & Fitzmaurice, 2021), which might be used also further. Hence, it is important to investigate how teaching via video-lectures affects students' learning of mathematics.

Past research indicates that students often perceive video-recorded lectures offered in addition to live lectures as beneficial for their learning. For example, in Yoon and Sneddon (2011) or Howard et al. (2018), who investigated students' usage of prerecorded video-lectures that were provided in addition to live lectures, the students emphasized that the videos allowed them to cover the material in their own pace, to decide themselves when to engage with the material, to revisit material, or to catch up lectures missed. However, past research also indicates – at least for captures of live lectures – that students who use video-recorded mathematics lectures frequently tend to perform lower in the exam (Howard et al., 2018; Lindsay & Evans, 2021). A reason for these contrasting findings is indicated in Trenholm et al. (2019). They found that students who used the provided recordings of live lectures frequently tended to use surface approaches to learning such as rote-learning. In a subsequent interview study in which Trenholm investigated students' cognitive processes while watching recorded lectures (Trenholm, 2021), some of the course participants also admitted to be less cognitively engaged when watching the recordings compared to live lectures. Although these studies only focused on captures of live lectures, they might also give indications about students' usage of video-recorded lectures in general – including prerecorded lectures. A relevant study investigating how students learn mathematical content from pure video-lectures was conducted by Weinberg and

Thomas (2018), who investigated how students tried to make sense of the content of two videos on introductory statistics. Their participants often did not recognize gaps in understanding while watching the videos, and commonly misinterpreted the instructor’s explanations. This was also the only study on tertiary students’ usage of video-recorded lectures we found that explicitly discussed the mathematical content covered, although the content is an essential aspect of students’ learning with media (Rezat & Sträßer, 2012). We therefore aimed at expanding these findings by investigating *how students use prerecorded mathematics lectures for getting acquainted with the content presented in these*, and compared this usage with the instructor’s intentions.

Theoretical framing

As we wanted to find out how students use certain media for getting acquainted with mathematical content, we used a theoretical framework that considers the usage of media as an artefact-mediated activity. Vygotsky argued that people’s behavior can be mediated by additional stimuli, and that the presence of such an additional stimulus makes a new indirect connection between the original stimulus and a subject’s reaction, which he visualized with a triangle (Vygotsky, 1997). This idea is an important basis for models describing artefact-mediated activities, e.g., by Cole (1996), which we used as theoretical basis for our research. He defined artefact as follows:

An artifact is an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action.[...], artefacts are simultaneously ideal (conceptual) and material. They are ideal in that their material form has been shaped by their participation of which they were previously a part and which they mediate in the present. (Cole, 1996, p. 117)

Hence, an artefact is something material, but always has to be viewed together with the purpose for which it was designed. Video-recorded mathematics lectures, for instance, are often designed to help students become familiar with new content. Aiming to describe how such an artefact might mediate behavior, Cole also created a triangle illustrating that an artefact adds a new indirect connection between a subject and an external phenomenon that he called “object” (see left graphic in Figure 1).

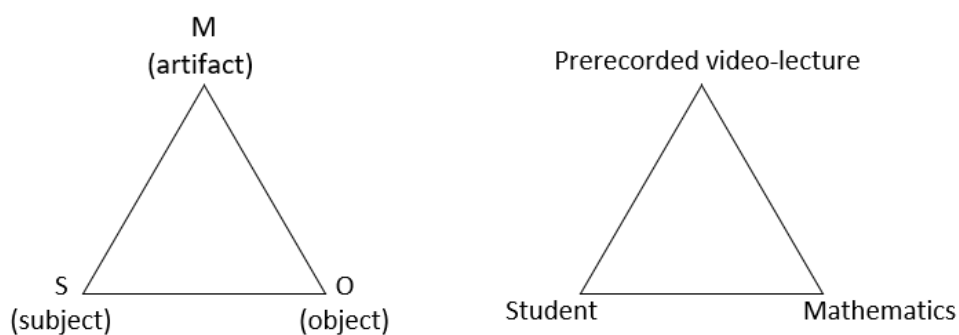


Figure 1: Mediational triangle by Cole (1996), and our specification for video-recorded lectures

Similarly to Rezat (2009), who used this framework for investigating how pupils use mathematics textbooks, we used it for investigating how students use prerecorded mathematics lectures for getting acquainted with the content presented in these. In our case, students of a linear algebra course were the subjects, the lecture’s contents can be considered as “the object”, and the prerecorded video-lecture was the mediating artefact (see right graphic in Figure 1).

In what we want to present here, we also consider the instructor. This might lead to the idea of using an extension of the triangle to a tetrahedron – as proposed by Rezat & Sträßer (2012). However, since our research focus did not lie on how the artefact “prerecorded video-lecture” influenced the instructor’s presentation of the content (although it certainly did), but on a comparison between the students’ usage of it and a usage intended by the instructor, we used for simplicity “an intended triangle from the instructor’s view” for conceptualizing the latter, and not a full tetrahedron.

Context of the study

Our study took place in a course “Linear Algebra and Analytical Geometry II” at a large German university in 2021. Its participants were teacher students who will later teach mathematics up to the end of secondary level. The topics were: affine geometry; scalar products and orthogonality; orthogonal decompositions of vector spaces; norms on vector spaces; determinants; eigenvalues, eigenvectors, and diagonalization; and, singular value decomposition of matrices.

Prior to the Covid-19 pandemic, the course consisted of two 90-minute lectures and one 90-minute tutorial per week. In addition, the students were obliged to solve written assignments. Due to the Covid-19 pandemic, in the year of our study, the instructor substituted each live lecture by three videos – each about 25-30 minutes long. He already had experiences in creating such videos from the previous linear algebra course with the same participants. The tutorials were given via ZOOM.

The course was proof-oriented and the lectures followed the traditional DTP-format (definition, theorem, proof). The style of the videos was the so-called *Khan-style* (Howard et al, 2018). This means that the instructor wrote into partly filled slides with a tablet while his narrations were recorded in real time. A sample slide can be seen in Figure 2. He covered about ten such slides per video.

Eigenschaften der Determinantenabbildung \det_2

$$\det_2: \mathbb{R}^{2 \times 2} \rightarrow \mathbb{R}, \quad \det_2(x, y) := \det_2 \begin{pmatrix} a & b \\ c & d \end{pmatrix} := ad - bc.$$

(D4) Bei Addition des c -fachen eines Vektors auf den anderen (mit $s \in \mathbb{R}$) gilt

$$\det_2(x, y + s \cdot x) = \det(x + s \cdot y, y) = \det(x, y).$$

$$\det \begin{pmatrix} a & s \cdot a + b \\ c & s \cdot c + d \end{pmatrix} = \cancel{as^2c} + ad - \cancel{as^2c} + cb = \det(x, y).$$

Figure 2: Sample slide of the video-recorded lectures (on a property of 2×2 -determinants)

On these slides he usually provided the definitions, theorems, and complex visualizations in print, while he filled in the proofs and examples, and made simple sketches live by himself. In addition, he provided lots of oral explanations on the covered definitions and theorems that aimed at explaining their meaning at an informal level. He made the three videos of a lecture available to the students shortly before the official lecture slot. Simultaneously, he provided the partly filled and the fully completed slides, as well as a script containing the entire content of the lecture in written form.

Methods

The first author of this study conducted *semi-structured interviews* with the instructor and nine students who volunteered to take part – out of 60 active course participants. They all had experiences with the same kind of prerecorded video-lectures from the previous course, and varied in their prior performance in other courses. Each participant was interviewed about *two lectures* – one introductory lecture on determinants and one on diagonalization. Due to space limitations, we focus on the first one here. The content of this lecture on determinants was: a geometric motivation of determinants, the definition and properties of 2×2 -determinants (including proof), a geometric derivation of a formula for 3×3 -determinants and the rule of Sarrus, an axiomatic definition of $n \times n$ -determinants, the effect of row operations on $n \times n$ -determinants (with proof), and a motivation of a recursive definition of determinants via the Laplace expansion for 3×3 -determinants.

Structure and content of the interviews: The semi-structured interviews consisted of two phases: an introductory phase and a main phase. The duration of the interviews ranged from 30 to 60 minutes (the ones with the instructor lasted about 55 minutes).

In the introductory phase, each participant was asked three general questions, which aimed at getting a first impression about the students' general behavior while watching the videos/ the instructors' intentions about it. Thereby, the questions for the instructor were related to the ones for the students, so that it was possible to compare the responses. The three questions for the instructor were:

1. *Why did you split the lectures into three videos, and how might students benefit from this splitting?*
2. *To what extent did you communicate the content differently than in a lecture on the board, and how might the students benefit from the video-recordings when engaging with the content?*
3. *To what extent should the students take notes while watching the videos?*

Similarly, the students were asked when they watched the video-lectures and if they took a break between the three videos belonging to one lecture, whether they engaged with the content differently than in a traditional lecture, and whether they took notes while watching.

In the main phase of the interview, the interviewer went with all interviewees through the whole lecture slide by slide. He asked the instructor at each slide whether the students should pause and why, and if they should note something. Likewise, he asked the students at each slide whether they had paused and why, what they had noted, and if they had understood the content. This had the aim to get a detailed picture about how the recordings might have mediated students' engagement with the content of the individual slides, and to compare it with the instructor's intentions.

Data collection: The interviews were conducted and recorded via ZOOM, and then transcribed. The instructor interview took place at the start of the semester. The student interviews took place directly after students watched the videos of the corresponding lecture in the 8th week. As this was towards the middle to end of the semester, they had probably already established methods of using the videos.

Data analysis: We coded the data with content analysis (Mayring, 2015), i.e., we assigned parts of the speech to different themes. One of these was “remarks related to content”, as our research focused on how students described their usage for getting acquainted with the content presented in the videos. The other themes covered activities students might carry out when watching video-lectures, which

emerged from our literature review and the data, e.g., pausing, rewinding, taking a break, or note-taking. The coding shall be illustrated with the following sample quote from the instructor:

Yes, here, the students could definitely use pen and paper, and retrace the calculation, I think.

The “here” is related to certain content mentioned before (multilinearity of 2×2 -determinants), and was assigned to the content theme, the latter part was assigned to “note-taking”.

Finally, we created for each interviewee a table. Its rows contained the individual slides of the lecture. One column named “remarks related to content” contained participants’ remarks on the content of the individual slides – including their remarks on whether they had understood the content. The other columns contained participants’ activities with the recordings at these slides. By comparing the activities mentioned at each slide with the column “remarks related to content”, we could then clearly relate our participants’ reported activities with the artefact “video-recorded lecture” to the specific content of the individual slides of the lecture, as represented via the indirect connection between the content of the lecture and the subjects in our theoretical framework (see Figure 1).

Some results of the study

In this paper, we want to *compare* important themes mentioned by the instructor about how the students might use and benefit from the video-lectures with the behavior reported by the students.

Four major themes mentioned by the instructor on how the students might use the videos

Splitting the lecture: The instructor split the lecture into three videos according to the topics covered in the lecture. He mentioned the following reason and benefit for the students:

On the one hand, for providing the content-units, but maybe also for providing a break, so that the students can note down questions and maybe look back at the corresponding positions for clarifying these.

He furthermore added:

The students also have the possibility to push the pause-button during the video. However, I think it is reasonable to provide something [some breaks] and to pre-structure.

Possibility to pause or revisit material: The instructor emphasized as a major benefit of the videos that the students can pause the recordings for carrying out additional activities or revisit certain material, especially where he has left gaps. As examples of such activities, he mentioned, for instance:

1. Verifying properties of determinants that he did not verify explicitly, for instance, the multilinearity property of 2×2 -determinants with the definition;
2. Thinking about warrants in the steps of the proofs presented, for instance, why each equality in the proof of the effect of row operations on $n \times n$ -determinants holds;
3. Retracing calculations in detail, for example, at a slide with the Rule of Sarrus;
4. Looking something up that the students might not have in their mind anymore, for example, the formula for the inverse of a 2×2 -matrix, but also labels introduced previously.

He also mentioned that it might be beneficial for students to pause in longer proofs for taking notes. Nevertheless, he hoped that students could watch most parts of the lecture without pausing.

Usage of content-related graphical elements: The instructor emphasized that it was easier to include graphical elements into the videos than in a live lecture, which he, for instance, did when motivating determinants geometrically. In his opinion, the students could especially make use of such graphical elements for gaining an understanding of the content.

Note-taking: The instructor thought that the students might benefit from taking notes for themselves. He especially hoped that the students would add their own additional notes while watching besides what was written on the slides. For example these might include: explanations provided orally on the proofs presented, verbalizations of formulae (e.g., the multilinearity), and especially the sketches he drew, as these, in his opinion, support students' understanding of the determinant and its properties.

In summary, the most important point from the interview with the instructor was that he thought the students might especially use the splitting of the lecture, the pause/rewind features of the videos, and the graphical elements he included for increasing their understanding of the lecture's content. Concerning note-taking, he hoped that they do not only copy the slides, but also add additional notes.

Students' reported usage of the videos with respect to the themes mentioned by the instructor

Splitting the lecture: Eight of our nine interview participants mentioned that they made use of the splitting of the lecture into three videos by taking breaks between them. Four students mentioned that they took such breaks to better integrate the videos into their day or for carrying out other activities in between such as eating, but also study activities for other courses. Three students mentioned that they used the breaks between the videos for regaining concentration or motivation. And finally, three students said to have used the breaks for processing the content, as intended by the instructor.

Possibility to pause or revisit material: Except for one student, all students mentioned that they paused or rewound the videos a lot. The most often mentioned reason was note-taking:

The videos are very practical, because you can pause. And I always write everything down, and try to do this as neatly and well as possible. Therefore, it is super if you can take as much time as you want for writing down and for comprehending, or to go some seconds back.

Six of the nine interviewed students paused often to take notes. However, the students also mentioned other activities as a reason for pausing or rewinding. These cover the points 2.-4. mentioned by the instructor on the last page, but also some more activities that can help to acquire an understanding of the content covered. Examples of such activities were: generating examples with numbers, e.g., at a slide with the Laplace expansion of 3×3 -matrices, reading slides with much printed text or many symbols carefully, clarifying confusions if the instructor made a small mistake, or repeating something if the students have been distracted.

Overall, six of the nine interview participants paused almost at every slide and therefore much more intensively than the instructor thought. However, three of them did so mainly for creating neat notes.

Usage of content-related graphical elements: Four students highlighted the graphical elements in the videos as an aid for gaining an understanding of the content presented, as intended by the instructor. However, there were also students who preferred calculations over pictorial explanations if the instructor offered both, for example, at the slides on properties of 2×2 -determinants.

Note-taking: The students' reported note-taking behavior varied, and mostly differed from the instructor's intentions. Two students did not take any notes. Six mainly copied the slides – maybe with omitting certain parts like proofs or sketches. Especially an omission of explanatory sketches (e.g., sketches explaining properties of the determinant) was contrary to the instructor's intentions. Only one student said to have taken additional notes on the content as the instructor hoped, e.g., a verbalization of the formula $\det(s \cdot x_1 + x_2, y) = s \cdot \det(x_1, y) + \det(x_2, y)$ as linearity.

On the whole, students reported to have used the splitting of the lecture for taking breaks to process the videos' content, as intended by the instructor, but also for organizational reasons. Furthermore, they often paused the videos, sometimes for activities to gain an understanding of the content as intended by the teacher, but mostly for note-taking. During the latter, they mostly copied the slides.

Summary and discussion

Overall, our research indicates that prerecorded mathematics video-lectures might mediate students' engagement with the content covered in various ways, which is indicated by the indirect connection between the students and the content via the prerecorded video-lecture in our framework (see triangle in Figure 1). However, these ways do not necessarily coincide with the instructor's intentions.

First, our data indicate that splitting of the lecture into shorter videos influenced our participants' engagement with the content. In particular, some of them took breaks between the videos to process topics right after their presentation, as intended by the instructor. But several participants also used the splitting for better integrating the lectures into their day, as also mentioned in Howard (2018). In this case, the activity of taking a break was not directed towards the lecture's content, and hence, was only part of the triangle side between the student and the recorded lecture in our framework.

Second, our data indicate that our student participants made use of the possibilities to pause or rewind the videos for engaging with the content in their own pace, similar to what Yoon and Sneddon (2011) or Howard et al. (2018) found for prerecorded lectures provided in addition to live lectures. In this case, the recordings mediated again the whole way the students engaged with the lecture's content, as indicated by the indirect connection in our framework (Figure 1). Concerning this engagement, our participants especially carried out several content-directed activities while pausing/rewinding, for instance, clarifying particular aspects they might be confused about or thinking about justifications. Many of these suggest a usage of these features for closing gaps in understanding, as also intended by the instructor. However, three participants paused almost only for taking neat notes – with a much higher intensity than the instructor expected. And contrary to the instructor's hopes, our participants' note-taking was mostly limited to copying the slides, and did not include writing down additional remarks on the content.

Overall, the study presented here gives indications about how tertiary students might use prerecorded lectures that replace live lectures. It shows several similarities to what had been found for students' usage of prerecorded lectures provided in addition to live lectures before, and specified some of the student activities with the recordings. Furthermore, it shows that there might be differences between how students use prerecorded lectures and the instructor's intentions. This shows, on the one hand, that if instructors want to encourage a certain way of use, it might be useful that they communicate their intentions explicitly, e.g., by including prompts for specific activities like tasks into the videos.

On the other hand, it shows the necessity to explore in more detail how students use prerecorded lectures, especially also by observing them, as we only relied on (detailed) retrospective reports.

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