Short introductory videos for elaborative encoding of physics principles

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Abstract: Introductory videos play a vital role in enabling active learning in the flipped classroom model, but guidelines for their content and structure are lacking, especially regarding specific learning processes. To address this gap, we developed a series of introductory videos intended to stimulate elaborative encoding of new physics principles. Over 60 introductory videos were produced, each covering a single physics principle or definition. These videos featured a brief intro, a pretest with elaborative encoding questions, answers to each question, a posttest, and an equation retrieval prompt. In a course with approximately 150 students, we conducted student interviews (n = 13) and surveys from two cohorts (n = 50 and 44). The students varied in how and whether they engaged with the videos. Several students noticed a large difference in how much they learned from lectures. The students felt that the videos provided a good overview and made it easier to learn the content of the course. Furthermore, 73% of the survey respondents would be "very disappointed" if they lost access to the videos, underscoring their perceived importance in the learning process. Our framework for introductory videos in physics can make it easier for lecturers to incorporate a flipped classroom approach with videos.

Keywords: Elaborative encoding, flipped classroom, physics education, instructional videos

1 Introduction

Active learning, particularly peer Instruction, outperforms traditional lectures in physics and science education (Balta et al., 2017; Chi, 2009; Crouch & Mazur, 2001; Deslauriers et al., 2019; Freeman et al., 2014; Hake, 1998). It's commonly integrated with flipped classrooms, where pre-lecture preparation enables more active student participation (DeLozier & Rhodes, 2017). Although meta-analyses reveal that flipped classrooms improve learning outcomes (Bredow et al., 2021; Låg & Sæle, 2019; Strelan et al., 2020), a significant challenge remains: many students do not prepare sufficiently (Akçayır & Akçayır, 2018).

Using introductory videos is a popular approach for making space for active learning in lectures. While not inherently superior to reading or other modalities (DeLozier & Rhodes, 2017), students find it mentally easier to prepare for lectures with videos than with written materials (Battaglia & Kaya, 2015), with the ability to pause, rewind, and speed up the videos (Battaglia & Kaya, 2015). When watching videos, students prefer information on which formulas are important, how to apply them, and concrete examples (Lin et al., 2017).

Producing introductory videos can be time consuming (Hew et al., 2021; O'Flaherty & Phillips, 2015), especially if one must create unique slideshows. Some report several hours of work to create a 10-minute video (Karim et al., 2017). Therefore, it is important to streamline the production of videos to lower the time cost.

There is a substantial body of research on multimedia learning, with most guidance focusing on managing cognitive load and complexity, increasing student engagement, and promoting generative learning (Brame, 2016; Mayer, 2021). Brame (2016) provides detailed recommendations for handling cognitive load, maximizing engagement, and fostering active learning. There are also guidelines emphasizing keeping videos short – ideally around seven minutes – using a high speaking rate, incorporating visuals like diagrams, and minimizing on-screen text (ten Hove & Meij, 2015).

However, despite these recommendations, specific guidance on the optimal content and cognitive processes for a single instructional video remains unclear. Determining the most effective structure, content, and targeted learning processes poses a challenge, and there is limited research exploring how learning processes function within video-based instruction (Pi et al., 2023). This gap presents a barrier for instructors seeking to create effective videos.

The success of a learning modality is dependent on the learning processes activated in the students (DeLozier & Rhodes, 2017). The goal of this work was to develop a simple framework for producing introductory videos with essential content elements. These videos were designed to stimulate effective cognitive learning processes, enhancing retention and understanding.

1.1 Elaborative encoding and retrieval

Building on the learning process framework of Gjerde et al. (2021), I propose that introductory videos should encourage *elaborative encoding,* which is to deliberately search for connections between knowledge units to create highly integrated, plentiful, meaningful, and predictive associative links (Anderson & Reder, 1979; Roelle & Nückles, 2019; Stein et al., 1984). In the context of introductory videos, we want the students to create associations within and between physics principles and to apply the principles to concrete examples. Enhancing elaborative encoding is particularly important for students with lower interest and less prior knowledge, as high-interest students do more spontaneous elaboration (Ozgungor & Guthrie, 2004).

Elaborative encoding of physics principles and definitions can also improve the effectiveness of *retrieval practice* (Gjerde et al., 2020, 2021; Roelle et al., 2023; Roelle & Nückles, 2019) – to actively recall information from memory to make key memories more accessible and fluent – which we encourage the students to do during and right after watching each week's videos. Together, elaborative encoding and retrieval practice can make it easier for students to recognize and retrieve physics principles during individual thinking and group discussions (Gjerde & Hagane, 2024; Gjerde et al., 2022; Gjerde et al., 2021).

Hence, I wanted our videos to stimulate elaborative encoding of physics principles and to set our students up for effective retrieval practice.

1.2 Pretesting

Pretesting enhances (elaborative) encoding of new information (Pan & Carpenter, 2023; Pan & Sana, 2021), activating background knowledge and improving attention (Carpenter & Toftness, 2017; Hausman & Rhodes, 2018). Therefore, I included pretesting in our videos. Pretesting has been shown to increase learning (Carpenter & Toftness, 2017), especially for factual questions (Hausman & Rhodes, 2018), and even when students have no prior knowledge (Pan & Carpenter, 2023). In some cases, it outperforms posttesting (Pan & Sana, 2021), particularly when elaborative encoding is more needed than consolidation. Unfortunately, students often underestimate the benefits of pretesting, preferring passive methods, but their beliefs can be influenced (Pan & Rivers, 2023).

Typically, pretesting is most effective when the answers to the pretest questions are readily identifiable from the learning material (James & Storm, 2019; St Hilaire & Carpenter, 2020). In our videos, the content is structured around the pretest questions, ensuring that students can easily find and verify the correct answers, thereby maximizing the pretesting effect.

1.3 Posttesting

We also included posttesting in our videos. Research has shown that posttesting increases the learning effect when learning new information (Dunlosky et al., 2013; Roediger Iii et al., 2011; Rowland, 2014; Yang et al., 2021). While pretesting seems to improve encoding of new information, posttesting mainly improves the consolidation of that information (Pan & Carpenter, 2023; Pan & Sana, 2021). Therefore, the results should be additive as is the case with elaborative encoding and retrieval practice (McDaniel, 2023).

1.4 The current study

The primary aim of this study was to explore how students engage with introductory videos designed to foster elaborative encoding of physics principles and to assess the perceived benefits of these videos as a study resource. Specifically, we added structured features, such as pretesting and posttesting, to support active learning, though we recognized that these might be perceived as mentally taxing, making it uncertain whether students would use the videos as intended. We also hypothesized that, for students to consistently engage with the videos and consider them valuable for lecture preparation, they would need to experience tangible benefits. Additionally, we wanted to determine whether the videos became an integral part of students' study routines.

Therefore, we posed the following three research questions: (1) How do students engage with the introductory videos? (2) Do they experience benefits from the videos? (3) Would the students be disappointed if they lost access to the videos? We also sought to gain insights into students' overall experiences and reflections on the videos.

To address these questions, we conducted surveys and one-on-one interviews, prioritizing qualitative insights to capture students’ actions and beliefs. The survey data provided quantitative insights into student engagement and perceived benefits, while the interview data offered deeper qualitative context to support and explain these findings. Since the videos are part of a larger research project, it was beyond our scope to isolate their specific impact on learning outcomes, and we did not expect the videos alone to produce a significant learning effect.

This study explores how students engage with structured introductory videos designed to stimulate elaborative encoding in physics. Based on these findings, I propose a framework that can guide the development of such videos for flipped classroom instruction.

2 Methods

This study was conducted over two semesters in an introductory physics course at a large Norwegian university. There were approximately 150 students enrolled at the start of both semesters. We interviewed 13 students in the 2022 semester and collected survey data from the 2022 and 2023 semesters (n = 50 and n = 44). All students in the 2022 cohort were invited to participate in the interviews, and 13 volunteered. Notably, there was no significant difference in final exam performance between survey respondents and non-respondents in the 2023 cohort (d = 0.19, p = 0.36), suggesting that the surveys were not biased toward higher-performing students. The 2022 cohort answered anonymously. The study was approved by the Norwegian Agency for Shared Services in Education and Research (SIKT) and all the participants provided informed consent.

2.1 Course and lectures

The course is part of a research project where learning strategies are integrated into instructional material and learning arenas. The videos are intended to be the students’ first introduction to new physics principles and definitions. The learning objectives for the videos are to (1) stimulate elaborative encoding (Anderson & Reder, 1979; Karpicke & Smith, 2012; Stein et al., 1984); (2) facilitate memory reconstruction of physics principles during retrieval practice (Hopper & Huber, 2018; Hopper & Huber, 2019); and (3) promote principle-based thinking and discussion during lectures. The motivational objectives of the videos are for students to (i) engage with the structured features of the videos, namely pretesting, posttesting, and retrieval; (ii) experience benefits from the videos; and (iii) integrate the videos as a crucial part of their study routine, specifically as preparation for retrieval practice and lectures. The aim of this study is to investigate these motivational objectives.

Students were repeatedly encouraged – both during lectures and through the digital learning system – to use the videos as preparation for the lectures, with specific guidance on integrating them into their overall learning routine. The students were encouraged to do retrieval practice of each week's key principles and definitions after viewing the videos (Gjerde et al., 2020, 2021). This combination of video-based elaborative encoding and retrieval practice sets the stage for effective learning during lectures. The two weekly lectures were held in an auditorium, with voluntary participation. They featured 30 minutes of think-pair-share problems, 10 minutes of retrieval practice, 2 hours of Peer Instruction, and an hour of active problem-solving with exam questions. Beyond lectures, students tackled two sets of physics exercises independently. One set was supported by weekly workshops for personalized assistance, while the other was accompanied by instructional videos teaching a five-step problem-solving strategy and self-explanation of solutions (Gjerde et al., 2022; Gjerde et al., 2021).

2.2 Video design

2.2.1 Content and length

Each video targeted a single physics principle or definition, e.g., Newton's Second Law or the definition of kinetic energy, totaling 61 videos. These were distributed across 11 of the 20 weeks in the semester, with between 4 and 10 videos per week and an average of approximately 6 per week. The videos ranged in length from 5 to 15 minutes.

2.2.2 Elaborative Encoding-questions

The videos were structured around a set of questions intended to stimulate elaborative encoding (Gjerde et al., 2021), along with a concrete example:

Within-principle questions:

1. What concepts and SI-units belong to the symbols in the principle?
2. What do these concepts mean?
3. What is the physical meaning of each element in the equation?

For-principle questions:

4. What is the principle called? Why?
5. What does the principle describe and how is it used?
6. What are the conditions of application for the principle?
7. Why is that a condition for the principle?

Between-principles questions:

8. What similarities and dissimilarities do you see with other principles in HPSM?
9. Is it an empirical principle or is it derived from other principles in HPSM? How?

Concrete example for Pascal’s Law:

“You dive down to four meters below the surface to pick up the cell phone you dropped from the dock. What is the pressure you experience?”

2.2.3 Structured features: Introduction, pretest, answers, posttest, retrieval

Each video began with a brief introduction of less than a minute, during which the lecturer showed and explained the equation for the principle, any conditions for its application, and its position within the Hierarchical Principle Structure for Mechanics (Gjerde et al., 2020).

Immediately after the introduction, students were prompted to pause the video and take a pretest on a subset of the questions – specifically questions 1, 2, 3, 5, and 6 – as well as the concrete example. This pretest aimed to increase cognitive engagement with the subsequent explanations and to encourage elaborative encoding of the information.

Following the pretest, the lecturer provided answers to all questions and the example, structured into four sections corresponding to the three types of questions and the example. This segment offered corrective feedback to enhance the benefits of the pretest (Hausman & Rhodes, 2018) and prepared students for the posttest.

Next, students were asked to pause the video again and complete a posttest covering all questions and the concrete example.

Finally, they were encouraged to retrieve the principle and its application conditions from memory.

2.2.4 Design and creation

The videos followed a consistent slideshow format, where only the name of the principle, its equation, application conditions, and the concrete example varied between videos. The videos were recorded with screen capture using video conferencing software, without a talking head, to simplify production. Some research has shown that the absence of a talking head does not impact learning effectiveness (van Wermeskerken et al., 2018). Although other studies suggest that a talking head can be beneficial, especially when gesticulations are included or compared to a static head (Mayer, 2021), we are not aware of any strong theoretical basis for how this would impact learning processes. Additionally, omitting the talking head greatly simplifies editing. The videos included no additional text beyond YouTube’s automatic captions. Although YouTube’s segmenting and naming features were not used, the structured format made it easy for students to navigate through each video.

2.3 Measures and data gathering

2.3.1 Surveys

All the students in the 2022 and 2023 cohorts were asked to respond to a voluntary mid-semester survey. The surveys were sent out the same week for the two cohorts. The survey addressed multiple aspects of a larger research project, with a subset of questions specifically relevant to this study's research aims. It was distributed to students via email, with reminders provided during lectures and through follow-up emails over the course of two weeks.

2.3.2 Survey measures

In the surveys of both cohorts, we asked students to estimate the percentage of the video lectures they had watched up to the survey date, using a slider from 0 to 100. The survey was conducted mid-semester, so the 2022 cohort did not yet have access to all 61 video lectures, whereas the 2023 cohort had full access. However, the 2023 students appear to have interpreted the question as referring to the videos covering content introduced so far, as indicated by their higher video completion rates. We also asked them to indicate their level of agreement with statements 2 to 6 on a Likert scale from 1 (completely disagree) to 5 (completely agree):

1. *PercVideo*: Estimate the percentage (0-100) of the video lectures you have watched so far.
2. *UsePretest*: I use the pretest questions as suggested by the lecturer in the videos.
3. *UsePosttest*: I use the posttest questions as suggested by the lecturer in the videos.
4. *UseRetrieval*: I retrieve the principle at the end of the video lecture.
5. *BetterOverview*: The video lectures provide a better overview of the subject.
6. *EasierLearning:* The video lectures have made it easier for me to learn the material in the course.

For Research Question 1, questions 2-4 explored their use of structured features (see Table 1, Section 3) and its correlation with viewership (question 1) and experienced benefits (questions 5 and 6, see Table 2). For Research Question 2, questions 5 and 6 investigated the benefits experienced from engaging with the videos (Table 1) and their correlation with viewership and use of structured features (Table 2). For Research Question 3, we added a question to the 2023 cohort survey: "How disappointed would you be if you lost access to the video lectures" (7: *DisappointmentVideo*), with response options ranging from 1 – Not disappointed to 3 – Very disappointed.

2.3.3 Validity of survey measures

Each survey item was intentionally concise and unidimensional, ensuring relevance and engagement for student respondents. To clarify the context and standardize scale understanding, anchoring vignettes were used. The survey's validity is evidenced by item correlations (Table 2, section 3) and supported by qualitative data, enhancing the survey's credibility through triangulated validation. The consistency between quantitative and qualitative findings underscores the measures' reliability. Additionally, respondent feedback on clarity and interpretability confirmed no misinterpretations or unintended response patterns.

2.3.4 Interviews

At the end of the 2022 semester, all students were invited to participate in one-on-one digital interviews with the first author, with thirteen students volunteering. Seven interviews were conducted in the two weeks before the final exam, and the remaining six took place in the two weeks following the exam. The interviews followed a semi-structured guide, with a subset of questions specifically addressing this study's research aims.

2.3.5 Interview questions

The following questions from the interview guide – translated from Norwegian – targeted the students' experiences and reflections on the videos:

1. What do you think about the video lectures?
2. Have you watched the video lectures that I have posted for all the principles and definitions?
    a. How many?
    b. When have you looked at them? As preparation for lectures?
    c. Do you watch the whole video? Are you speeding up?
3. How do you use the video lectures to learn?
    a. Why do you use them like that?
    b. How do you use the pretest questions?
    c. How do you use the explanation part of the video?
    d. How do you use the post test questions?
    e. How do you relate to the call for retrieval at the end?
    f. Has it changed during the semester how you use the videos?
    g. What do you think is the purpose of the video lectures?
4. How well did your strategy for understanding the principles and concepts in the course work?
5. Are you familiar with the term elaborative encoding?
    a. What do you think the term means?

2.4 Analysis

2.4.1 Interviews and open survey questions

The interview data was transcribed intelligent verbatim by a company that offers transcription services with confidentiality agreements. I analyzed the data using thematic analysis (Braun & Clarke, 2006) in the software NVivo (QSR International, 2018). I combined the findings from the interviews and the open survey questions.

The author (VG) repeatedly reviewed the interview transcripts and survey responses to identify inconsistencies or overlooked themes. VG categorized the transcriptions according to the research questions, refining the themes through re-analysis for internal coherence and external distinguishability until the codes were perceived as stable (Braun & Clarke, 2006). The findings are presented narratively in section 4.

2.4.2 Likert-type survey questions

The quantitative survey data was statistically analyzed in R (R Core Team, 2022).

3 Quantitative Results

For reference, Cohen's d effect sizes of 0.2, 0.5, and 0.8 are often treated as small, medium, and large effects, respectively. Correlations of $r < 0.2$, $0.2 < r < 0.3$, and $r > 0.3$ can be thought of as small, medium, and large correlations, respectively (Gignac & Szodorai, 2016; Hemphill, 2003).

Table 1 shows that in 2023, respondents watched more lecture videos. There was considerable variation in students' usage of pre- and posttests in both cohorts. Usage of end-of-video retrieval practice slightly increased from 2022 to 2023. Students generally believed the videos improved their course overview and learning, particularly in 2023, where there was a significant increase in agreement.

Table 1. *Descriptive statistics of survey measures and a comparison between the 2022 and 2023 cohorts. The students responded on a scale from 1 (completely disagree) to 5 (completely agree).*

Measure	Mean (std. dev.)	Mean (std. dev.)	Cohen's *d* (*p*-value)
	2022 (n = 50)	2023 (n = 44)	2023 vs 2022
PercVideo	63.7 (29.3)	81.5 (26.3)	0.64 ($p < 0.01$)
UsePretest	2.9 (1.2)	3.1 (1.4)	0.15 ($p = 0.63$)
UsePosttest	2.8 (1.2)	2.9 (1.4)	0.08 ($p = 0.80$)
UseRetrieval	3.2 (1.3)	3.7 (1.2)	0.40 ($p = 0.07$)
BetterOverview	3.9 (1.0)	4.6 (0.7)	0.80 ($p < 0.001$)
EasierLearning	3.6 (1.0)	4.5 (0.7)	1.04 ($p < 0.001$)

The correlations between the survey measures for the 2022 and 2023 cohorts can be found in Table 2. The pattern of results was identical in the two cohorts and the data was therefore collapsed.

Table 2. *Correlations between the survey measures for the combined 2022 and 2023 cohorts.*

	PercVideo	*UsePosttest*	*UseRetrieval*	*BetterOverview*
UsePretest	0.19 [a]			
UsePosttest	0.20*			
UseRetrieval	0.35***	0.48***		
BetterOverview	0.42***	0.30**	0.35***	
EasierLearning	0.37***	0.38***	0.39***	0.81***

Note. *** $p < .001$, ** $p < 0.01$, * $p < 0.05$, [a] $p < .10$

On the question, "how disappointed would you be if you lost access to the video lectures?", 4 students would not be disappointed, 8 students would be somewhat disappointed, while 32 students (73%) would be very disappointed. The only measure that correlated with *DisappointmentVideo* was *Easier Learning*, $r = 0.32$, $p < 0.05$.

4 Qualitative Findings

The thematic analysis revealed several key themes related to students' engagement with the videos: (1) primary reliance on videos versus textbooks, (2) perceived benefits of videos for learning and lecture preparation, (3) the strong impact of video preparation on lecture comprehension, (4) diverse reasons for not watching videos, (5) variation in engagement with structured features, and (6) the importance of following the suggested structure for maximum benefit. Below, we present qualitative findings within these themes, illustrating students' perspectives with representative quotes.

Most students used the videos as their main method for building an initial understanding of new content. Many did not open the textbook. A few students combined the two modalities, and a couple of students preferred the textbook. The students who mostly relied on the videos said that it helped them get an overview of the course, that it was a great introduction to the content, and that the combination with the active lectures worked well. A student said,

> “Getting that prior knowledge from the videos has worked well. Then you can rather focus on the lectures in a slightly different way. You don't have to concentrate so much on concepts and all that.“

Almost all students reported that whether they had watched the videos before the lectures had a large effect on how easy it was to follow and learn from the lectures. A student said,

> “At first, I watched almost none of the videos. I watched one once and then I realized that this was actually quite useful. I got a lot more out of the lectures after I started watching them beforehand.”

A couple of students noted the videos' value for dyslexics and those with reading difficulties. Others appreciated the flexibility and brevity of the video introductions. Many students expressed their satisfaction and gratitude for having access to the videos.

While the reasons for watching the videos were almost exclusively that it helped them learn, the reasons for not watching the videos were diverse. Some preferred traditional lectures over video introductions, while others found the videos slow, lengthy, repetitive, or time-consuming.

Students who watched the videos primarily did so for lecture preparation, finding it highly beneficial. Those who viewed them post lecture reported less benefit. Some students revisited the videos when the need arose, e.g., during problem-solving.

Engagement with the video's structured features varied widely, consistent with the quantitative results. Some students skipped the pretest questions completely, while others answered them regularly or irregularly. Some used the pretest in the beginning of the semester, but gradually stopped. Several students skipped the pretest but completed the posttest. Most students reported performing retrieval at the video's end. Some preferred completing a full structured retrieval session after watching all the week's videos, following the instructor's recommendations.

Finally, several students said that the videos were the most beneficial when they followed the suggested structure. A student said,

> "And if you also write and do all the things you encourage at the start, to first try to explain the principle, explain all the symbols in the principle and write all the names, all together, and do all those steps, then the videos are very useful I feel."

5 General Discussion

5.1 How do students engage with the introductory videos?

Our first research question asked, "How do students engage with the introductory videos?" Both the quantitative data in Table 1 and the qualitative findings uncovered diverse engagement levels. Students' engagement ranged from minimal, skipping both tests, to full utilization of pre- and posttest questions. Notably, the smallest correlations in Table 2 are between the number of videos watched and the use of structured features. The students tended to follow the prompt to do retrieval practice to a somewhat larger extent than the pre- and posttests, perhaps reflecting the lower mental effort required.

Understanding this variability is vital for educators. Qualitative insights reveal diverse student engagement, with some skipping pretests due to cognitive load and others valuing structured retrieval after content review. This indicates that students tailor their use of video features to their needs, mental energy, and prior knowledge. Interpolated pretesting, distributing pretest questions throughout the video (Pan & Carpenter, 2023), could potentially boost engagement by easing cognitive load.

5.2 Do the students experience benefits from the videos?

Our second research question asked, "Do they experience benefits from the videos?" The students noticed a large difference in how easy it was to follow and learn from lectures depending on whether they had watched the videos beforehand. This aligns with previous research emphasizing the importance of preparation for active teaching methods like Peer Instruction (Lim & Park, 2023), as well as research showing that peer discussions are most effective when students actively incorporate physics principles (Gjerde & Hagane, 2024).

Table 2 shows strong links between the use of structured features and perceived benefits, indicating these features enhance student experiences. This aligns with previous research on the effects of pretests and posttests (Adesope et al., 2017; Carpenter & Toftness, 2017; Pan & Carpenter, 2023; Pan & Sana, 2021; St Hilaire & Carpenter, 2020). Qualitative data also highlights the videos' simplicity and brevity as positive factors, as reported in other research (ten Hove & Meij, 2015). There was a strong correlation between the percentage of videos watched and the perceived benefits, suggesting a reciprocal relationship between video engagement and benefits—a relationship corroborated by interview findings.

The increase in video usage and perceived benefits from 2022 to 2023 (Table 1) may result from improved instructor advocacy and clearer guidelines on integrating videos with other study practices. The lecturer talked to the 2023 cohort about the experiences of the 2022 cohort, which may have affected their attitudes toward the videos.

5.3 Would the students be disappointed if they lost access to the videos?

Our third research question asked, “Would the students be disappointed if they lost access to the videos?” In the 2023 survey, over 70% of students would be strongly disappointed by such a loss, indicating the videos' crucial role in their learning. Disappointment levels were closely tied to 'Easier Learning,' supporting the idea that perceived benefits drive video acceptance. Notably, only 9% would be strongly disappointed about losing textbook access.

6 Conclusions

In conclusion, students derived benefits from these videos and expressed strong disappointment at the prospect of losing access. The varied use of structured features suggests that students adapted their engagement with the videos to fit their individual needs and available cognitive resources.

6.1 Reflections on the framework

Part of our aim for this research was to present a simple framework for creating introductory videos in physics. Our video structure aligns with the recommendations of (Brame, 2016; Mayer, 2021) to balance cognitive load and maximize engagement through short, structured videos, which may explain students’ engagement with the content. Additionally, we specify that the content of the videos focuses on a single principle or definition, and we introduce a consistent structure based on learning theory (Gjerde et al., 2021) that is maintained across videos and supported by prior research (Carpenter & Toftness, 2017).

6.1.1 Increase elaborative encoding and retrieval

The use of elaborative encoding questions, together with pre- and posttesting, seems to have increased the students’ use of elaborative encoding in their preparation for lectures, as these structured video features were evidently used to a substantial extent. Students also tended to follow the prompt to retrieve the principle. In separate research (Gjerde et al., Submitted for publication), we found that a substantial portion of students do structured retrieval practice of the current week’s principles and definitions immediately after having watched the videos, indicating that the videos supported retrieval. This aligns with other research, showing that elaborative encoding supports retrieval practice (Karpicke & Smith, 2012; McDaniel, 2023). While it was beyond this study's scope to directly test whether students who watched the videos gained more from retrieval practice, future research could further investigate this.

6.1.2 Efficient production

The consistent structure made video production efficient, with each video typically completed in two to three takes and a total of approximately 20 to 30 hours spent on screen capturing. Achieving an optimal speaking rate of over 150 words per minute and a target video length of around 7 minutes, as suggested in previous research (ten Hove & Meij, 2015), would likely require additional practice and more takes. However, since students tended to speed up the videos – and were encouraged to do so if needed – this effectively achieved the desired pacing.

6.1.3 Increasing viewership

Our efforts to increase viewership included frequent reminders about the importance of lecture preparation, clear guidance on incorporating the videos into a study routine – such as pairing them with retrieval practice – and discussing the experiences of previous students. We conclude that these strategies were effective. To further increase viewership, potential measures could include incorporating pre-lecture quizzes – either as a requirement or with a less controlling incentive – or adding some of the video questions to the final exam. However, we are uncertain whether pushing viewership through mandatory activities would be beneficial, as students have varied needs and preferences, and such measures could reduce their sense of autonomy (Deci & Ryan, 2008; Vansteenkiste et al., 2004).

6.1.4 Why not put the elaborative encoding questions in a quiz?

The pretest and posttest questions in the videos could potentially have been implemented as a quiz on the learning management system. However, to effectively stimulate elaborative encoding, these questions would need to require written responses. This setup, combined with managing two separate windows, would likely increase cognitive load and time commitment, which might lead to lower engagement with these features. Our aim is for students to think deeply, not necessarily to write. Additionally, using a quiz format would require students to actively restart the test to complete both a pre- and posttest.

6.2 Weaknesses and strengths of this study

This study might have volunteer bias, yet it mitigated this by interviewing a diverse group of students—consistent viewers, early dropouts, and late starters—ensuring that varied experiences and feedback were captured. Aiming to identify as many themes as possible, the 13 interviews offered a thorough insight into the key themes regarding video material usage.

The survey responses were limited relative to the course size but mainly came from lecture-attending students, the main video material audience. Our focus was on students' video engagement as lecture preparation. Despite the somewhat limited responses, the data provided statistically significant insights into strong relationships, affirming the reliability of our findings for the intended analysis.

This study's quantitative part relied on correlational self-report data, preventing causal inferences about learning outcomes. The focus was not on validating the video features' effectiveness, as prior studies have already established the impacts of pretesting (Pan & Carpenter, 2023; St Hilaire et al., 2023), posttesting (Pan & Sana, 2021; Yang et al., 2021), and retrieval practice (Chan et al., 2018).

This study's purpose and strength are in elucidating students' actual interactions with videos, a vital element of educational research. Its robustness also stems from mixing qualitative and quantitative (correlational) data.

6.3 Future research

Future studies should compare regular and structured videos using the test questions as a controlled metric for assessing the video structure's impact on learning. Additionally, experimental research should explore the videos' indirect effects on active learning environments and their potential to enhance retrieval practice benefits.

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