On the Educational Impact of Lecture Recording Reduction: Evidence from a Randomised Trial

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ABSTRACT

Students often use lecture recordings to learn and revise. This approach, however, demands time to locate and review relevant topics. The automatic reduction and indexing of lecture recordings, then, could focus students' attention on the most relevant content. This article investigates whether lecture recording reduction leads to improved learning outcomes on an undergraduate computer networking module. Students participated in a randomised trial which compared lightly edited full lecture recordings to those that had been significantly reduced in duration and indexed. A pre-test conducted after the initial lecture series was followed up with a post-test after several weeks of using the recordings. The results show a statistically significant difference between the groups in terms of perceived effort. However, only the students with little prior knowledge showed a statistically significant difference in learning outcome in favour of the reduced lecture recordings. Moderating factors, such as prior knowledge, warrant further research to help elicit guidelines to inform the design and deployment of future lecture video reduction approaches.

CCS CONCEPTS

• **Applied computing → E-learning**; • **Human-centered computing →** *Empirical studies in HCI*; • **Information systems →** Multimedia information systems;

GENERAL TERMS

Experimentation, Human Factors

KEYWORDS

lecture; video; recording; summaries; reduction; learning; revision; randomised trial

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1 INTRODUCTION

Producing archives of lecture recordings for the purpose of student revision can be well received by students [5, 6, 12, 16, 20] and has been shown to support their learning [9, 22]. However, many students do not always watch lecture recordings for their full duration, often taking a more strategic approach during sessions of revision [1, 7, 16, 18]. As such, manually navigating lecture recordings to find particular content may not represent a productive use of their revision time. In order to minimise this limitation, the content of lecture recordings could be reorganised. More specifically, the topics could be indexed into segments and prioritised. Furthermore, unnecessary content could be removed, in accordance with the learning objectives. Such changes might help to focus students' attention on the most relevant content and therefore lead to enhanced learning outcomes.

Judgements must be made regarding what content to include and what content to discard. This often requires substantial human input. An approach that aims to minimise the time needed to provide such input is using metadata associated with the presentation slides as a framework for reduction. Prior work shows that such meta-data can be mined from slides, notes, and audio from the lectures themselves [23], minimising the preparation required to edit the recordings. However, the implications of using this technique for revision purposes are not clear. Therefore, prior to investing time and resources into developing a high fidelity toolset, this research acts as a feasibility study, exploring the educational impact of lecture recording reduction.

The following section of the article provides some background on the use of lecture recordings and the pedagogical theories that could inform efforts to modify lecture videos to enhance student learning. The proposed approach to reducing the lecture recordings is then described. The research questions and the expected outcomes, in the form of hypotheses, are then made clear. The following sections then describe the methodology of the experiment, the results, and a discussion of the findings.

2 BACKGROUND

A literature review on the use of podcasts in education highlights that the use of lecture recordings is associated with a range of benefits, including: positive attitudes; sense of control over learning; improved study habits; and increased learning performance [10]. As such, there is considerable evidence supporting the use of lecture recordings to help students understand and revise lecture content. However, there are several open questions with respect to how lecture recordings should be presented. The review makes a number of suggestions regarding avenues for future research, including: a focus on the quality and design of videos; their relationship with pedagogical strategies; viewing strategies; and their impact on learning effectiveness. This perspective is extended in a further review [17] which points out that a number of studies have not applied appropriate measurement approaches, often using self-report measures for variables such as learning.

It is, therefore, important to further investigate whether different styles and presentations of videos will have different impacts on key variables of interest, such as student learning, using appropriate measurement approaches. Students have demonstrated a range of different approaches to interacting with videos, sometimes leading to only surface-level learning [11], and so lecture recordings are often considered to be complementary to existing teaching methods. Given that the recordings, therefore, make effective revision tools, it is then possible that designing them with revision in mind could enhance their effectiveness.

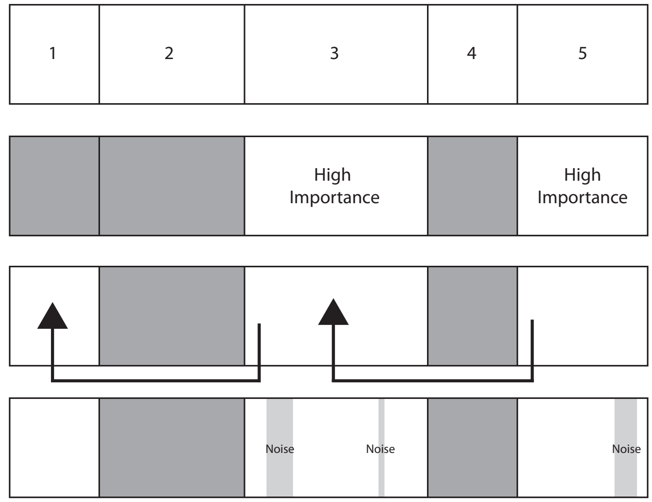
Such a strategy could be realised through the utilisation of a number of pedagogical strategies. The principle of constructive alignment [2] emphasises that only material that will be tested should be formally covered. It is likely that questions and points raised in lecture discussions, although useful for students' deeper and future learning, will not be tested on. As such, this unnecessary material can be cut from the lecture recording. Similarly, the principle of scaffolding [4], which emphasises that students receive additional support when first introduced to a topic (in line with their zone of proximal development [21]), can be used to ensure that material is ordered such that topics build upon each-other and enable students to easily identify related topics. Another key concept is cognitive load [19]. This theory contends that the amount of information that can be processed in working memory is finite and so presenting too much information simultaneously can overload working memory and subsequently impede learning. It is not unusual to find that lecture slides are over-crowded with information. Such content can be re-organised in post-production to reduce cognitive load and consequently focus students' attention more effectively [3].

3 EXPERIMENTAL TOOL

The proposed system aims to apply the concepts of constructive alignment [2], scaffolding [4], and cognitive load theory [3, 19] to the reduction of lecture recordings. Using this approach, data about the slides is applied in three ways: assigning topic importance; indicating dependencies to previous slides; and coding the purpose of a slide (e.g. presenting information, questioning the audience, etc.). Additionally, further data about each slide is captured, including: slide duration; and slide-associated audio.

The proposed work-flow, shown above in Figure 1, is a semi-automatic process for reducing the duration of lecture recordings. Firstly, the recording is segmented based on the structure of the slide show that accompanies the lecture. Secondly, segments of the lecture are removed based on a back-propagation technique using the data provided. Slides associated with a low importance topics and their supporting slides are removed, while slides that do not present new information are also removed. Existing content analysis techniques (see [13] for a review) are then applied to further eliminate interruptions within each segment. Such techniques also

Figure 1: Workflow for Editing Lecture Recordings



highlight segments that potentially present a high cognitive load, for final manual editing in the post-production stage.

4 RESEARCH QUESTIONS & HYPOTHESES

In the educational context, "impact" can have different meanings. This article investigates educational impact in terms of the following research questions:

- RQ1. Do students use full lecture recordings in the same way as reduced lecture recordings?
- RQ2. Does the use of reduced lecture recordings lead to different learning outcomes compared to full lecture recordings?
- RQ3. Do students hold different perceptions of full lecture recordings and reduced lecture recordings?

The first research question examines one hypothesis: there will be no significant difference between the number of minutes that students spend watching either type of video (H_1). The second research question also examines one hypothesis: students watching the reduced lecture recordings will score higher on a test of the intended learning outcomes (H_2). The third research question examines five hypotheses: students will find reduced lecture recordings more useful (H_3); students will perceive reduced lecture recordings to be of higher quality (H_4); students will perceive the full lecture videos as being too long (H_5); students will perceive the full lecture videos as requiring too much effort to watch (H_6); the students will perceive an increase in their performance after watching the reduced lecture video (H_7).

5 METHOD

A short series on four lectures on an introductory computer networking course (designed and performed by the second author) were recorded (by the first author)[1]. Edited lecture videos were then prepared and created (by the first author) according to recommendations generated by a low-fidelity prototype based on the

[1] Both authors were at the same institution at the time of the study.

Table 1: Content of the Lecture Videos

#	Lecture Topics	Slides	Video Duration	
			Full	*Reduced*
1	Course Intro, General Definitions, Operating System History, Networks and Operating Systems	42	47.06	19.02
2	Internet History, Internet Protocols, Layers, Physical Media, Switching, Network Throughput, Security	83	67.35	36.23
3	Application Layer Protocols, HTTP, FTP, SMTP, POP3, IMAP, DNS	48	80.11	52.40
4	Client-Server, Peer-to-Peer, TCP and UDP Protocols, Socket Programming	66	81.31	35.38

slide meta-data (provided by the second author). Two videos for each lecture in the lecture series were then produced: one that had been lightly edited; and one that had been heavily edited, and thereby reduced. The prototype did not manipulate the lecture recordings directly, but instead generated recommendations which were manually applied using Sony Vegas 10.0.

These were uploaded to YouTube and were selectively made available to participants through the BlackBoard virtual learning environment. The impact of each recording on student learning was compared using an experimental approach. YouTube analytics (such as minutes watched) and a post-study questionnaire were used to evaluate student perceptions of the videos, while learning was examined through an online test taken by each participant before and after the experiment.

5.1 Experimental Design

The experiment used a between-participant design because practice and preference effects could have biased the evaluation if each participant was exposed to both experimental conditions. The experimental design itself consisted of a parallel-group double-blind randomised trial, incorporating balanced allocation between two groups (1:1).

Two versions of each lecture recording were compared, one edited using the recommendations produced by the prototype implementing the proposed method (experimental group) and the lightly edited version, that included the full lecture (control group) as listed above in Table 1. A pre-test is conducted to establish whether the groups are equal before the experiment and a post-test is conducted after the students have used the videos to examine differences between the groups.

5.2 Recruitment

Participants were recruited from an introductory computer networking course within the undergraduate computer science degree programme at the authors' institution. The study was promoted via: institutional email; notices on the relevant BlackBoard module; and a course-related FaceBook group. Participation was voluntary in accordance with ethics guidelines.

5.3 Data Collection

A pre-test was deployed on BlackBoard six weeks into the course, after the first five lectures had been delivered (four, of which, were recorded for the study). The pre-test was available for 10 working days after which, in the ninth week, the relevant videos were released to students in accordance with their group allocation. The post-test was then made available on BlackBoard in the eleventh week, alongside a post-survey that was emailed to eligible students via SurveyMonkey. This was also made available to participants for 10 working days.

Table 2: Participant Characteristics

Characteristic	Sample (%)	HESA (%)	χ^2	p
Male	83.3	82.3		
Female	16.7	17.7	0.36	.848
Traditional Student	87.0	88.9		
Mature Student	13.0	11.1	.170	.679

5.4 Sample Size

Hattie suggests an appropriate effect size for educational relevance is: $d > .40$ [8]. Thus, an *a priori* power analysis was conducted using the statistics software G*Power 3.1.3 to determine an appropriate sample size ($\alpha = .05, 1-\beta = .80$). Based on conducting an ANCOVA analysis, a minimum of 52 cases is suggested. A sample of 60 was obtained and included in the analysis for this study.

6 DATA ANALYSIS

The data was analysed in PASW 18.0.3 for Windows. There were no cases with missing data. All reported p-values are two-tailed and significance has been determined at the conventional .05 level.

6.1 Participant Characteristics

All participants were students enrolled on a second-year undergraduate computer networking module, having passed CS1 and CS2. Note that these students also typically required at least 300 points on the University and College Admission System (UCAS) to enrol on the course (see [omitted for review] for details). For ethical reasons, all participants were volunteers. So, although all of the students in the cohort were invited to participate in the study, the initial response rate was ~50% (75 of 151 students), but with an attrition rate of 20%, resulted in only ~40% (60 of 151 students). Thus, self-selection bias is a possibility. Table 2 contrasts the descriptive statistics of the sample with known population proportions in the 2011-2012 dataset available from the United Kingdom's Higher Education Statistics Agency (HESA). As there are no statistically significant differences, in terms of age or gender, the sample is assumed to be adequately representative of a typical computer science cohort in the UK.

Table 3: T-Tests Comparing Length and Amount Watched for the Experimental and Control Videos (Full Sample)

Measurement	$\bar{x}$	σ	t	df	p
Minutes Watched					
Experiment	323.50	109.70			
Control	389.00	117.30	-1.169	3	.189
Minutes Duration					
Experiment	35.92	13.73			
Control	69.09	15.95	-7.685	3	.005

Table 4: T-Tests Comparing Learning Outcomes (Low Pre-Test Scores Only, N = 40)

Measurement	$\bar{x}$	σ	t	df	p	d
Pre-Test Score						
Experiment	-7.41	5.65				
Control	-9.94	8.05	-1.167	38	.250	—
Post-Test Score						
Experiment	3.13	10.51				
Control	-4.77	11.69	-2.252	38	.030	-0.73

6.2 Measurement Validity and Reliability

The measurement used in the pre-test and post-test was created for the purpose of this study, based on the content of the first four lectures. Five learning objectives were identified, and a pool of 30 items was created (six questions for each learning objective). As this test was created for the study, prior to the analysis, the test was reviewed for appropriate validity and reliability.

Firstly, the pool was reviewed for content validity by the three teaching assistants assigned to the unit. No items were removed at this stage. Secondly, validity was then further assessed through a pilot study using a difficulty metric, based on avoiding extreme proportions of student success on an item, and an appropriate discrimination metric, ensuring success on an item is related to success on the test overall. Items were included based on the following criteria: $(10\% < difficulty < 90\%) AND (discrimination > 0.1)$. Four items were eliminated at this stage. Thirdly, the reliability of the remaining items for each learning objective was assessed using Cronbatch's α. Each group of items, based on the five learning objectives, exceeded the 0.7 threshold proposed in [15]. Therefore, validity and reliability can be considered adequate.

6.3 Video Usage (RQ1)

In order to examine H_1, the duration of each video was examined and the estimated total minutes watched was captured from the available YouTube analytics. This data is summarized in Table 3.

The table shows that the duration of the experimental reduced lecture videos was statistically significantly shorter than the lightly edited lecture videos (p = .005), with the prototype tool achieving a typical 49% reduction, based on the four example cases ($\bar{x} = -33.16 minutes$, $\sigma = 8.63 minutes$). However, of the 2850 minutes that participants in the study watched the videos for, the overall amount of time that students spent watching the different types of video was not statistically significantly different ($\delta\bar{x} = 65.5 minutes$, $p = .189$). This supports the notion that students engaged with the videos in a similar way, in terms of allocating time to watch them, despite their substantially different durations.

6.4 Impact on Learning Outcomes (RQ2)

Analysis of statistical assumptions suggested that an ANCOVA may not be appropriate due to the heteroskedasticity assumption. There was considerable variance in pre-test scores and the regression predicting post-test score did not appear to be equal across the range of scores. Consequently, the sample was segmented into two sub-samples based on pre-test score: high performing; and low performing. Thus, two independent sample t-tests were conducted on these sub-samples to examine H_2 and shown in Figure 2.

The data in Table 4 only shows data for the low performing students. The table shows no statistically significant difference in the pre-test ($\delta\bar{x} = 2.54, p = .250$). However, a statistically significant difference was found between the two groups in the post-test ($\delta\bar{x} = 7.90, p = .032$). Thus, although the groups were equal at the start of the experiment, those students who had been assigned the reduced lecture videos to watch received a higher score on the test compared to those students who had been assigned lightly edited full lecture videos to watch by the end of the experiment ($d = 0.73$).

On the other hand, there was no statistically significant difference between pre-test and post-test scores for students in the high performance sub-sample (t[19] = -1.210, p = .241), this suggests that the lecture video reduction had no measurable impact on the intended learning outcomes. This is unlikely to be due to a ceiling effect as the maximum possible score on the measurement was not achieved. However, as there were only 20 students in this sub-sample, a lack of statistical power should be noted. A *post hoc* power analysis indicates that the sensitivity of the statistical test ($\alpha = .05, 1-\beta = .80$), in this case, is $d > .66$, rather than the $d > .40$ criterion suggest by Hattie [8].

6.5 Difference in Perceptions (RQ3)

In order to examine H4-8, the data from the post-survey was analysed using a series of Mann-Whitney U Tests because Likert-type items were used and the data did not appear to follow a normal distribution. These items and their analyses are shown in Table 5.

Based on a maximum score of six, with higher scores denoting agreement, the results indicate that students tended to endorse the usefulness of the revision videos. They tended to disagree that the videos were poor. They also tended to endorse the notion that their performance increased. There was little consensus about whether the videos were too long, although there was no statistically significant difference between the groups. However, there was a statistically significant difference with respect to effort required to watch the video. Although students allocated to watch either type of video both tended to disagree with the statement, those allocated to watch the reduced lecture videos seemed to perceive much less effort being required ($\delta\bar{x} = 0.88, p = .024$).

Figure 2: Box-Plot Illustrating Gain Scores Between Sub-Samples and Experimental Allocation

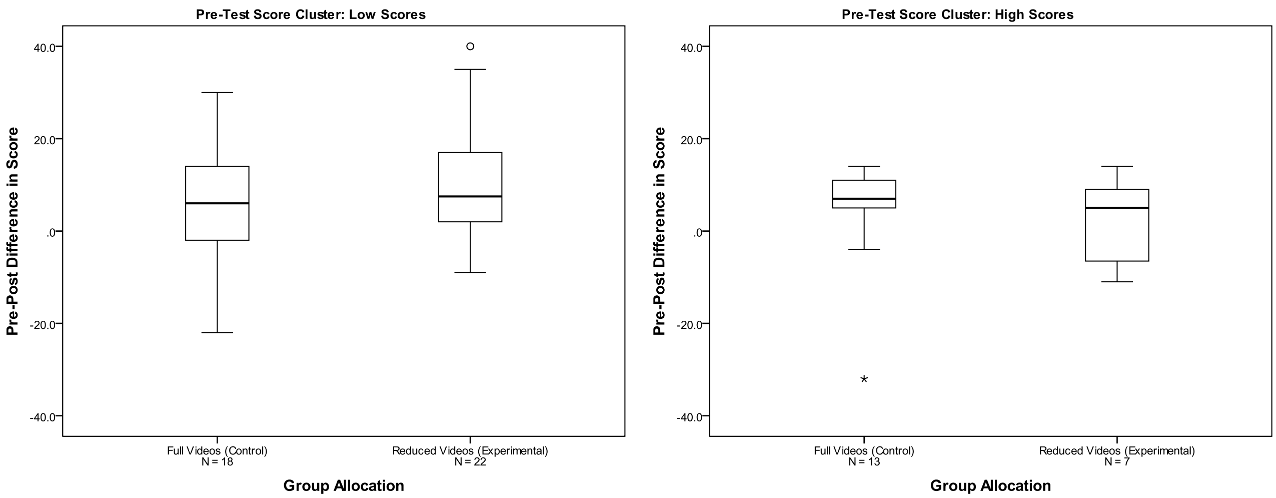


Table 5: Mann-Whitney U Tests Comparing Student Attitudes Between the Experimental and Control Conditions

Measurement	$\bar{x}$	σ	U	p
These revision videos were useful				
Experiment	5.00	0.92		
Control	4.47	1.34	204.0	.243
I believe the quality of the revision videos was poor				
Experiment	3.18	1.29		
Control	2.86	1.35	211.5	.461
The revision videos were too long				
Experiment	3.86	1.20		
Control	4.17	1.26	202.5	.238
Watching the revisision videos required too much effort				
Experiment	2.59	1.14		
Control	3.47	1.30	156.5	.024
I believe I increased my performance on the tests using revision videos				
Experiment	4.95	0.95		
Control	4.47	1.41	211.5	.321

7 DISCUSSION

7.1 Findings

Few studies evaluate lecture recordings in the computing context. Fewer still explore the educational impact of content reduction. This paper contributes to this literature by showing, through the use of a low-fidelity proof-of-concept prototype, the efficacy of lecture recording reduction in an undergraduate computer networking module. The experiment reveals mixed impacts on learning outcomes. Some positive and some questionable. This may be because many students do not allocate study time based on the nature of the available material. This notion is supported by the number of minutes spent watching videos being the same for both groups; despite the videos provided to one of the groups having substantially longer durations. This presents an opportunity to improve lecture recordings based on constructive alignment [2], scaffolding [4], and cognitive-load theory [3, 19].

Reducing the duration of the lecture videos and indexing their content facilitates search and review, permitting greater focus on the most pertinent material. This notion is supported through the learning demonstrated by those students with low pre-test scores. Although both groups improved, the post-test scores reveal a statistically significant and educationally relevant improvement for those students viewing reduced lecture videos. Additionally, there was a statistically significant difference in perceived effort required to watch the reduced lecture videos, which may have aided engagement.

However, it is important to note the lack of a difference for those students who performed well on the pre-test. This is indicative, perhaps, of an interaction between the type of video and prior knowledge. One potential hypothesis can be found in research on science videos: when students feel they already know a topic, they only perceive that the content of videos reinforces their existing misconceptions (irrespective of the actual content) [14]. Given that participants were not made aware of their pre-test scores during the study, students with prior knowledge of the topic may have encountered such a phenomenon. Another hypothesis is that depth of learning is a factor (see Biggs and Tang [2]). The reduced lecture videos only focus attention on surface-level material, denying the depth of discourse needed to promote learning enough to achieve the higher scores.

It would also be interesting to see how lecture recording reduction impacts absentees. The approach seems effective for students with low pre-test scores (such as absentees) and may be suited to help students achieve the most important learning objectives.

Table 6: Summary of Findings and P-Values

RQ	H_n	Hypothesis	Observation	p	Conclusion
1	H_1	$\Delta Usage = 0$	$t = -1.169$	.189	*Supported*
2	H_{2a}	$\Delta Learning \neq 0$	$t = -2.228$	.032	*Supported*
	H_{2b}	$\Delta Learning \neq 0$	$t = -1.210$	.241	—
3	H_3	$\Delta ATT1 \neq 0$	$U = 204.0$	.243	—
	H_4	$\Delta ATT2 \neq 0$	$U = 211.5$	.461	—
	H_5	$\Delta ATT3 \neq 0$	$U = 202.5$	.238	—
	H_6	$\Delta ATT4 \neq 0$	$U = 156.5$	.024	*Supported*
	H_7	$\Delta ATT5 \neq 0$	$U = 211.5$	.321	—

7.2 Limitations

It is important to note the sample size as a limitation in this study. As statistical assumptions did not hold, the sample had to be divided into two sub-samples at the data analysis stage. This not only has implications for the representativeness of theses sub-samples and the generalizability of the results. In particular, as there were a relatively small number of students receiving high scores on the pre-test (N = 20), statistical power for the analysis of this group was low. Therefore, the risk of Type-II error for H_{2b} is increased, with a noted sensitivity of $d > .66$. Further research with a larger sample size and an experimental design that accounts for a possible interaction effect is therefore needed.

It is also important to note that it was not possible to explore and differentiate between individual students' video usage behaviour based on the data provided by YouTube analytics. As such, neither the different ways in which the participants potentially used the lecture recordings, nor whether either version of the videos were an important revision tool could be established. The use of qualitative research methods and an additional no-video control group may be necessary to establish this.

8 CONCLUSION

This article presents a proof-of-concept, demonstrating the impact of lecture video reduction using slide meta-data. It was hypothesized that the time students spend watching lecture videos would not depend on their duration. Thus, editing lecture videos would encourage students to spend a greater proportion of their time focusing on relevant content; thereby, enhancing performance on the intended learning outcomes. The results of the trial, summarized in Table 6, support several of these hypotheses. However, a possible interaction effect is revealed: those who performed poorly on the pre-test only benefited from watching the reduced lecture videos (H_{2a}), while those who performed well on the pre-test did not seem receive any benefit (H_{2b}). This suggests that reducing lecture videos can be worthwhile when compared to lightly edited full lecture videos, but only for those students with little prior knowledge. Further work is needed to explore this interaction in more detail and to elicit guidelines to support the development of future lecture video reduction approaches.

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