Student Perceptions and Engagement in Video-based Learning for Microbiology Education

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Abstract

Online learning increases the physical distance between instructors and students and depending on the mode of delivery, it can be challenging to close this gap. To ameliorate this potential for student isolation, instructors need to communicate to students in a variety of ways, blending original online resources with synchronous interactive learning activities. During 2020, 34 lecture videos were created for a large undergraduate microbiology and immunology course offered at The University of Queensland. The teaching team applied a subset of Mayer's multimedia learning design principles – embodiment, mixed perspectives, segmenting, signalling – to create videos featuring instructor presence, multiple presentation styles, and dynamic pacing. When compared to voice-over presentations created by automated lecture capture software, the outcomes of this design process increased student engagement in video-based learning across the 2020 and 2021 course offerings. Analysis of student perception data collected by online questionnaires and interviews revealed broad agreement with the design principles used for video-based learning. However, their value of on-screen instructor visibility, graphics, and text was variable as a result of individual preferences. Together these findings present a case study in which instructional videos were developed iteratively through the selective application of multimedia design principles and strategic adaptation of existing learning resources.

Background

Video resources have been adopted as a flexible instructional tool for many applications, ranging from filmstrip analysis of battle strategies in World War II (Hovland, Lumsdaine, & Sheffield, 1949) to remedial mathematics teaching in lower-performing schools (Santagata, 2009). The effectiveness of the medium stems from its multisensory presentation of audio and visual stimuli, which according to the dual channel principle allows learners to process more information simultaneously via separate visual and verbal channels (Paivio, 2014). This has the potential to mitigate cognitive overload resulting from information processing (Sweller, 2011), and video has been demonstrated to be more effective for student learning than presenting information through words alone (Mayer, 2002).

The historical implications for the widespread uptake of instructional video have been described in detail across several recent reviews (Mayer, Fiorella, & Stull, 2020; Sablić, Mirosavljević, Škugor, 2021; Yousef, Chatti, & Schroeder, 2014). Against the backdrop of this broader context, the Higher Education sector took a circuitous route before integrating video-based learning into the broader student experience. Video production is a labour and resource intensive endeavour, but the availability of lecture capture software installed in teaching spaces lowered the technological bar of entry. Although lecture capture software such as Echo360 does not film the presenters, it can record images and cursor movement presented on a computer slideshow and combine it with recorded audio from in-room microphones. The automated translation of every class into an online recording sparked sector-wide concerns over student engagement, learning outcomes, and instructor autonomy (Banerjee, 2021). Early studies showed that lower-achieving students were more likely to view lecture recordings than higher-achieving students (Owston, Lupshenyuk, & Wideman, 2011), and recordings were initially perceived as supplemental materials at best (Fei et al., 2013). Over time however, students increasingly used lecture recordings as a substitute for attending classes in person, even as studies revealed strong positive correlations between in-person attendance and academic performance (Edwards & Clinton, 2019; Newman-Ford, Fitzgibbon, Lloyd, & Thomas, 2008). Predictably, the perceptions towards the value of these resources from students (positive) and instructors (negative) continued to diverge (Dommett, Gardner, & van Tilburg, 2020).

The COVID-19 global pandemic overwhelmed many of these concerns as part of an overall Emergency Response Teaching (ERT) effort in moving to an entirely online mode of instruction (Slade et al., 2021). Past experiences in developing Massively Open Online Courses (MOOCs) became instructive in this online pivot, and instructors needed to balance synchronous delivery of online lectures and tutorials with the creation of asynchronous learning resources for students. Videos have been shown to be the most accessed resource in online learning environments (Breslow et al., 2013), and video-based instructional design can be analysed across two dimensions: how the instructor is embodied, and the type of instructional media presented on screen (Chorianopoulos, 2018). There are eight common video presentation styles that can be viewed through the lens of this design taxonomy (Table 1). “Voiceover presentation” – instructors narrating over a slideshow off-camera - is the baseline output from existing lecture capture systems. However, it is currently unclear whether this presentation style is optimised for student learning and engagement.

Table 1 – Common Video presentation styles (Chorianopoulos, 2018)

Presentation Style	Description
Voiceover presentation	Instructor talking over a slideshow.
Talking head	Presentation where the image of the instructor takes up most of the screen
Picture-in-picture	Visible image of instructor superimposed over a slideshow
Writing/typing	Instructor writing or typing in real time during the presentation. Only instructor hands are visible on screen.
Screencast	A video of the instructor teaching in a lecture hall with a whiteboard or screen visible
Interview	Two-way conversation between two or more people depicted on screen
Demonstration	Instructor demonstrating procedures, equipment, or software
Animated voice-over	Computer generated images with voiceover

Mayer and colleagues have established a substantial body of research in this area over the past 30 years, coining the Multimedia Theory of Learning along with accompanying design principles for producing learning resources (Mayer & Fiorella, 2014). A subset of these design principles is especially relevant to video-based learning and is summarised in Table 2. The segmenting principle - splitting videos into digestible portions to lessen cognitive load - is regarded as particularly useful in organising the information presented in videos (Fiorella & Mayer, 2018), and has been shown to improve procedural learning (Biard, Cojean, & Jamet, 2018). When considering the types of instructional media to represent on screen, the use of animations and extraneous video footage does not necessarily improve learning over simple graphics and text (Mayer & Fiorella, 2014; Mayer, Heiser, & Lonn, 2001). A more strategic video design approach may involve the "mixed perspectives" principle - considering how existing learning materials can be viewed through different angles and presentation styles to improve student immersion and learning outcomes (Boucheix, Gauthier, Fontaine, & Jaffeux, 2018).

The "image" principle suggests that showing an image of the instructor on screen throughout a video has mixed results and is not necessarily conducive to improved learning. Studies have demonstrated improved attention, information retention, and student satisfaction in response to instructors' on-screen presence (Kizilcec, Papadopoulos, & Sritanyaratana, 2014; Wang & Antonenko, 2017), yet instructor visibility may also distract students from other important on-screen information (Korving, Hernández, & De Groot, 2016). Alternate mechanisms for establishing instructor presence involve the 'embodiment' and 'dynamic drawing' design principles (Mayer & Fiorella, 2014; Mayer et al., 2020), displaying gestures and movement such as drawing or writing on a board, all of which can direct the gaze of the viewers (Fiorella, Stull, Kuhlmann, & Mayer, 2019). Maintaining an informal conversational tone and speaking clearly and with enthusiasm may further improve the personalisation of videos (Brame, 2016), and generative activities that invite audience interactions through answering questions or writing summaries, can also promote student engagement (Mayer et al., 2020).

These design principles have been tested under controlled conditions where participants finish watching each video before assessing its impact on their learning. However, this is not an accurate representation of the *ad hoc* online learning environment created during the global pandemic, and the self-directed nature of online learning can increase the risk of student disengagement (Alraimi, Zo, & Ciganek, 2015). Instructors need to assume that most instructional videos will not be watched in their entirety without the influence of extrinsically motivating factors. Effective video-based instruction under these conditions must therefore not only reduce cognitive load, but also promote and maintain student engagement. Time-poor instructors are more likely to adapt existing resources than create new videos, and the resource constraints imposed by the pandemic may further limit the feasibility of incorporating Mayer's design principles into scripted video content.

Informed by the above design principles, the teaching team of an undergraduate microbiology and immunology course offered at the University of Queensland (UQ) in Australia aimed to redesign the entire suite of video-based learning resources in the course to better meet the needs for online delivery in 2020. This project's accompanying evaluation strategy aimed to address two interrelated research questions (RQ):

RQ1: Which design principles should instructors prioritise when adapting learning resources for video-based learning, and what impact will this have on student engagement?

RQ2: How do science students perceive video-based learning, and which design principles for videos do they value for their learning?

Table 2 – Multimedia Learning theory design principles (Fiorella & Mayer, 2018; Mayer & Fiorella, 2014; Mayer et al., 2020)

Principle	Explanation
Animation	Animation does not necessarily improve learning more than static diagrams
Coherence	Excluding extraneous information improves learning
Dynamic drawing	On-screen instructors drawing graphics on a board while lecturing improves learning over referring to pre-drawn graphics
Embodiment	On screen elements that display human like gestures and movements improves learning
Gaze guidance	On-screen instructors shifting gaze between audience and the board while lecturing improves learning when compared to looking only at the audience or board
Generative activity	Asking audiences to engage in summarizing during the video improves learning
Image	Having an image of an instructor on screen does not necessarily improve learning
Mixed perspectives	Showing a process from multiple angles or perspectives improves immersion and learning
Modality	The combination of graphics and narration improves learning more than graphics and printed text. Applicable if video is presented in the learner's first language.
Personalization	Presenting words in conversational rather than formal style improves learning
Perspective	Video lectures filmed from first-person perspective improves learning compared to a third-person perspective
Pre-training	Pre-training in names and characteristics of key concepts improves learning
Seductive details	Extraneous video footage does not improve learning in a multimedia lesson
Segmenting	Presenting information in a piecemeal fashion rather than all at once improves learning
Signalling	Cues that highlight key information and its organisation improves learning
Voice	Clear audio is easier to understand and improves learning

Methods

Ethical Considerations

The University of Queensland's Human Research Ethics Committee granted ethical approval to the study (Approval Number: 2016001757). Written informed consent and gatekeeper approval was obtained from course coordinators before students were recruited, and informed consent was obtained for each participant.

Research participant recruitment

436 students enrolled in the 2020 course were invited to participate in an online survey via email invitation. 80 student responses were included after filtering for validity (answered >75% of questions) with an overall completion rate of 18.3%.

Video production

38 lecture videos were created from in-person lectures delivered during the 2019 course offering using Echo360 - automated lecture capture software which records the slideshow and microphone input. No footage of the instructor presenting on camera is captured, and recordings are automatically scheduled to start and stop after 50 min. No editing or post-production was done.

34 lecture videos were created before the start of the 2020 course offering using the 2019 slide-decks. While minor modifications were made to the introductory slides to improve the consistency in visual layout, the total number of slides and core concepts presented in each lecture remain unchanged. Instructors were filmed presenting slides to camera along with screen recordings of their slideshow, computer animations, and/or hand-drawn diagrams. This footage is interspliced using video-editing software (Final Cut Pro X), and video timestamps corresponding to each slide in the slideshow is annotated on student handouts. The same 34 lecture videos were utilised in the 2021 course offering.

Learning Analytics

The lecture videos from the 2019, 2020, and 2021 course offerings were downloaded using the courses' Learning Management System (Blackboard) and parsed for overall duration and the number of scene changes per video. A scene change is defined as a transition between two different video presentation styles outlined in Table 1. Anonymous video-viewing analytics were downloaded from Blackboard, and the average video views per lecture were calculated using the total views for each lecture video presented that week. As per this study's ethical considerations, this data was de-identified and did not track video views for individual students.

Data analysis

Video-viewing analytics

Students were presented with 3 lecture videos throughout each week of the teaching semester in 2019, 2020 and 2021. The average video views per lecture across the 2019, 2020, and 2021 course offerings were modelled using a simple linear regression followed by an Analysis of Covariance (ANCOVA). The slope and intercept of the lines generated from each year were compared to explore any statistically significant differences. The average completion rate for each lecture video was collated across the 2019, 2020, and 2021 course offerings.

Mean helpfulness ratings

Survey respondents were asked to rate the helpfulness of each video presentation style on a scale from "No help", "A little help", "Moderate help", "Much help", "Great help"). These categories were converted to a numerical scale from 1 - 5 respectively, with mean ratings and Standard Error of the Mean (SEM) calculated from the responses. p-values were derived from a one-way ANOVA (Kruskal-Wallis H-test) using the Dunn's post-hoc test with Bonferroni correction for multiple comparisons.

Correlation matrix
The correlation coefficient Pearson's r was calculated between each pairwise set of helpfulness ratings for all video styles. An ordinary least-squares (OLS) linear regression was then developed for every pairwise set of helpfulness ratings for each video style. From this regression, the p-value was calculated using a Student's t-test on the slope of the regression assuming a parametric distribution.

Thematic analysis
Deductive thematic coding of student responses ($n = 74$) to the open-ended question "What are the most helpful and least helpful aspects of video-based learning?" was conducted using NVivo 12, using 16 video-based learning design principles (Table 2) as primary nodes, each with "Agree" and "Disagree" sub-nodes. Interrater reliability across 2 independent coders was calculated, with Cohen's Kappa = 0.72 indicative of moderate to strong agreement (McHugh, 2012).

Results

RQ1: Which design principles should instructors prioritise when adapting learning resources for video-based learning, and what impact will this have on student engagement?
It became clear from the review of prior research into video-based learning that the automated lecture captures used in the 2019 iteration of the course were not designed to optimally engage students studying online. The teaching team (comprising of 8 instructors, including the course coordinator) committed to a new suite of lecture videos for the course in 2020. Given the resource and timing limitations across the sector however, there was an emphasis on adapting existing learning resources rather than a complete ground-up re-design. The team aimed to produce videos with distinct visual stimuli that had the potential to improve student engagement, and accordingly prioritised 4 video-based learning design principles (Table 2):

1. Incorporate human-like gestures and movements on screen to help establish instructor presence (embodiment)
2. Utilise a range of different presentation styles to improve learner immersion in video lectures (mixed perspectives)
3. Allow instructors to readily incorporate on-screen cues to highlight important concepts (signalling)
4. Employ video-editing techniques to incorporate chapter markers that allow students to progress through the video at their own pace (segmentation).

The 2019 automated Echo360 lecture capture process had generated videos that were uniform in length (50 minutes), capturing slides and lecturer audio in the "voice-over presentation" style. The production of the 2020 lecture videos involved filming instructors presenting from the 2019 slides in an unscripted manner while in parallel recording the computer screen to capture their slideshow that was being projected. This process provided the option to create at least three different presentation styles that could be integrated in post-production (voiceover presentation, talking head, picture-in-picture), while capturing the mouse pointer gestures used by the instructor to emphasise important concepts on screen. Additional scenes depicting the instructor writing on screen or physically demonstrating techniques were filmed separately and interspliced using video-editing software.

The transition between different presentation styles can be quantified as a “scene change”. The 2020 lecture videos had an average of 79.61 +/- 3.45 scene changes per video, an increase compared to videos from 2019, which averaged 2.71 +/- 0.52 scene changes per video. The post-production process for the 2020 lecture videos also allowed for the removal of long pauses and gaps, which resulted in a reduction in average video length (28.59 +/- 0.96 min in 2020 compared to 50 min in 2019). This afforded instructors the opportunity to merge lecture topics (38 lectures in 2019 became 34 lectures in 2020), despite using the same slide content resources as in 2019. Timestamps denoting the start and end point of each slide were provided as segmented chapter markers in the video as well as on slide handouts provided to students. The production of all lecture videos prior to the start of the teaching semester allowed for a different online release schedule. In 2019, lecture videos and accompanying slide handouts were released online one at a time, within 4 hours of the conclusion of the related in-person lecture delivery. In 2020, 2-3 lecture videos were batch released at the start of every week, along with annotated slide handouts. The same lecture videos and release strategy in 2020 were used for the 2021 offering of the course to evaluate the sustainability of any effects on student engagement. A summary of the design differences between the 2019 and 2020/2021 lecture videos is presented in Table 3 and Figure 1.

Table 3 – Design features of video-based learning resources

	2019	**2020/2021**
Recording protocol	Automated lecture-theatre recording of projector and microphone inputs	Lecturers filmed and slides recorded separately. Interspliced and edited in post-production
Presentation styles used	Voiceover presentation Animated voiceover Writing/typing	Talking head Voiceover presentation Picture-in-picture Animated voiceover Writing/typing
Number of lecture videos	38	34
Average video length	50 min	28.59 +/- 0.96 min
Average scene changes per video	2.71 +/- 0.52 scene changes per video	79.61 +/- 3.45 scene changes per video
Release schedule	One lecture video at a time, <4 hours after the live face-to-face lecture	2-3 lecture videos batch released at the start of every teaching week.
Format of student handouts	Slides created from the instructors’ slide deck	Slides created from the instructors’ slide deck (same as 2019) but annotated with video timestamps

Figure 1 – Comparison of video presentation styles used in 2019-2021.

The 2020 lecture videos incorporated instructor presence through a range of different presentation styles, had more dynamic pacing through scene changes between these styles, used signalling and segmentation cues to facilitate viewer navigation, and were overall much shorter in length. Similar student cohorts were enrolled in all three offerings of the course from 2019-2021, in terms of class size, field of study, age distribution, and country of birth (Table 4). It should be noted that the 2020 and 2021 courses offered dual mode delivery to accommodate students that were unable to enter the country due to international travel restrictions, whereas the 2019 course was only offered internally prior to the pandemic. In 2020 and 2021, course summative assessment also shifted to an open-book short-answer online format, as opposed to the 2019 closed-book, in-person examination consisting of multiple choice and short answer questions. The final grade distributions for students reveal that there were comparable proportions of high-achieving (26-39% of the cohort), mid-achieving (46-54% of the cohort), and low-achieving (6-13% of the cohort) students across all 3 years. However, given the change in assessment practices between 2019 and 2020/2021, it is inappropriate to attribute outcomes to the impact of new video-based learning resources on student performance in the course.

Table 4 –Student demographics across 2019-2021 course offerings

	2019	**2020**	**2021**
Delivery Mode	Internal	Internal + External	Internal + External
Exam format	Closed-book Multiple-choice + short-answer	Open-book short answer	Open-book short answer
Class size	389	436	440
High-achieving students (>=75%)	26.2%	39.9%	28.6%
Mid-achieving students (50-74%)	48.3%	54.4%	54.3%
Low-achieving students (<50%)	13.1%	5.7%	9.5%
Enrolled in science	36.5%	38.3%	37%
Enrolled in biomedical Science	42.1%	40.6%	44.5%
Enrolled in biotechnology	4.4%	4.8%	5.9%
Enrolled in health Sciences	2.3%	1.6%	1.4%
Enrolled in dual programs	10.3%	14%	10.2%
Enrolled in other	4.4%	0.7%	1%
<18 years old	0.5%	0	0.5%
18-19 years old	57.6%	60.55%	55.2%
20-21 years old	29.8%	26.8%	29.3%
22 or older	12.1%	13.6%	15%
Country of birth (AUS)	81.7%	82.8%	81.1%
Country of birth (outside AUS)	18.3%	17.2%	18.9%

Even though the 2019 pre-pandemic version of the course offered internal classes only, less than 10% of the cohort opted to consistently attend lectures on campus. A similar attendance rate was observed in 2020 and 2021 (<10%), despite the fact that in-person attendance was available for the majority of the student cohorts (there were no mandatory state-wide lockdowns in Queensland during these semesters).

As the majority of enrolled students were choosing not to directly engage with in-person lectures, the project team sought to determine their engagement with the courses' video-based learning resources. The degree of student engagement in video-based learning was determined by the number of views each lecture video generated. In 2019, the average views per lecture throughout the whole semester was 353.84 +/- 10.9 views/lecture in a class size of 389 students. In contrast, the average views per lecture throughout the whole semester for 2020 (560.32+/- 16.5 views/lecture) and for 2021(559.82 +/- 21.9 views/lecture) was greater than the total number of students enrolled (436 students in 2020, 440 students in 2021).

To explore the statistical significance of these observations, the average number of video views per week for lecture videos was analysed using linear regression modelling, where the slopes and intercepts for each year's viewing data were compared using Analysis of Covariance (ANCOVA) in Figure 2. In all three semesters, the average lecture video views per week declined over time, and the slopes of the linear regression lines were not significantly different across any of the semesters. However, when comparing the intercepts of the linear regressions, 2019 was significantly lower than both the 2020 ($p<0.001$) and 2021 ($p<0.001$) viewing data. No statistical difference was observed between the 2020 and 2021 video-viewing data. The average completion rate for each lecture video was also lower in 2019 (44.08 +/-1.154%) than in 2020 (72.21 +/- 1.456%) and 2021 (68.25 +/- 0.6342%). It appears that students were watching lecture videos more frequently and to a higher rate of completion in response to the re-design in 2020 and 2021.

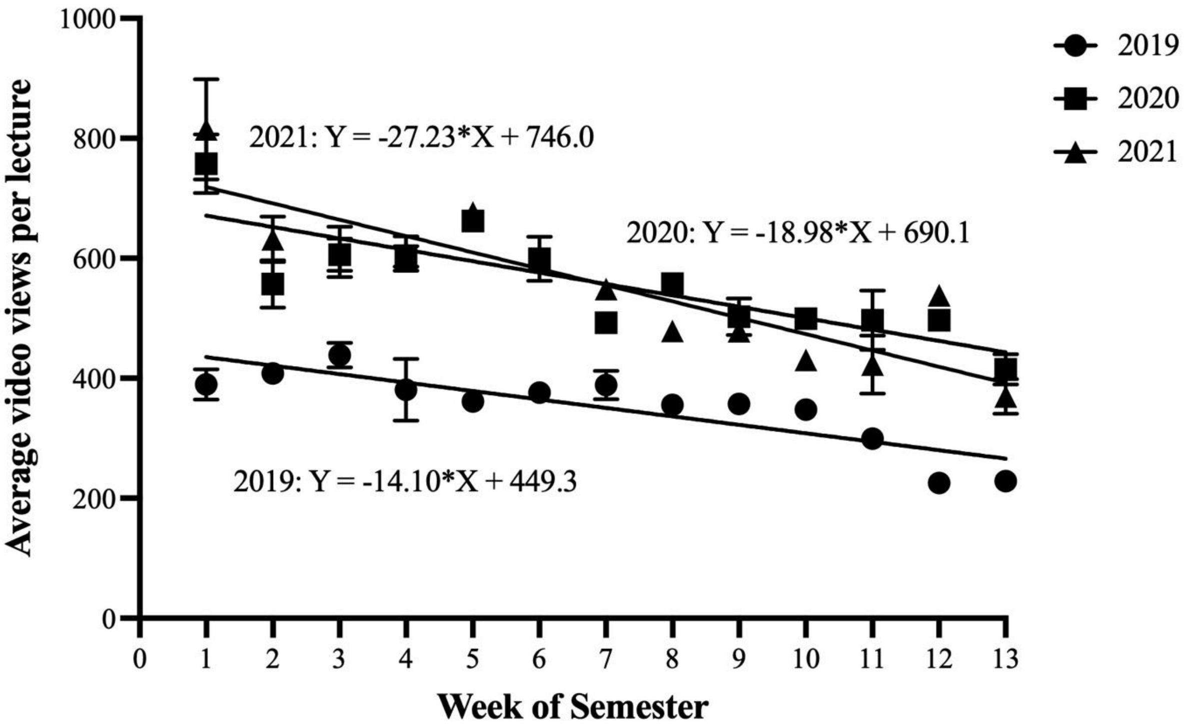

Figure 2 – Linear regression of average lecture views/week +/- SEM from 2019-2021.

RQ2: How do science students perceive video-based learning, and which design principles for videos do they value for their learning?

While it is difficult to directly connect engagement in video-viewing with improved student learning outcomes through the nature of the data collected in this study, student perceptions on video-based learning were further explored. Due to the sudden pivot to online delivery, a thorough evaluation of student perceptions could not be completed prior to the redesign of video resources in 2020. However, at the conclusion of the 2020 course offering, 80 valid student responses to the online survey (18.3% completion rate) were analysed to evaluate the impact of different video design principles and presentation styles on their perceptions of online learning. Within the survey, respondents were asked to assess "How much did each of the video presentation styles help your learning in the course?" on a continuous 1-5 scale (1 – no help; 2 – a little help; 3 – moderate help; 4 – much help; 5 – great help). The mean helpfulness rating of each of the presentation styles is presented in Table 5, which were analysed using a Kruskal-Wallis one-way ANOVA and the Dunn's multiple comparison post hoc test with Bonferroni correction. "Voiceover presentation" scored a mean helpfulness rating of 2.8 +/- 0.12 and given its ubiquity in videos created by automated lecture capture, served as the benchmark point of comparison against all other presentation styles. The three highest mean helpfulness rating styles were "picture-in-picture", "writing/typing", and "demonstration", but only the mean ratings for "demonstration" were regarded as statistically more helpful than "voiceover presentation" ($p<0.05$). These styles featured additional elements of instructor presence combined with voiceover narration, either directly visible on camera or via gestural actions including writing, typing, or demonstration. Of note, while "talking head" and "screencast" presentation styles directly show instructors directly on camera, they were not rated higher in terms of mean helpfulness compared to voiceover presentation. "Interview" and "animation" scored the lowest mean helpfulness ratings amongst all presentation styles. In fact, "animation" was rated to be statistically less helpful compared to "voiceover presentation" ($p<0.05$). These findings support the notion that instructor presence is perceived to be helpful by students in video-based learning (Fiorella et al., 2019), but the degree to which instructors are embodied on screen may obfuscate the concepts being communicated (Korving et al., 2016).

Table 5: Mean ratings and comparison of each video style to Voiceover (n = 80)

Style	Mean rating	p-value
Voiceover	2.8 ± 0.12	-
Talking head	2.6 ± 0.15	1.0
Picture-in-picture	3.3 ± 0.10	0.11
Interview	2.0 ± 0.27	0.61
Writing/typing	3.3 ± 0.11	0.11
Animation	1.7 ± 0.23	0.013*
Screencast	2.6 ± 0.16	1.0
Demonstration	3.5 ± 0.095	0.00072*

To further analyse the relationships between video presentation styles, a Pearson's r correlation matrix that compares helpfulness ratings for each style was generated (Table 6). The "demonstration" presentation style exhibited statistically significant correlations with "talking head" and "picture-in-picture". Similarly, "talking head" and "picture-in-picture" styles also demonstrated significant correlation with each other. The strong correlations between similar types of instructor embodiment suggests that there may be a subset of students who prefer on-screen instructor presence in video-based learning (Kizilcec et al., 2014; Wang & Antonenko, 2017).

Table 6: Correlation matrix between mean helpfulness ratings of each video-style a perceived by students. ** denotes p < 0.01, * denotes p<0.05

	Voice -over	Talking head	Picture-in-picture	Interview	Writing/ typing	Animation	Screencast	Demo
Voiceover		-0.015	0.077	-0.20	0.0095	0.37	0.097	0.040
Talking head	-0.015		0.31*	0.37	0.090	0.15	0.081	0.35**
Picture-in-picture	0.077	0.31*		0.43	0.090	0.24	0.18	0.28*
Interview	-0.20	0.37	0.43		0.22	0.26	0.11	0.35
Writing/ typing	0.0095	0.090	0.090	0.22		0	0.31	0.18
Animation	0.37	0.15	0.24	0.26	0		0.19	-0.13
Screencast	0.097	0.081	0.18	0.11	0.31	0.19		0.30
Demo	0.040	0.35**	0.28*	0.35	0.17	-0.13	0.30	

To gain further insight into these findings, students' written responses to the open-ended question "What are the most helpful and least helpful aspects of video-based learning?" in the survey were analysed. 74 out of the 80 respondents answered the question and their answers were deductively coded applying the 16 video-based learning design principles presented in Table 2. Sub-nodes for "agree" and "disagree were allocated for each response. The coding was performed by two independent coders, and the inter-rater reliability using Cohen's Kappa was calculated to be 0.72, indicative of moderate to strong agreement (McHugh, 2012). The frequency of references made by students to each design principle is summarised in Table 7.

Table 7 – Coding of student preferences in video-based learning (n=74).

Principle	Total references	Sub-node
Animation	4	Agree: 2
		Disagree: 2
Coherence	14	Agree: 14
		Disagree: 0
Dynamic drawing	22	Agree: 20
		Disagree: 2
Embodiment	17	Agree: 17
		Disagree: 0
Gaze guidance	0	Agree: 0
		Disagree: 0
Generative activity	10	Agree: 10
		Disagree: 0
Image	47	Agree: 17
		Disagree: 30
Mixed perspectives	7	Agree: 5
		Disagree: 2
Modality	12	Agree: 5
		Disagree: 7
Personalization	1	Agree: 0
		Disagree: 1
Perspective	0	Agree: 0
		Disagree: 0
Pre-training	0	Agree: 0
		Disagree: 0
Seductive details	2	Agree: 2
		Disagree: 0
Segmenting	21	Agree: 21
		Disagree: 0
Signalling	9	Agree: 9
		Disagree: 0
Voice	8	Agree: 8
		Disagree: 0

The highest number of references were observed for the nodes assigned to “image” (n = 47 references), “dynamic drawing” (n = 22), “segmenting” (n = 21), and “embodiment” (n = 17). The instructors in this project opted to incorporate “segmenting” and “embodiment” principles as part of their video design objectives. The high number of references to design principles of “dynamic drawing”, “segmenting”, and “embodiment” reflect other features that students value in video design. In contrast, references to the "image" principle indicated mixed perceptions – 17 agree and 30 disagree, as illustrated by the following quotes:

Student 1: *"I found the headshots (or the 'talking head style') to be a nuisance, as I couldn't see the slides and whilst it made the videos more interesting, it* ***made it more difficult to learn as we became disorientated every time it switched from the slides to the talking heads****."*

Student 2: *"It helps to see the lecturers face and* ***this is engaging and helps to maintain an interest and engagement with online learning.*** *If there is a lack of person to person engagement in an online setting, then it quickly becomes similar to watching online YouTube videos or staring at a device for hours on end. This is too similar to every other activity, such as scrolling through social media or staring at Netflix."*

The "modality" principle contained 12 references split across the "agree" (5 references) and "disagree" (7 references) sub-nodes. The students who disagreed with this principle cited their perceived value of text-based learning:

Student 3: *"I appreciate too much text is overwhelming and doesn't make a good presentation, however having the key points that are necessary to know whether for skill in the topic or for an assessment highlighted and present on the slide helps to push that message across. Having pictures relevant to what is being said is useful however* ***it is not great for people who need the written words to fully understand.****"*

"Signalling" and "mixed perspectives" principles were part of the project's design objectives but were not frequently cited by students in response to this question (fewer than 10 references for both nodes). The majority of coded references agreed with the "mixed perspectives" principle, except under a specific circumstance:

Student 4: *"When there is* ***quick/constant flicking*** *between screens of text to the presenter talking, it is* ***quite distracting and difficult to take notes/focus****."*

Overall, these findings provide additional context for the increased student engagement in video-based learning in 2020 and 2021.

Discussion

The self-directed nature of online learning environments can further exacerbate student disengagement and attrition, and the emergence of tools designed to measure online attention spans suggests that maintaining engagement is a pervasive problem throughout the sector (Karthikraj, Patil, Thanneermalai, & Yadav, 2021; Oppl, Gutmann, Lazic, & Mühlburger, 2019). This study presents an example of the rapid adaptation of face-to-face lectures into online instructional videos through the intentional use of design principles for video-based learning. Instead of producing scripted instructional videos supplemented by new graphics and animations that required extra time and effort to produce, the teaching team filmed instructors presenting their existing teaching materials in a lecture theatre. Camera footage of the instructors was interspliced with slideshow screen recordings and videos of demonstrations and hand-drawing diagrams, all of which are edited, condensed, and timestamped to enhance the student viewing experience. This production process applied and integrated a subset of Mayer's multimedia learning design principles (embodiment, mixed perspectives, signalling, and segmentation), which effectively increased student engagement with the video-based learning resources in 2020 and 2021. The average number of views per video in 2020 and 2021 exceeded the number of enrolled students in each semester, suggesting that a persistent sub-cohort of students were choosing to watch each lecture video more than once.

Student perceptions are mostly positive regarding instructor presence in videos but variable in their preferences on how instructors should be embodied on screen. Video presentation styles that feature elements of instructor embodiment were perceived to be more helpful by students than voiceover presentations – the default output of automated lecture capture software (Echo360). The image principle suggests that seeing the instructor on screen does not necessarily improve learning, and the variability in student perceptions around the benefit of instructor visibility (Table 5) is in accordance with published literature (Kizilcec et al., 2014; Korving et al., 2016; Wang & Antonenko, 2017). “Lightboard videos” have been suggested as a single presentation style that encompasses instructor visibility and hand-drawing diagrams on screen (Jose, Kochandra, & Daniel, 2021), but the present study found no student consensus around the optimal amount of on-screen instructor visibility. Filming the instructors alongside slideshow screen recordings, however, opens possibilities for the creation of new presentation styles through simple video editing techniques (e.g., “picture-in-picture” with the instructor’s face in the corner of the slide). Incorporating multiple presentation styles from different perspectives and angles has been shown to better immerse students into the learning environment (Boucheix et al., 2018), and a video production process that is flexible enough to create multiple presentation styles and scene transitions will better fulfil this design principle. Notably, students did highlight one potential drawback to this approach if scene transitions occur too quickly between presentation styles. However, this must be weighed against the benefits of segmenting videos and excluding long pauses and extraneous information. These design features were highly prioritised by students in this study, and were also previously linked to improved learning outcomes (Fiorella & Mayer, 2018).

The “modality” principle posits that graphics with voiceover narration is more effective for learning than diagrams with subtitles, as this may overload cognition and lower comprehension (Tarchi, Zaccoletti, & Mason, 2021). This principle is reversed when considering the perspectives of culturally and linguistically diverse students, for whom subtitling is very useful (Mayer et al., 2020). The students who disagreed with the “modality” principle in this study may speak English as an additional language, but other than “Country of Birth” (Table 3), demographics data on language was not collected in this study, nor was language cited as a factor in student responses.

This study considers these findings and its implications for academic digital upskilling in the context of a post-pandemic landscape, where science educators need to create original online learning resources that facilitate the development of core competencies within the discipline. Despite negative academic perceptions towards their own digital competencies (Zhao, Pinto Llorente, Sánchez Gómez, & Zhao, 2021), the tools for digital content creation have never been more accessible. Web conferencing software can record webcam footage from online meetings and classes, and basic video editing applications come pre-installed out of the box in most new computers. It stands to reason then that the digital upskilling required of academics in a post-pandemic landscape revolves around the effective utilisation of these tools to create videos and online resources. Video editing has also been used as a reflective exercise where teachers visualise, process, and re-sequence video footage of their own teaching, in order to develop multifaceted reflections on the efficacy of their instruction (Calandra, Brantley-Dias, Lee, & Fox, 2009; Trent & Gurvitch, 2015). Higher Education institutions should be strategic in their approach to professional learning and support academic and professional staff members in their digital content creation of novel online resources. Coordinated training sessions for specific digital tools, as well as empowering technology champions within departments that foster peer-to-peer mentoring all represent effective mechanisms for professional learning going forward.

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