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RESEARCH ARTICLE

Two sides of the same coin: video annotations and in-video questions for active learning

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Abstract
Video in education has become pervasive. Globally, educators are recording instructional videos to augment their students' learning and, in many contexts, replace face-to-face lectures. However, the mere act of watching a video is primarily a passive learning experience likely leading to lack of student engagement hindering learning. Active learning strategies such as video annotations and in-video questions have the potential to shift the passive experience of watching an instructional video to a more active one by engaging students with learning strategies designed to promote self-regulated learning and improve content knowledge. This experimental study investigates the impact of in-video questions compared to video annotations on learning and self-efficacy in an experimental setting. Findings revealed that learners who annotated videos had higher self-efficacy than those who completed in-video questions likely due to the immediate feedback received from the in-video questions. The study further concluded that prior knowledge plays a critical role in selecting appropriate active learning strategies, suggesting that video annotations be considered when students have prior knowledge about a topic whereas in-video questions with immediate feedback be interspersed in videos when students do not have prior knowledge about a topic.

Keywords Videos · Prior knowledge · Video annotations · In-video questions · Self-efficacy · Video-based learning

Introduction

Videos have become ubiquitous in society and the education sector is no exception. The use of video to support learning and teaching has been an instructional strategy for decades dating back to the 1970s when German universities recorded lectures to use for debriefing afterwards (Rolf et al., 2014). During this time, educational video has been used to augment the learning experience but was limited to physical video tapes being used either in the classroom or mailed to students studying remotely. With improved access to the Internet and advancements in video compression techniques, video streaming services became

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Extended author information available on the last page of the article viable in the early 2000s and flourished with the arrival of YouTube in 2005, changing the cultural landscape of how videos, including educational videos, are shared (Weller, 2020). Institutionally-supported video recording, editing, and streaming technologies such as *Kaltura* and *Panopto* have also become more readily available coupled with more reliable internet connection compared to previous decades, positioning video as a key learning and teaching tool across the education sector (Kleftodimos & Evangelidis, 2018). Prior to the current video-sharing era, videos had to be commissioned or purchased leading to high costs for the educational institutions, instructors, or the students (Weller, 2020). Such institutionally supported technologies have helped alleviate the costs associated with developing educational videos by providing instructors with tools to record and share their own videos with their students with relatively ease of use. Further, the rise of flipped classroom initiatives, whereby students watch videos prior to class time, and the rapid growth in fully online course offerings, where videos are a core medium for information transmission, has led to videos becoming more common place (Xiu et al., 2019). The introduction of massive open and online courses (MOOCs) in 2012 has further fuelled the rapid adoption of educational videos, particularly lecture or concept recordings produced by the instructor which are central to the learning experience (Guo et al., 2014).

There has been a steady increase in research on video-based learning since 2006 (Giannakos, 2013; Poquet et al., 2018), potentially due to the simultaneous expansion of video-sharing through YouTube. Studies have shown that active learning, the notion that learners interact with their learning material and resources rather than learning being a passive non-interactive experience, can be applied to video-based learning (Giannakos et al., 2016). However, much of the research has focused on the ways videos have been presented or used, largely as a passive learning resource, rather than investigating the ways in which videos could support active learning.

Watching a video is largely a passive experience that could lead to students becoming disengaged or not reflecting or constructing their own understanding of the content presented in a video (Shin et al., 2018). Embedded in-video quiz questions and video annotations are some of the tools that can help facilitate active learning experiences with video. However, to our knowledge, the only study, to date, that has investigated in-video quiz questions and video annotations simultaneously focused on student engagement patterns with respect to students note-taking behaviour with a video annotation tool and completing in-video quiz questions (van Sebille et al., 2018). In that study, even though engagement with the video annotation activity was optional, there was an initial uptake by students at the start of the semester. In parallel, a similar pattern emerged with respect to students' in-video quiz submissions with the total number of submissions tapering as the course progressed. While van Sebille et al.'s (2018) study explored student engagement with video annotations and in-video quiz questions in tandem, given the video annotation activity was not an integral component of the course, the study did not investigate the impact of annotating videos on student learning and was limited to engagement patterns.

Designing video-annotation activities or questions to embed within a video is time-consuming and resource intensive for instructors. Hence, studies are needed to ascertain whether the time and resources that instructors put into developing interactivity within their videos lead to better learning outcomes compared to merely providing a video for students to watch passively without any interactive elements. However, there are no studies, to date, that have measured the impact of in-video quiz questions compared to video annotations alongside a control group with a passive video-based learning experience. This is the issue that this study addresses by investigating the differences in learning outcomes, if any, between three groups of learners who watch the same video but with three different pedagogical approaches: in-video quiz questions, video-annotations, and passive watching. Further, the study is designed upon the theoretical framework of self-regulated learning (SRL) and hence learners' self-efficacy, a component of SRL, is also investigated in the context of video-based activities namely video annotations and in-video quiz questions. Finally, as the study considered students' prior knowledge, associations between prior knowledge and engagement with the video annotations and in-video quiz questions are also explored.

Background

Active learning and self-regulated learning

The use of video as an instructional tool relies heavily on students sufficiently engaging with the material being presented. Video, much like the lecture, requires students to self-direct their attention to the ideas and concepts being covered, such is the nature of essentially passive learning activities. Existing essentially as a form of broadcast, videos have traditionally been considered a purely passive form of learning. However, as Dall'Alba and Bengtsen (2019) point out, the notion of active learning as it has been commonly interpreted tends to overemphasise students 'doing' things. Active learning can be more than students demonstrating that they are on task. Thinking about ideas, making sense of them and other forms of cognition are 'active' and as important, if not more important, than observable behaviour. This cognitive form of active learning is core to students' learning from videos, particularly when considering cognitive engagement in combination with observable behaviours such as annotations and note taking.

As a broadcast, there is very little that a video can do to force cognitive engagement, with perhaps the only exception being to create a sense of disequilibrium (see Muller et al., 2007). As such, it is therefore contingent on each individual student to conscientiously engage with the content and this requires of students a capacity for self-regulated learning (Panadero et al., 2017). For example, according to self-regulated learning theory, a student demonstrating effective self-regulation of learning while watching videos will be paying careful attention to what is being said, what is being presented and may be taking notes (i.e. annotating) or re-watching any segment of the video that they do not sufficiently understand. There are two key elements to the self-regulated learning in this example. The first is that the student is cognitively engaged in the video and is monitoring their progress as they go. The monitoring will result in the second element, which is to engage in actions such as deciding to re-watch a segment or make note of an important point (Lodge et al., 2018a). The monitoring of progress and the decisions to take some action to ensure they are learning effectively suggest that the student is actively engaged in learning leading to a higher likelihood that they will reach the goal of learning what they need to from the video.

The use of self-regulated learning strategies also leads to enhanced self-efficacy (Schunk, 1990). Effective learning strategies, such as the effective use of annotations, help to give students more confidence in approaching new knowledge. However, effective annotations require students to already have some self-regulatory strategies in place. Another way to prompt these strategies and enhance self-efficacy is to use in video quiz questions (Hodges, 2016). Self-efficacy, developed whether through engaging in effective learning strategies or through being prompted by quiz questions, is a particularly important attribute for students to develop. This is especially the case when being asked to learn new concepts online and in videos, where there are fewer opportunities for getting help or interacting with peers or teachers to monitor progress (Lodge et al., 2018b). Hence, strategies such as taking notes and in video quizzes may support students' development of their self-efficacy and confidence in engaging with new ideas and concepts.

Video annotations

Video annotation or note-taking while watching videos is not a new technical innovation. It stems from paper-based note-taking during face-to-face lectures, a learning strategy used by students to stay focused in class and develop study guides for future study (van Meter et al., 1994). With the shift to recording lecturers and students watching lecture videos, students have applied the same paper-based note-taking study tactic. Generative learning theory stipulates that the act of writing summary notes after sections of a video primes three cognitive processes namely selecting, organising, and integrating information resulting in deeper learning outcomes and improved performance on transfer tests (Mayer et al., 2020). A generative learning strategy is one way that a learner makes sense of the material they are intending to learn and often involves translating from one form of representation to another (e.g. writing a short summary or notes after watching a video segment). This translation requires the learner to select relevant parts of the information to include, organise it in a way that make sense, and integrate it with relevant prior knowledge—all which support generative learning (Fiorella & Mayer, 2015). Note-taking or annotating, hence, are specific forms of generative learning strategies underpinning generative learning theory that stipulates that learning occurs when learners "paraphrase, organise, and make sense of the presented material" (Peper & Mayer, 1978, p. 515). Video annotation tools provide students with a mechanism for making time-stamped notes while watching a video, allowing students to return to the specific point in the video for future revision (Dawson et al., 2012).

Video annotation tools date back to the late 1990s with the launch of the Microsoft Research Annotation System (MRAS) which allowed for the provision of time-stamped notes to be made on a video (Bargeron et al., 1999). The use of video for distance education or workplace learning was on the rise from the late 1990s and web-based annotations tools, such as the MRAS, helped shift the video-watching experience from a passive experience to a more interactive one with the mechanism for students to make notes online linked to a specific timepoint in the video rather than paper-based notes peripheral to the video. Further, without a video annotation tool, students had to manually record the time stamp of the video alongside their paper-based notes in order to be able to locate the particular point in the video in the future for review (Mu, 2010).

More recently, in the past decade, various video annotation tools have been developed and piloted such as the Media Annotation Tool (MAT), designed for annotations to be made on any type of media and to be readily shared with peers or teachers for collaborative reflective learning (Colasante, 2011; Colasante & Douglas, 2016). Similarly, another video annotation tool, DiViDu, has been used by medical students to make time-specific critical reflections of their recorded consultations with simulated patients to improve their clinical skills (Hulsman & van der Vloodt, 2015; Hulsman et al., 2009). Few studies have explored the relationships between video annotations and learning particularly in experimental settings. One study conducted by Thomas et al. (2016) investigated the impact of annotations (specifically noting of key words) while simultaneously viewing a video compared with delayed annotation (after the video), and no annotations at all with findings revealing no significant difference in performance on recall or inference questions between the conditions when viewing an easy video. However, the simultaneous annotation group significantly underperformed on inference questions for a difficult topic revealing the use of video annotations are not always conducive to learning.

One study conducted by Pardo et al. (2015) investigated patterns in student engagement with video annotations and academic performance in a first year Engineering flipped classroom course finding a significant correlation between the extent of video annotations made and performance on the midterm exam. A much earlier yet still relevant study, prior to video annotation tools being available, conducted by Peper and Mayer (1978) investigated the impact of note-taking alongside watching a video lecture on computer programming and statistics on knowledge transfer. The study revealed that students who wrote summary notes while viewing a video lecture performed better on far transfer tests than students who only viewed the video lecture while no difference was found between the two groups with respect to retention or near transfer tests. A more recent study examined the effect of textual and graphical annotations on comprehension revealing that students who annotated a video on applying first aid performed significantly better than those who only watched the video (Chiu et al., 2018).

In-video quiz questions

Embedding formative quiz questions within a video is a teaching strategy that helps overcome the issue of passively watching a video by providing a more active experience (Cummins et al., 2016). It also enables students to receive immediate feedback on their learning to assess areas of weakness and support their self-regulated learning skills (Panadero et al., 2017). In-video quiz questions, a form of regular formative assessment interpolated within videos, has become common in educational settings with the rise of MOOCs (Cummins et al., 2016) and streaming video technologies, such as *Panopto*, that provide the functionality for teachers to readily embed a variety of questions within their lecture or content videos.

Early studies on the effect of in-video questions highlight that the embedded questions enhance student learning alongside increased student interactivity with videos (Vural, 2013), increased attention by reducing mind wandering and encouraged more frequent note-taking (Szpunar et al., 2013). This is supported by research on memory and recall indicating that interpolating periods of learning with tests or questions helps students to stay focused benefiting their learning (Pastötter et al., 2011). Further, regular retrieval of information, through testing as one mechanism, promotes longer term retention (Roediger & Butler, 2011), a learning strategy supported by frequent in-video questions.

Recent studies on the relationship between completing in-video quiz questions and academic performance have revealed, unsurprisingly, that there is a positive relationship between completing in-video quiz questions embedded throughout a video and performance on a subsequent recall test (Rice et al., 2019). Simpson and Bolduc-Simpson's (2018) qualitative study revealed that students perceived in-video questions as an effective learning strategy as it motivated them to watch the video in order to answer the questions, allowed them to revisit the questions in the future, and helped them ascertain whether they understood the video content. Further, a statistical study conducted by Haagsman et al. (2020) in an authentic setting concluded a significant effect of in-video quiz questions on overall test scores with students scoring significantly higher on tests when having watched videos with in-video quiz questions compared to their absence. Interestingly, no significant effect was detected between the scores on the in-video quiz questions and the test scores suggesting that the presence of in-video questions provides an indirect effect on student learning.

As the studies above have discovered, in-video quiz questions coupled with effective feedback can support students' learning of key concepts discussed in a video while video annotations can promote student learning, engagement, and reflective practice. However, what remains unknown is whether there is any difference between student engagement and learning when in-video quiz questions are interpolated in a video compared to video annotation or passively watching the same educational video. The study reported here investigates this issue by addressing the following research questions:

RQ1 What is the impact of in-video learning activities on learning?
RQ2 What is the role of prior knowledge when investigating the impact of in-video learning activities on learning?
RQ3 What is the impact of in-video learning activities on learners' self-efficacy?

Method

This study used an experimental design to examine students' engagement and learning under three different video-based learning tasks.

Participants

This study was carried out at a higher education institution in Australia. Ethical approval for the study was obtained from the institution's Human Research Ethics Committee. The sample consisted of 93 participants, who were students and staff at the institution. The majority of the sample (61%, n = 57) were female. Participants ranged in age from 18 to 70 years old, with a mean of 30 years (SD = 12.45). 49 participants (53%) reported they had prior knowledge of the topic in the video. At the start of the study, participants reported a mean confidence level of 35.7% (SD = 28.4) to answer questions about the topic in the video. As compensation for their participation, participants received a $20 gift voucher at the end of the study.

The video and video annotation platform—OVAL

The video used in this study was 11:52 min in duration and covered a basic introduction to neuroscience. The video was presented as a voice-over graphics presentation using a video annotation tool. While the video annotation tool offers a suite of features to support students' self-regulated learning, the main features of interest in this study were the time-stamped annotations and in-video quiz functionalities. Figure 1 shows the video annotation interface as experienced by a participant in this study.

To make an annotation at any point during a video, the user can click on the annotations button, which automatically pauses the video and opens a dialogue box for students to input their annotations (see Fig. 2). These annotations are then saved with the respective time-stamp. Users can see the annotations that they and others have made, as circles below the video. Clicking on a circle denoting an annotation allows users to review their annotation.

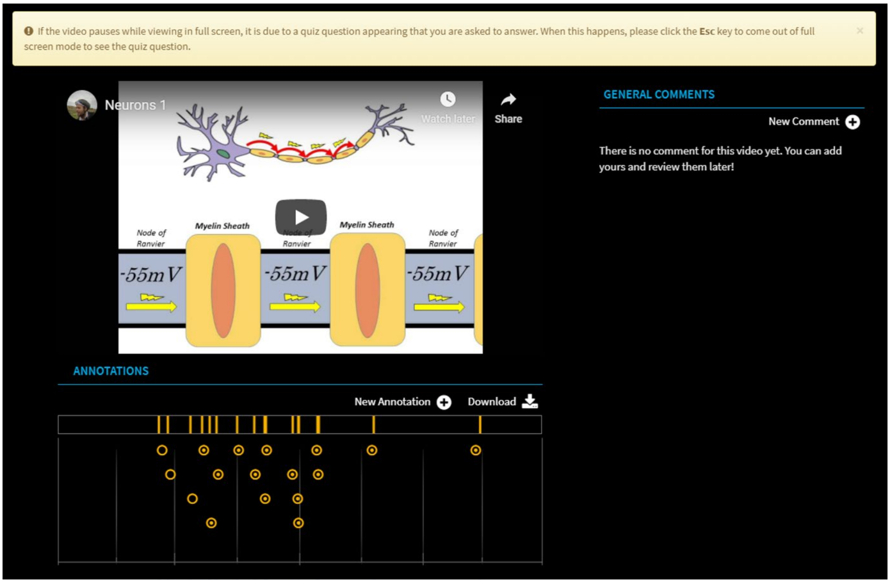

Fig. 1 The OVAL user interface as seen by participants in this study

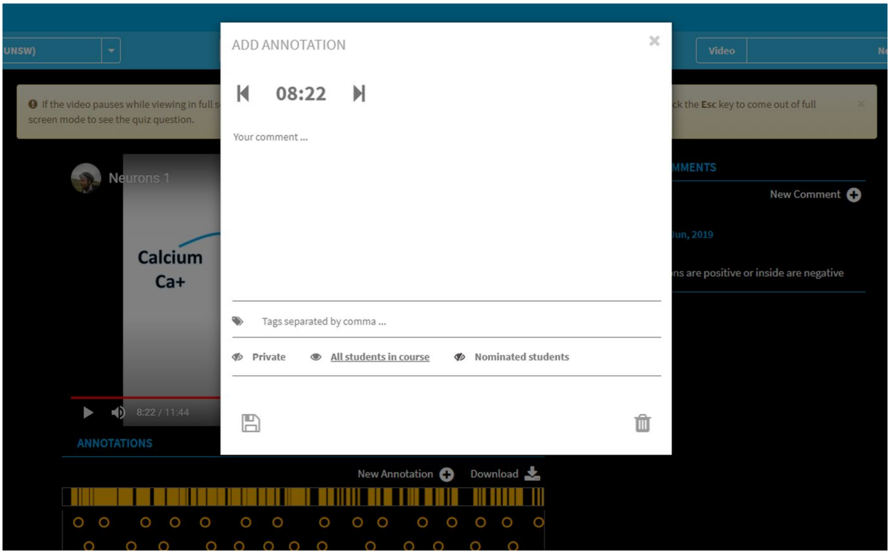

Fig. 2 Creating a time-stamped annotation in OVAL

To make an in-video quiz, questions can be in multiple-choice or open-text formats and can be set up to appear automatically at specific time points in the video. Upon submission of a response to each question, immediate feedback is provided.

Quizzes

A bank of content-related questions was used for in-video quizzes and for the pre-test and post-test. These questions included a mixture of recall and transfer questions as established and recommended on the basis of similar previous studies (e.g. Tangen et al., 2011). The questions captured both participants' capacity to remember the information and consider how it applies to other contexts. The pre and post knowledge tests both consisted of 16 similar but different questions testing students' recall and transfer of concepts in the video (e.g. neurons, actions potentials, and synapses). Specifically, there were 6 labelling questions where participants were asked to label a diagram of a neuron followed by 9 multiple choice questions related to a range of neuroscientific concepts (e.g. synaptic and action potential processes, de-polarisation, and hyperpolarisation). All questions and scoring were developed by a content-matter expert with extensive experience as both a researcher and teacher of foundational neuroscience. The bank of questions has been piloted, validated and used in multiple previous studies using the same video material (Srivastava et al., 2019, 2020). The participants completed all quiz questions and survey items using an online survey instrument, Qualtrics, and were automatically scored using the scoring metrics supplied by the subject matter expert.

Experimental design

As this study employed an experimental design, participants were randomly assigned to one of three conditions:

1. *Group 1: Passive condition (n = 30)* Participants completed a pre-test and then were asked to watch a 12-min video followed by a post-test and a survey. They were instructed not to rewind or scrub forward during the video. This group served as the control group for the study. The time on task for these participants when watching the video was the duration of the video (12 min).
2. *Group 2: Video + in-video quiz condition (n = 30)* Participants followed the same protocol as Condition 1 but were presented with six in-video quiz questions. There were three multiple choice questions and three open-ended questions interspersed over the duration of the video. The questions appeared as pop-ups which caused the video to pause. Participants submitted a response followed by immediate feedback. The video then resumed playback. For the multiple-choice questions, students received feedback indicating whether their response was correct or incorrect as well as a brief explanation associated with their mark (e.g. why their response was incorrect). For the open-ended answers, participants were presented with an ideal answer so they could compare their answer and self assess against the correct ideal answer. As the participants were asked to answer in-video questions, their cognitive processing would have been more than Group 1 (control group). Similarly, their time on task when watching the video was slightly longer (~ 5 min) as they had to spend time answering the questions.
3. *Group 3: Video + annotation condition (n = 33)* Participants followed the same protocol as Condition 1 but were asked to make a brief annotation at points in the video that they thought would be helpful for their learning. They were asked to make a minimum of three annotations. Similar to Group 2, the participants in this group would have had

increased cognitive processing due to being asked to make in-video annotations and spent more time on task (~ 10 min longer) than Group 1 (the control group).

Protocol

The study was conducted in a laboratory setting. After informing participants about the nature and purpose of the study, they were asked to complete a pre-survey which included a pre knowledge test. To assess participants' baseline self-efficacy, the survey also asked participants about their level of confidence (0 to 100) in answering questions about the topic. After completing the pre-survey, participants were led to the respective video activity depending on their randomly assigned condition group. Upon completion of the video activity, they were requested to complete a post-survey that included a post knowledge test and a request to rate their level of confidence (0 to 100) to determine changes in their self-efficacy. They were also asked to indicate (yes/no) whether they had previously studied or been exposed to neuroscientific principles to gauge whether they had prior knowledge of the topic.

Data analysis

To address RQ1	a total score was computed for the post knowledge test by aggregating individual item scores. The maximum total score was 15. Kruskal–Wallis tests were performed to examine differences among the three groups. We also examined the distribution of the post test scores visually.
To address RQ2	the participants' responses (Yes/No) to the question regarding their prior knowledge of the topic were used for analysis. Specifically, we investigated the association of in-video activities and learning performance (i.e. post-test score) separately for the participants with and without prior knowledge. Since the sample size did not allow for a trustworthy regression analysis (N values of less than 20 after splitting the groups based on prior knowledge), we relied on descriptive statistics and data visualization for insights into this question.
To address RQ3	Kruskal–Wallis test was done to examine the presence of a significant difference among the three condition groups based on their responses to the post-video question related to self-efficacy after watching the video. The question reads: 'On the following scale, please indicate how confident you are that you understand what is in the video (0 being not confident, 100 being very confident).' This was followed by Mann–Whitney tests, with False Discovery Rate correction, to uncover pair-wise differences.

Findings

RQ1: the impact of in-video learning activities on learning

A Kruskal–Wallis test showed no statistically significant difference amongst the three condition groups ($\chi^2(2) = 3.9294$, $p = .1402$, $\eta^2 = 0.0214$). We also considered

Table 1 Descriptive statistics for the post-video test score (0–15 range) across the three conditions

	N	Q1	Mdn	Q3
Control	30	5	6	9
In-video quizzes	30	5	7	9
Video annotation	33	5	9	12

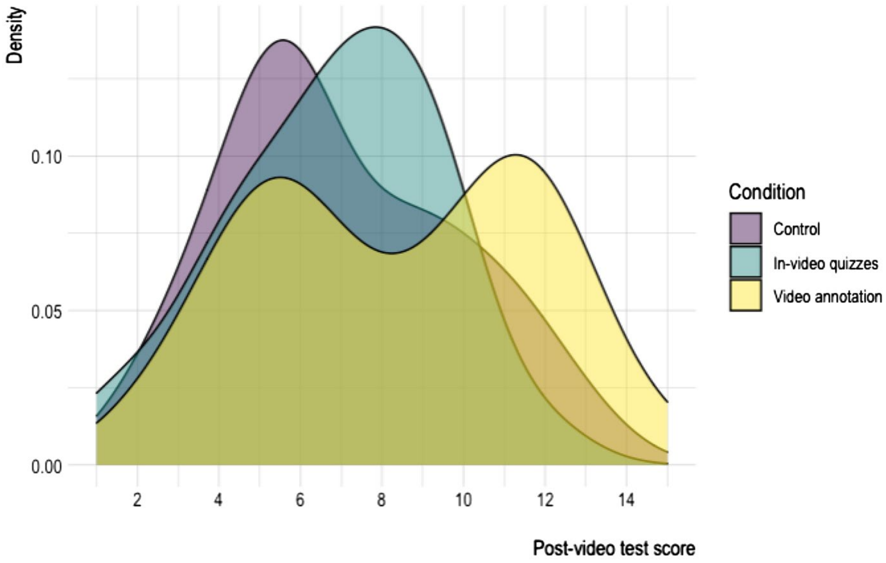

Fig. 3 Distribution of post-video test scores for the 3 experimental conditions

Table 2 Descriptive statistics for the post-video test score (0–15 range) across the three conditions and based on prior knowledge

	Prior know	N	Q1	Mdn	Q3
Control	No	15	5	5	7
	Yes	15	6	9	10.5
In-video quizzes	No	15	6	7	8
	Yes	15	5	7	9
Video annotation	No	19	5	6	10
	Yes	14	8.25	11	12

descriptive statistics (Table 1) and examined the distribution of the post test scores visually (Fig. 3). Both the table and the figure indicate an apparent difference between the video annotation condition and the other two groups. In particular, the video annotation condition had a larger proportion of higher scores on the post test.

Fig. 4 Distribution of post-video test scores for the 3 condition groups, when prior knowledge is considered

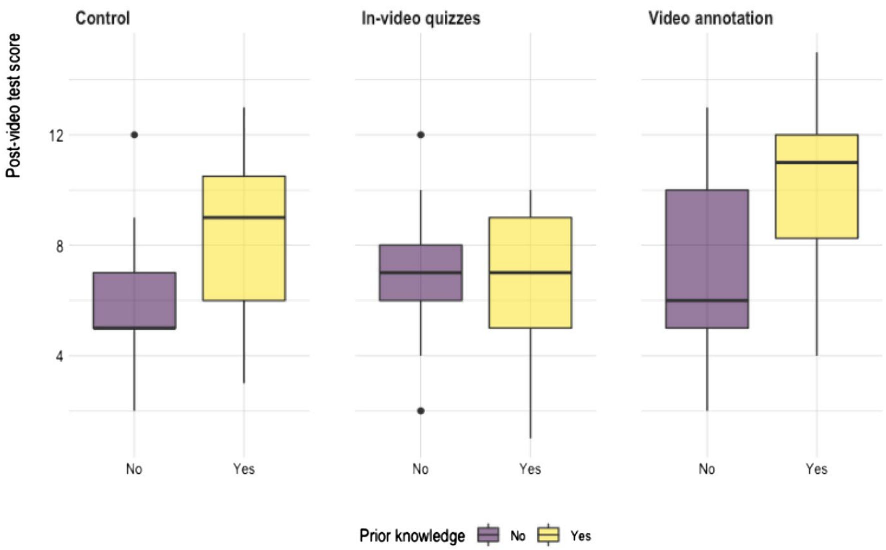

Fig. 5 Distribution of post-video test scores across the 3 experimental conditions, when considering the presence of prior knowledge

RQ2: the role of prior knowledge in the impact of in-video activities on learning

To further examine the impact of in-video activities on learning, we considered the participants' prior knowledge obtained through the pre-video survey. In particular, we investigated the association of in-video activities and the post knowledge test score separately for the participants with prior knowledge and those without prior knowledge.

Table 2 presents summary statistics for post-video test scores across the three condition groups, when prior knowledge is considered.

Figure 4 illustrates that regardless of the presence of prior knowledge, the distribution of the post-test scores for participants in the video annotation condition was more skewed towards higher scores compared to the other two conditions.

Figure 5 shows that the participants in the in-video quizzes condition performed equally well on the post-video test regardless of prior knowledge. Further, participants in this condition who did not have prior knowledge, on average, seem to have performed better on the post-video test than participants in the control condition and in the video annotation condition who also did not have prior knowledge of the topic. In addition, participants in the video annotation condition who had prior knowledge appear to have performed better on the post-video test than those in the other two conditions who also had prior knowledge of the topic.

RQ3: the impact of in-video learning activities on learners' self-efficacy

Kruskal–Wallis test was done to examine the presence of a significant difference among the three condition groups based on their responses to the post-video question related to self-efficacy after watching the video. The test indicated a statistically significant difference among the groups ($\chi^2(2)=7.875$, $p=.0195$, $\eta^2 = 0.0653$). Pairwise Mann–Whitney tests that followed showed that a significant difference was present only between the in-video quizzes condition and the video-annotation condition ($Z=-2.8245$, $p=.0043$, $r=0.3559$). In particular, the in-video quizzes condition had significantly lower self-efficacy score than the video annotation condition. Summary statistics for the self-efficacy score (0–100 range) across the three conditions is given in Table 3.

We have also examined correlations between the post-video test score and self-efficacy score in each group, using Spearman's rank correlation coefficient (the scores did not follow normal distribution). The results revealed a significant correlation of medium strength in the control group (rho $=0.544$, $p=.002$) and a significant medium-strength correlation in the in-video quizzes group (rho $=0.353$, $p=.055$), but no correlation in the video annotation group (rho $=0.022$, $p>.05$).

Discussion

With respect to the impact of in-video activities on student learning (RQ1), this study revealed that there was no significant difference amongst the three conditions which is partially supported by Thomas et al. (2016) who also discovered no significant impact of simultaneous video annotation on recall. Similarly, Peper and Mayer's (1978) study on note-taking while watching a video lecture also concluded that there was no significant impact on retention or near transfer. Hence, statistically, video annotations do not appear to have a significant impact on recall or near transfer although prior studies have determined statistical impact on

Table 3 Descriptive statistics for the post-video self-efficacy score (0–100 range) across the three conditions

	N	Q1	Mdn	Q3
Control	30	40.00	63	80
In-video quizzes	30	26.25	45	61
Video annotation	33	52.00	65	85

comprehension (Chiu et al., 2018). Exploratory analysis (descriptive statistics and visualisations), however, revealed that participants in the video annotation condition had a larger proportion of higher scores on the post-test than the other two conditions. The results related to in-video quiz questions and their lack of significant impact on learning however contradicts the findings from earlier studies that identified a significant positive relationship between in-video quiz questions and recall (Rice et al., 2019) and comprehension (Haagsman et al., 2020).

Further, regardless of prior knowledge (RQ2), participants in the annotation group still had a greater distribution of higher post-test scores than the other two conditions. While these initial findings suggest that video annotation activities play a role in improving student learning, further analysis revealed that amongst the participants who did not have prior knowledge of the topic across all three conditions, those who were in the in-video quizzes condition scored higher on the post-tests than those in the other two groups who also did not have prior knowledge of the topic (Fig. 5). These findings are in part supported by van Sebille et al. (2018) who identified a positive association between the completion of in-video quiz questions and academic performance (e.g. final course grade) in an introductory Health Sciences course and Haagsman et al. (2020) who concluded that in-video quiz questions had an indirect effect on students' test performance in a freshman Molecular Biology course. The higher scores for students with no prior knowledge in the in-video quizzes condition may be attributed to the immediate feedback and guidance that they received after submitting their answers.

Conversely, of the participants who had prior knowledge of the topic, participants in the video annotation condition seem to perform better on the post-test (findings based on descriptive statistics). These findings suggest that while in-video quizzes and immediate feedback can support learning particularly for those who do not have prior knowledge of the topic, video annotation activities may be useful for promoting learning amongst those who have some prior knowledge. Hence, when considering the integration of active learning activities in a course, the findings of this study suggest that instructors consider the prior knowledge of their students. For instances where students do not have much prior knowledge, such as introductory courses, then investing time in preparing in-video quiz questions and associated feedback could support students' attainment of the new concepts. However, in circumstances where students have some prior knowledge of the topic, such as more advanced courses, video annotation activities may provide greater opportunity for students to enhance their knowledge of a topic compared with in-video quizzes. Since there hasn't been any other study that has investigated the impact of video annotation activities compared with in-video quiz questions on student learning, these findings provide some initial insight into when such in-video activities can best support student learning outcomes.

Finally, the study also investigated the role of in-video quizzes and video annotation activities on self-efficacy revealing a significant difference between the two conditions (noting no significant difference between these two conditions and the control group). The participants in the in-video quizzes condition reported significantly lower self-efficacy than those in the video annotation condition on their post-test survey. This finding may be due to the participants feeling less confident in knowing the topic of the video after receiving feedback on their in-video quizzes. Participants in the video annotation condition did not receive any feedback on their understanding or on their annotations and hence, the lack of feedback may have contributed to higher self-efficacy scores and their potential overestimation of their understanding. Conversely, the participants in the in-video quiz condition may have used the feedback from their quiz responses to have a more realistic understanding of the video material. Regular and timely feedback that is not limited to just a mark or grade but provides guidance and support is essential for learners to appraise their learning and identify areas of improvement (Boud & Associates, 2010). This type of feedback was not available to the participants in the video annotation condition and hence may have contributed to the results. Since the provision of in-video quizzes allows learners to receive immediate feedback on the accuracy of their response with suggestions for improvement as needed, they can assist learners in monitoring their learning and modify their learning strategies as needed (Butler & Winne, 1995). This can be particularly useful for introductory classes where students generally do not have prior knowledge and require additional support in regulating their learning.

Limitations and future directions

The results from this study suggest that differential strategies are worth considering when designing video-based learning activities to help students with different levels of prior knowledge of a topic. However, since these findings are based on data visualisation and descriptive statistics due to a low sample size for reliable statistical analysis, future research with a larger sample size of participants with and without prior knowledge could investigate whether there is any significant impact of video activities on learning when controlling for prior knowledge. The low sample size also makes it difficult to conduct any meaningful analysis on any potential age differences and future studies with a larger sample size or with participants from particular age groups, could investigate whether participants' age contributes towards differences in learning outcomes or self-efficacy with in-video activities.

Further, as the study is designed in an experimental setting rather than a naturalistic setting, the number of videos and data collection points are limited and could be greater if the study was conducted over a course of a semester with multiple videos. Future studies could investigate the impact of video annotations compared to in-video quiz questions in introductory and advanced courses. Another limitation relates to the pre and post knowledge tests designed to be different yet similar and testing understanding of the overall video and hence examining the indirect effect of in-video activities rather than the direct effect. Future studies could investigate the direct effect of in-video activities by having the same questions in the pre and posts knowledge tests and having in-video quiz questions that are identical to the post test questions. The video annotation activity could also be more directed by specifically asking participants to annotate specific questions or focus their annotations on key words or more complex summaries allowing opportunity to examine the nuance between generative learning occurring from key word annotations compared to summaries. Further, in the study design, only participants in the in-video quiz group received immediate feedback on their understanding. Future studies that incorporate immediate feedback with video annotation activities as well as feedback after in-video quiz responses can further investigate the difference between these two in-video activities on learners' self-efficacy. Finally, the video utilised in this study was on neurons and hence specific to human biology. Future studies can utilise videos from other disciplines to determine whether the findings remain consistent or are discipline specific.

Conclusion

The study presented in this paper was an attempt to better understand the effect of activities aimed at assisting students to experience deeper learning through video instruction, which is fundamentally passive. In-video annotations and quiz questions provide viable options for prompting more active engagement with video content and potentially increase student self-efficacy (i.e. confidence) in approaching complex material presented in video format. This study revealed a significant difference in self-efficacy between those who completed the in-video quiz questions and those who wrote annotations. This difference could be attributed to the in-video quiz question group receiving immediate feedback on their answers potentially affecting their self-efficacy of the video material while the video annotation group did not receive any feedback. With respect to in-video activities affecting learning, this study reveals that there was no significant impact of video annotations or in-video quizzes on learning (as measured by a post knowledge test) across the groups. However, when considering the absence or lack of prior knowledge, the findings suggest that in-video quizzes are particularly beneficial for students with low levels of prior knowledge of a topic, whereas annotations are useful for students with some prior knowledge. In sum, this study reveals that when designing video-based learning activities it is worthwhile to consider students' prior knowledge and provide opportunity for students to receive timely formative feedback to support their accurate appraisal of their understanding to identify strategies to support and enhance their learning.

Declarations

Conflict of interest The authors are not aware of any conflict of interest that would have influence or bias the work presented in this manuscript.

Ethical approval The research was conducted after receiving ethical approval by the University of South Australia's Human Research Ethics Committee with all participants providing informed consent.

References

Bargeron, D., Gupta, A., Grudin, J., & Sanocki, E. (1999). Annotations for streaming video on the Web: System design and usage studies. *Computer Networks, 31*(11), 1139–1153. https://doi.org/10.1016/S1389-1286(99)00058-4

Boud, D., & Associates. (2010). *Assessment 2020: Seven propositions for assessment reform in higher education*. Australian Learning and Teaching Council. https://www.uts.edu.au/sites/default/files/Assessment-2020_propositions_final.pdf

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*(3), 245–281. https://doi.org/10.3102/00346543065003245

Chiu, P.-S., Chen, H.-C., Huang, Y.-M., Liu, C.-J., Liu, M.-C., & Shen, M.-H. (2018). A video annotation learning approach to improve the effects of video learning. *Innovations in Education and Teaching International, 55*(4), 459–469. https://doi.org/10.1080/14703297.2016.1213653

Colasante, M. (2011). Using video annotation to reflect on and evaluate physical education pre-service teaching practice. *Australasian Journal of Educational Technology, 27*(1), 66–88. https://doi.org/10.14742/ajet.983

Colasante, M., & Douglas, K. (2016). Prepare-participate-connect: Active learning with video annotation. *Australasian Journal of Educational Technology, 32*(4), 68–91. https://doi.org/10.14742/ajet.2123

Cummins, S., Beresford, A. R., & Rice, A. (2016). Investigating engagement with in-video quiz questions in a programming course. *IEEE Transactions on Learning Technologies, 9*(1), 57–66. https://doi.org/10.1109/TLT.2015.2444374

Dall'Alba, G., & Bengtsen, S. (2019). Re-imagining active learning: Delving into darkness. *Educational Philosophy and Theory, 51*(14), 1477–1489. https://doi.org/10.1080/00131857.2018.1561367

Dawson, S., Macfadyen, L., Evan, F. R., Foulsham, T., & Kingstone, A. (2012). Using technology to encourage self-directed learning: The Collaborative Lecture Annotation System (CLAS). *Ascilite Conference, 2012*. https://www.ascilite.org/conferences/Wellington12/2012/images/custom/dawson,_shane_-_using_technology.pdf

Fiorella, L., & Mayer, R. E. (2015). *Learning strategies that foster generative learning*. Eight Learning Strategies that Promote Understanding. Cambridge University Press. https://doi.org/10.1017/CBO9781107707085

Giannakos, M. N. (2013). Exploring the video-based learning research: A review of the literature. *British Journal of Educational Technology, 44*(6), E191–E195. https://doi.org/10.1111/bjet.12070

Giannakos, M. N., Krogstie, J., & Aalberg, T. (2016). Video-based learning ecosystem to support active learning: Application to an introductory computer science course. *Smart Learning Environments*. https://doi.org/10.1186/s40561-016-0036-0

Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: An empirical study of MOOC videos. *Proceedings of the First ACM Conference on Learning @ Scale Conference*, 41–50. https://doi.org/10.1145/2556325.2566239

Haagsman, M. E., Scager, K., Boonstra, J., & Koster, M. C. (2020). Pop-up questions Within educational videos: Effects on students' learning. *Journal of Science Education and Technology, 29*(6), 713–724. https://doi.org/10.1007/s10956-020-09847-3

Hodges, C. (2016). The development of learner self-efficacy in MOOCs. *Global Learn 2016*, 517–522. https://www.learntechlib.org/primary/p/172763/

Hulsman, R. L., Harmsen, A. B., & Fabriek, M. (2009). Reflective teaching of medical communication skills with DiViDU: Assessing the level of student reflection on recorded consultations with simulated patients. *Patient Education and Counseling, 74*(2), 142–149. https://doi.org/10.1016/j.pec.2008.10.009

Hulsman, R. L., & van der Vloodt, J. (2015). Self-evaluation and peer-feedback of medical students' communication skills using a web-based video annotation system: Exploring content and specificity. *Patient Education and Counseling, 98*(3), 356–363. https://doi.org/10.1016/j.pec.2014.11.007

Kleftodimos, A., & Evangelidis, G. (2018). Augmenting educational videos with interactive exercises and knowledge testing games. *IEEE Global Engineering Education Conference (EDUCON), 2018*, 872–877. https://doi.org/10.1109/EDUCON.2018.8363322

Lodge, J. M., Kennedy, G., & Hattie, J. (2018a). Understanding, assessing and enhancing student evaluative judgement in digital environments. In D. Boud, R. Ajjawi, P. Dawson, & J. Tai (Eds.), *Developing Evaluative Judgement in Higher Education* (pp. 70–78). Routledge.

Lodge, J. M., Kennedy, G., Lockyer, L., Arguel, A., & Pachman, M. (2018b). Understanding difficulties and resulting confusion in learning: An integrative review. *Frontiers in Education, 3*, 49. https://doi.org/10.3389/feduc.2018.00049

Mayer, R. E., Fiorella, L., & Stull, A. (2020). Five ways to increase the effectiveness of instructional video. *Educational Technology Research and Development, 68*(3), 837–852. https://doi.org/10.1007/s11423-020-09749-6

Mu, X. (2010). Towards effective video annotation: An approach to automatically link notes with video content. *Computers & Education, 55*(4), 1752–1763. https://doi.org/10.1016/j.compedu.2010.07.021

Muller, D. A., Bewes, J., Sharma, M. D., & Reimann, P. (2007). Saying the wrong thing: Improving learning with multimedia by including misconceptions: Misconception-based multimedia instruction. *Journal of Computer Assisted Learning, 24*(2), 144–155. https://doi.org/10.1111/j.1365-2729.2007.00248.x

Panadero, E., Jonsson, A., & Botella, J. (2017). Effects of self-assessment on self-regulated learning and self-efficacy: Four meta-analyses. *Educational Research Review, 22*, 74–98. https://doi.org/10.1016/j.edurev.2017.08.004

Pardo, A., Mirriahi, N., Dawson, S., Zhao, Y., Zhao, A., & Gašević, D. (2015). Identifying learning strategies associated with active use of video annotation software. In *Proceedings of the Fifth International Conference on Learning Analytics and Knowledge*, pp. 255–259. https://doi.org/10.1145/2723576.2723611

Pastötter, B., Schicker, S., Niedernhuber, J., & Bäuml, K.-H.T. (2011). Retrieval during learning facilitates subsequent memory encoding. *Journal of Experimental Psychology, 37*(2), 287–297. https://doi.org/10.1037/a0021801

Peper, R. J., & Mayer, R. E. (1978). Note taking as a generative activity. *Journal of Educational Psychology, 70*(4), 514–522. https://doi.org/10.1037/0022-0663.70.4.514

Poquet, O., Lim, L., Mirriahi, N., & Dawson, S. (2018). Video and learning: A systematic review (2007–2017). In *LAK '18 Proceedings of the 8th International Conference on Learning Analytics and Knowledge*, pp. 151–160. https://doi.org/10.1145/3170358.3170376

Rice, P., Beeson, P., & Blackmore-Wright, J. (2019). Evaluating the impact of a quiz question within an educational video. *TechTrends, 63*(5), 522–532. https://doi.org/10.1007/s11528-019-00374-6

Roediger, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Rolf, R., Reuter, H., Abel, M., & Hamborg, K.-C. (2014). Requirements of students for video-annotations in lecture recordings. *Interactive Technology and Smart Education, 11*(3), 223–234. https://doi.org/10.1108/ITSE-07-2014-0021

Schunk, D. H. (1990). Goal setting and self-efficacy during self-regulated learning. *Educational Psychologist, 25*(1), 71–86. https://doi.org/10.1207/s15326985ep2501_6

Shin, H., Ko, E.-Y., Williams, J. J., & Kim, J. (2018). Understanding the effect of in-video prompting on learners and instructors. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems—CHI '18*, pp. 1–12. https://doi.org/10.1145/3173574.3173893

Simpson, M., & Bolduc-Simpson, S. (2018). Interactivity: Engaging video activities in online courses. *Journal of Education and Social Development*, *2*(2), 10–14. https://doi.org/10.5281/ZENODO.1403941

Srivastava, N., Nawaz, S., Lodge, J. M., Velloso, E., Erfani, S., & Bailey, J. (2020). Exploring the usage of thermal imaging for understanding video lecture designs and students' experiences. *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge*. https://doi.org/10.1145/3375462.3375514

Srivastava, N., Velloso, E., Lodge, J. M., Erfani, S., & Bailey, J. (2019). Continuous evaluation of video lectures from real-time difficulty self-report. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1–12. https://doi.org/10.1145/3290605.3300816

Szpunar, K. K., Khan, N. Y., & Schacter, D. L. (2013). Interpolated memory tests reduce mind wandering and improve learning of online lectures. *Proceedings of the National Academy of Sciences, 110*(16), 6313–6317. https://doi.org/10.1073/pnas.1221764110

Thomas, A. O., Antonenko, P. D., & Davis, R. (2016). Understanding metacomprehension accuracy within video annotation systems. *Computers in Human Behavior, 58*, 269–277. https://doi.org/10.1016/j.chb.2016.01.014

van Meter, P., Yokoi, L., & Pressley, M. (1994). College students' theory of note-taking derived from their perceptions of note-taking. *Journal of Educational Psychology, 86*(3), 323–338. https://doi.org/10.1037/0022-0663.86.3.323

van Sebille, Y., Joksimović, S., Kovanović, V., Mirriahi, N., Stansborough, R., & Dawson, S. (2018). Extending video interactions to support self-regulated learning in an online course.pdf. In M. Campbell, J. Willems, C. Adachi, D. Blake, I. Doherty, S. Krishnan, S. Macfarlane, L. Ngo, M. O'Donnell, S. Palmer, L. Riddell, I. Story, H. Suri & J. Tai (Eds.), *Open oceans: Learning without borders. Proceedings ASCILITE 2018 Geelong*, pp. 262–272. http://ascilite.org/wp-content/uploads/2018/12/ASCILITE-2018-Proceedings.pdf

Vural, O. F. (2013). The impact of a question-embedded video-based learning tool on e-learning. *Educational Sciences: Theory and Practice*, *13*(2), 1315–1323. https://files.eric.ed.gov/fulltext/EJ1017292.pdf.

Weller, M. (2020). *25 years of Ed Tech*. Athabasca University Press. https://www.aupress.ca/books/120290-25-years-of-ed-tech/

Xiu, Y., Moore, M. E., Thompson, P., & French, D. P. (2019). Student perceptions of lecture-capture video to facilitate learning in a flipped classroom. *TechTrends, 63*(4), 369–375. https://doi.org/10.1007/s11528-018-0293-6

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