Video and Learning: A Systematic Review (2007-2017)

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ABSTRACT

Video materials have become an integral part of university learning and teaching practice. While empirical research concerning the use of videos for educational purposes has increased, the literature lacks an overview of the specific effects of videos on diverse learning outcomes. To address such a gap, this paper presents preliminary results of a large-scale systematic review of peer-reviewed empirical studies published from 2007-2017. The study synthesizes the trends observed through the analysis of 178 papers selected from the screening of 2531 abstracts. The findings summarize the effects of manipulating video presentation, content and tasks on learning outcomes, such as recall, transfer, academic achievement, among others. The study points out the gap between large-scale analysis of fine-grained data on video interaction and experimental findings reliant on established psychological instruments. Narrowing this gap is suggested as the future direction for the research on video-based learning.

CCS CONCEPTS

• **Human-centered computing** ~ Human-computer interaction ~ Empirical studies in HCI

KEYWORDS

Systematic review, video-based learning

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1 INTRODUCTION

Wide-spread use of digital learning environments has facilitated the integration of a diverse range of video materials into course and program curriculum. Although earlier forms of video, such as film and television, have been commonly used to enhance and support learning for decades [24], in recent years the higher education sector has witnessed a surge in student access to videos. Such expansion has been powered by the relative ease of video production (e.g. voice over PowerPoint) with accessible ready-to-use tools, institutionally-available recording studios, and streaming media platforms, such as YouTube [18]. Further, video is becoming the main method of content delivery in online education [10], a sector that is steadily experiencing growth [1].

The interest in the use of video as a mainstream educational resource is further evidenced by the large volume of research on the topic. Giannakos [9] suggested that the research on video-based learning post 2006 is markedly different to prior work in this area. The difference predominantly stems from the changes in and advancement of video-based technologies. With the rise in the use of video, there has been a parallel increase in research since 2006. Additionally, there has been a higher focus on quantitative empirical studies and on more developed types of technology for video use. In light of the burgeoning research around the use of video, a systematic review of the literature is timely. A review of the current literature on the use of video in learning can address concerns associated with the mixed evidence about the effect of video use on student learning, attendance and overall academic performance [20]. A review of the literature also provides a timely opportunity to identify practices that have a positive impact on student learning outcomes [10]. For instance, a review can assist with a much-needed synthesis of current empirical results to inform video design and video-based learning and identify existing research gaps [21].

This study provides an overview of the effects of video on learning and the measures used to capture them. We present a preliminary synthesis of empirical findings gleaned through a systematic review of peer-reviewed research published in 2007-2017.

The search was limited to Scopus and WoS databases, complemented by a manual query of selected conference proceedings and Google Scholar. The conclusions are drawn from the in-depth analysis of 196 unique studies reported through 178 peer-reviewed papers. The paper summarises the effects of video and related pedagogical conditions on learning as measured through student online traces, measures of learning gain, performance and learning-related psychological constructs, such as cognitive load.

2 RELATED WORK

As research in the field of video-based learning has grown over the past decade, several reviews have been published. Early attempts to synthesize the evidence around student use of video and learning date back to 2006. Specifically, Mayer summarized evidence around multimedia for learning by listing 12 design principles grounded in educational psychology, educational design, and the learning sciences [17]. Mayer's work has formed a theoretical foundation for much of the current research around the use of video. More recently, several related reviews have been published. Kay [12], for instance, reviewed the use of video podcasts in education. The author discussed how video podcasts can benefit student attitudes, control over learning and improve study habits, as well as learning performance. However, the studies offered mixed findings around the relationship between the use of video and student learning outcomes. In their review of the student, teacher and institutional perspectives of lecture recordings (i.e. 'lecture capture'), O'Callaghan and colleagues noted the mixed evidence around attendance and academic performance – two of the most researched learning outcomes [20]. A positive association between the use of video and performance was observed when students used lectures as a supplement rather than a substitute to attendance. Mixed evidence around effectiveness of the use of video has been also observed in a review of video-based learning 2003-2014 [24], as well as a review of lecture capture in 2012-2015 [23]. A focused scoping review of research from 2005-2015 has been conducted on videos for teacher professional development [16]. The authors reported videos as having a significant effect on teacher's cognition and classroom practice, and recommended that video be adopted among key means to improve teachers' professional development.

Current reviews of video research have not been systematic and have been undertaken without an exclusive focus on the impact on student learning, motivation or engagement. An exception to this case is the work of Major and Watson [16], however, in this instance with a narrow focus on the role of videos for pre-service teachers, limiting the breadth of application of the findings. Our literature review complements this related work by focusing on (1) all types of educational videos; (2) all disciplines in formal higher education, including video-based learning for professionals; and (3) studies that do not solely present self-reported data (e.g. students' perspectives or attitudes towards video-based learning).

3 METHODS

A systematic review of the extant literature was conducted to address the following research question: **What is the effect of educational videos on student activity and learning as documented through peer-reviewed empirical research in psychology, education and learning analytics from 2007 to 2017?** We were also interested in how learning was defined and captured through these analyses, and the extent to which learning analytics were adopted in the studies.

Scopus and WoS (titles, abstracts and keywords of the studies) were queried with: (video OR film OR animation) AND (lecture OR analytics OR multimedia OR "Multimedia learning" OR "Multimedia instruction" OR "Video-based learning" OR "Multimedia learning" OR "instructional strategy" OR "learning from observing" OR "vicarious learning" OR "blended learning") AND (learning OR "Cognitive load" OR "Learning effectiveness" OR "Learning outcom*" OR "Learning performance" OR "Learning gain") AND (treatment OR condition OR " effect*" OR "assigned".

Due to the breadth of the initial dataset, the scope of inquiry was limited to higher education, professional learning and MOOCs and studies written in English. Overall, the exclusion criteria were made in relation to context, types of video, specificity of the described intervention and the nature of data reported. First, studies describing learning in online and blended settings in higher education, workplace learning and adult learning were included. Face-to-face, K-12 and language learning settings were excluded due to their contextual differences from university-level or professional work-placed learning settings.

Secondly, instructional videos, video lectures, tutorials and animations were included. The inclusion of animations was due to their widespread use in STEM-related courses. We excluded videos explicitly described as lecture capture, i.e. a recorded lecture of face-to-face provisions, as well as 'video podcasts', and 'video livestreaming'. These video formats were not considered due to the presence of existing literature reviews focused on these types of videos. Studies where videos were created to offer feedback to students, as well as the instances where video production was a part of the assessment were excluded.

Third, we did not include research that evaluated videos as a part of wider pedagogical interventions. These were identified in studies on flipped classroom, mobile learning, video games or interactive multimedia modules. Although videos were a part of these interventions, a range of features within the intervention could have affected learning, and the experiments were not limited to a well-defined intervention.

Fourth, literature reviews, scoping studies and conceptual papers were excluded. The dataset contained primary evidence capturing the effect of videos on student learning conducted through experiments or case studies. Finally, given our interest in learning analytics and due to the breadth of the literature, studies solely reporting learner perceptions as learning outcomes of video use were also excluded.

An overview of the selection process is reflected in Table 1. An initial query from Scopus and WoS resulted in 2531 papers as potentially relevant. Three researchers collectively read a total of 150 abstracts with four rounds of discussions to refine the inclusion and exclusion criteria. After each round inter-rater reliability was established, and the criteria were adjusted. With final inter-rater reliability kappa of 0.71 [7], the researchers independently screened the abstracts. Following the resolution of uncertain items, an in-depth analysis was undertaken for the remaining papers resulting in a final data set of 170 papers. These were complemented by a further 8 papers obtained through manual search of the Proceedings of Educational Data Mining Conference, European MOOC Stakeholder conference (both not indexed through Scopus) and Google Scholar search. The manual search aimed to capture the most cited MOOC studies published through reports and research venues not indexed within the Scopus and WoS databases.

Table 1: Papers included in the search and analysis

Retrieved	Included	Added	Analysed
2531	170	8	178

4 ANALYSIS

4.1 Dataset Description

Descriptive analysis of the dataset demonstrated a growing interest in empirical research on videos used for educational purposes (Figure 1). The dataset largely consisted of peer-reviewed journal papers from venues such as *Computers & Education*, *Computers in Human Behaviour*, *Learning and Instruction* with a lower ratio of peer-reviewed conference papers (e.g. *CHI, LAK, Learning@Scale*). The number of peer-reviewed journal publications grew considerably in 2016, possibly suggesting a wider adoption of video within learning management systems at the tertiary level.

4.1.1 Types of video materials. During the analysis, "video" category embraced video materials that could be categorized as short video lectures or short films. Animations and worked examples (e.g. tutorials, code-along videos, etc.) were coded as separate categories as they were frequently used. Videos such as situational case studies, student-generated instructions and film-like vignettes were categorized as 'other'. CD/DVD was also recorded as a separate category used in earlier research.

4.1.2 Population. Studies were predominantly conducted with students; the majority of students were studying STEM disciplines, followed by Psychology majors, and Humanities and Social Sciences. Diverse populations of learners were observed in the included 17 studies investigating the use of video in MOOCs.

4.1.3 Control for Prior Knowledge. The majority of studies controlled for prior knowledge (n=116), whereas a large part did not (n=57), and sometimes this information was not evident (n=23). The majority of studies conducted in the lab controlled for prior knowledge whereas research on natural class activities only controlled for prior knowledge in about half of the cases.

4.1.4 Sample Size. For studies conducted in settings other than MOOCs (n=179), the minimum number of participants was ten, and a maximum number of participants was 2029 (*M=127, SD=225*). For the studies conducted in MOOC settings (n=17), the minimum sample size was 194, while the maximum was 127839 learners (*M=40699, SD=42265*).

4.1.5 Methods. Most studies reported findings from random controlled trials (RCT, n=119), followed by case studies (n=32), and quasi-RCT (n=22). There were few instances of repeated measures, longitudinal studies and other types of methods employed.

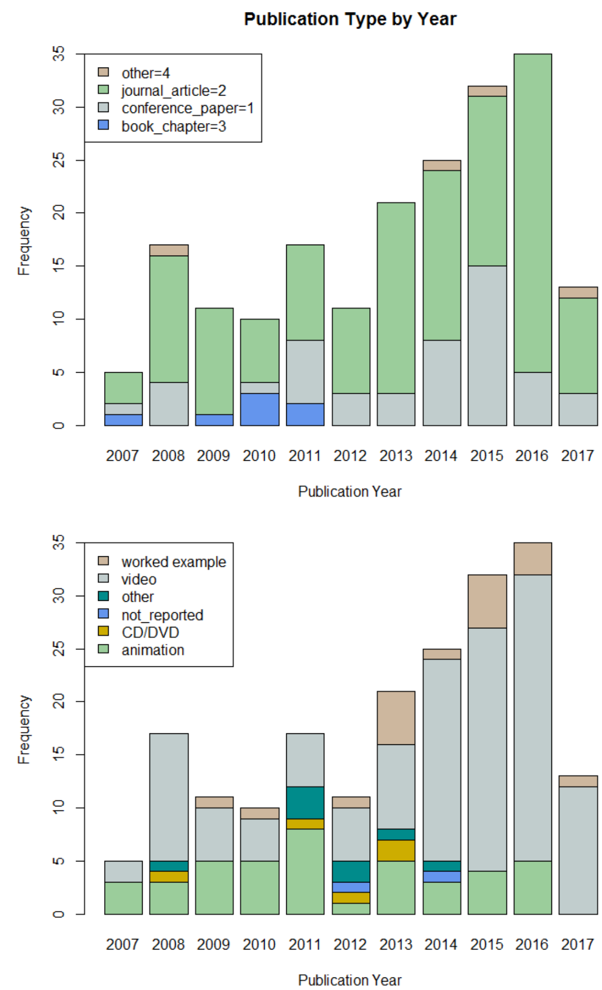

Figure 1: Dataset Description.

4.1.6 Independent Variables used in the Research on Educational Videos. Features related to the presentation of the video were among the most commonly used independent variables. The most common focus of the studies was on video modality (i.e. text, audio, animation, voice over PowerPoint). These studies manipulated how the information in the video was presented. Another common intervention addressed personalization of the text (e.g. by making the narrative address the learner, for instance through personal pronouns, rather than abstractly reporting information, or by manipulating the presentation of instructor presence). The third most common video intervention was signaling, i.e. using visuals to highlight relevant information that required learner attention. Presentation was also manipulated through the change of the language of instruction, subtitles, speed, redundancy and segmentation but these were less common than modality, personalization and signaling.

Table 2: Independent and dependent variables commonly used across the dataset

Independent variables (number of studies)	Dependent variables (number of studies)
Presentation (94)	Recall test (107)
Video Use (30)	Other (76)
Content (23)	Self-reports (63)
Task (20)	Transfer test (46)
Learner characteristics (13)	Grades (30)
Learner control (10)	Cognitive load (19)
Quizzes (8)	Engagement (17)
Distraction (4)	Knowledge gain (14)

A commonly used independent variable was the use of online video resources as opposed to face-to-face lectures, or no use of video resources. For studies that focused on video content, changing the genre of the video was most common (see section 4.2 for details). For the manipulation of tasks, experiments using annotation software were most prevalent, followed by a range of diverse tasks used alongside the video, such as free or prompted recall, watching video alone or together, identifying correct items or errors in the presentation, etc. Timing of quizzes referred to manipulations around immediate or delayed quizzes, as well as in-video quizzes. Table 2 presents common independent and dependent variables used in the studies of educational videos, presented as ranked through the number of studies that reported on them.

4.1.7 Dependent Variables (Measured Learning-Related Outcomes). The scores of post-tests or recall tests were most frequently used data sources across a variety of studies as a dependent variable to capture the learning outcome after viewing the video. The scores of recall tests were often coupled with self-reported student perceptions used to elicit student satisfaction, perceived learning or similar. Transfer tests were also frequently used as a dependent measure of learning, with testing the demonstration of a skill being less common. Motivation, cognitive load, mental effort, attention, and affect were all used as dependent variables, and were captured by either well-established psychological instruments or by using gaze tracking or analysis of clickstream data. The use of metrics of cognitive load or gaze tracing derived from physiological data became more common in the later studies. The category 'other' encompassed diverse metrics used as dependent variables. Metrics in this category were largely (1) related to time (i.e. time on task, or combination of time and accuracy); and (2) analyzing student text in annotations/self-explanations/summaries, usually derived through qualitative interpretation. This category also included infrequent instances of drop-out, judgement of difficulty/comprehension, among others. In further analysis, we broadly interpret the category of 'other' as the quantity of studying and quality of artefacts resulting from the task. In sum, the data sources used in the studies varied from grades, test results, log data and time on task, to scores for various psychological constructs or student perceptions captured through the self-reports.

4.2 Overview of Empirical Findings

Overview of findings is presented through significant effects/associations of the most common interventions and metrics. Table 3 summarizes these findings through the counts of instances of effect recorded within the studies. For instance, the same study could include a manipulation of modality in video (i.e. if content is presented via audio, video, text, image, or combination of these), a manipulation of the technical aspect of the video (i.e. the size of the screen), and a manipulation of the task (i.e. the presence or absence of the task); combined with standard control for learning recall and transfer, that would result in 6 individual instances examined by the researchers. Table 3 presents significant and no effect cases, as well as cases where the outcome differed, with significance for only one of the treatment groups.

4.2.1 Effect of Manipulating Video Presentation, i.e. Modality, Personalisation, Signalling, Subtitling, and Similar, on Learning-Related Outcomes. The analysis of identified articles suggests that video presentation can impact both positively and negatively on student recall, and to some extent perception of the course of study and instructor (satisfaction, perceived learning, perception of instructor, or enjoyment). Studies demonstrate that modality impacts how much content students remember, in alignment with multimedia principles [17]. Although students seem to have a stronger recall of the content from videos, viewing can also impact on their perceptions, and may result in poor judgment of their perceived learning.

Table 3: Most common interventions that yielded statistically significant effect (S), no effect/non-significant effect (N) or mixed (M) effects on selected learning outcomes. Counts represent separate instances of interventions.

	Presentation			Video Use			Content			Task		
	S	*N*	*M*	*S*	*N*	*M*	*S*	*N*	*M*	*S*	*N*	*M*
Recall	49	44	15	3	4	0	5	7	1	6	6	1
Other	37	33	8	5	3	3	8	4	0	26	18	4
Self-reports	28	20	4	5	5	2	9	0	2	0	2	0
Transfer	10	18	4	0	2	0	9	6	1	3	2	0
Grades	2	4	0	11	6	2	2	1	0	3	0	0
Cog. Load	8	11	4	1	1	0	3	0	0	0	3	0

Manipulating instructor presence within the video suggests that the personalization principle has limited effect on learning.

Signaling or cueing was more frequently noted to have a positive effect on recall. When several presentation principles (i.e. modality, segmenting, cueing) are manipulated within the video, learning is likely to be affected [S87]. A closer look at studies examining the impact of captions as a part of the video presentation exemplifies why there is a diversity of evidence, i.e. a high number of significant and no-effect studies. The use of subtitles has been reported as having no effect on learning, but this pattern changes with a significant effect on recall when the condition's interaction effect with learner language proficiency is taken into account [S175]. No-effect or even negative effect of subtitles on recall for native speakers is similarly shown in other studies [S135, S121] - in line with the redundancy principle. The impact of manipulating the video presentation on cognitive load is among the underlying theoretical principles in research on multimedia learning. This effect was observed through a number of studies in the reviewed dataset [eg. S91, S5, S167]. The dataset also offers evidence that manipulating the video presentation has significant effect on learner attention, and student satisfaction [S166, S167].

The mixed picture of both significant and no-effect findings of presentation interventions could in part be explained through the inter-relationship between learners' prior knowledge, the nature of the learning outcomes, and the type of presentation intervention. For instance, 3D animations were reported to have a positive effect on remembering a demonstration of an operational process. This is particularly relevant for Health Professionals [S30]. However, when used for biology learners understanding of cells, 3D animations were found less effective than text-based schematic visualizations [S141], with learners getting overwhelmed with the realistic details. In that sense, it is not the animation per se that impacts learning. Rather, an interaction between prior knowledge, ease of the content presentation and details of what should be learnt can lead to differences in memorizing the content across various learner populations.

4.2.2 Effect of Manipulating Tasks on Learning-Related Outcomes. Task interventions reported in the studies included video annotation conditions, presence of self-reflection prompts or open-ended questions, identification of errors (vs. correctly stated facts), and graded vs. non-graded instructional conditions. Task conditions appeared to have significant effect on the outcomes measuring quantity of studying and quality of artefacts produced. Namely, examples of learning outcomes affected by the conditions included: counts of self-reflection annotations [S50], linguistic processes evident in annotations [S50], time on task [S39], frequency of viewing supplementary sources [S39], quality of paraphrase sentences in self-explanations [S103], meta-comprehension accuracy [S40], linguistic features of annotations derived from natural language processing [S49], number of scientific concepts [S47], length of notes [S112], among others. In short, the presence of the task seems to help learners apply mental effort and attention. A large-scale study from a MOOC setting on 27720 learners lends support to such a premise by demonstrating that solely doing activities impacts learning more so than solely viewing videos [S89]. Similarly, the effect of engaging in an activity post-viewing the video is observed through the experimental manipulations of embedded and delayed quizzes that appear to have varying effect on recall and transfer.

4.2.3 Effect of Manipulating the Way Content is Structured and Communicated in the Video. Manipulation of the video content appears to have significant effect on how well students transfer learnt information, as well as to some extent on information recall. Interventions were implemented by presenting videos in dialogue vs. exposition styles [S114, S115]; in linear presentation of content blocks rooted in instructivist theory vs. thematic video-based materials based in situated learning [S13, S26]; by using representational animations vs. directive animations [S122], by presenting learners with narratives that addressed alternative conceptions vs. those that did not [S115], by using mnemonic metaphors to help remember the process vs. descriptive language [S69], by manipulating video complexity [S175, S87] and similar. Manipulating video content showed that students appear to learn better by observing dialogue than by observing exposition [S114], videos designed to produce cognitive conflict [S1] impact transfer; and learners exposed to non-linear thematic content outperform on the use of integrating statements (evidence of higher order thinking) in their reflections throughout the progression of the term. The interventions in these studies tap into germane load – an element of cognitive load assisting with comprehension, and commonly measured through a validated survey instrument [14].

4.2.4 Effect of Using Video on Learning-Related Outcomes. Significant effect of the 'video use' condition on academic achievement reflects the dominant research design in studies examining such conditions. Research examining 'video use' was often case-study based or undertaken by comparing historical cohorts: the impact of introducing video was compared to the outcomes of prior cohorts. These studies report an association between video viewing behavior and higher achievement; such a finding has been similarly reported in MOOC contexts.

4.2.5 Analysis of the Use of Videos at Scale. The dataset widely used psychological instruments, unique metrics of learning and external data sources to capture the effects of videos. Studies conducted in MOOC settings differed as they focused on describing clickstream and video interaction patterns. Few MOOC studies reported experimental findings [e.g. 87]; otherwise MOOC studies were descriptive or correlational. Yet, the evidence offered about how students interact with video materials makes a substantial contribution due to the scale and granularity of student behavior when learning with video.

The availability of student access to videos or fine-grained second-by-second user clicks provides unique insights into video use beyond conventional learner self-reports. Video access data is commonly used in the analysis of clickstream data [S146] combined with time spent watching. Leaner video behavior has been found predictive of overall dropout in the course [S89]. Kim et al. [S85] found that over a third of video dropouts happened within the first 3% of video length. By classifying overall video behavior, it was demonstrated that drop-outs belong to two different learner categories: first-time watchers or those who are re-watching for specific details. A more granular analysis of millions of interaction patterns demonstrated that in-video quizzes increase learner interaction with the video content [S90]. Another considerable contribution by Guo and colleagues [S57] stems from 6.9 million video watching sessions. The study concluded that the median watching time was a maximum of 5 minutes, and that learners often dropped out less than halfway through videos that were longer than 9 minutes.

Researchers have also explored deeper and more fine-grained video analytics by examining very specific in-video learner interactions. For example, Li et al [S99, S100] examined learners' interactions with the four different video controls in Coursera: play/pause, seek forward, seek backward and adjust video speed. Based on these interactive controls, 7 video interaction profiles were classified as either non-interactive (Silent, Implicit-speeding, Explicit-Speeding) or interactive (Pausing, Skipping, Replaying, Mixed-Interacting). Using mixed linear model analyses on each profile to assess its relationship with perceived video difficulty, they discovered that the 'Explicit speeding' profile was related to lowest perceived difficulty; in contrast, the Pausing, Replaying, and Mixed-interacting profiles were related to higher perceived difficulty. In an extension of that study, the authors looked at the sequence of in-video interactions and clustered them, to create 9 video interaction patterns. Using mixed-model ANOVA, the researchers showed that the perceived video difficulty varied depending on the video interaction pattern. For example, patterns of replaying and frequent pausing were associated with a higher perceived difficulty, while the pattern of speeding up the video was associated with a lower perceived level of difficulty.

However, a strong linkage between psychological theories and granular clickstream analysis is largely unexplored. Among the few examples is the study by Sinha et al [S149]. The authors analyzed video clickstream sequences at three levels, converting raw data to behavioral actions, and then translating these into a learners' information processing index based on the "Limited Capacity Information Processing Approach" [13]. Using summarized behavioral action vectors, they could predict in-video drop-out and complete course dropout.

4 DISCUSSION

4.1 Summary

The study presented a preliminary high-level overview of effects of educational videos on learning. The identified results stem from experimental and case studies in higher education and professional learning. The findings suggest that presentation interventions that affect video modality, segmenting, personalization, signaling, and complexity of text, affect recall and student perceptions. Interventions manipulating content organization and genre impact learning outcomes related to comprehension. Interventions around the task associated with the video impact time spent studying and the quality of artefacts students produce in that process.

In addition, as MOOCs platforms provided a rich source of user-trace data, research around the use of video in MOOC contexts has been developing a range of metrics related to student behavior. However, few researchers have grounded their explorations in educational or psychological theory, and extrapolation of these metrics to psychological instruments or theory is rare. Bridging the gap between granular analysis of video clickstream data, and the use of established psychological measures, is a promising area to strengthen the insights around the impact of video on learning.

4.2 Limitations

The insights gleaned from the analysis are restricted in a number of ways. We have searched two databases only, limiting the inclusion of educational research papers that may have been indexed through ERIC. Our research query has been geared towards capturing measured effects on video, rather than capturing learner interactions with video. As a consequence, our review of metrics used for clickstream data analysis are strictly related to either MOOC contexts due to the scale of analysis and the particular query we used. We acknowledge that the metrics in use for video interaction are a lot more diverse than briefly reviewed above, or represented through the dataset. Yet, we were aware that such metrics may not necessarily reflect the relationship with learning that we were interested in. Finally, we have opted to exclude studies that only presented student perceptions of learning, and did not consider reports on student focus groups in this review. All these considerations were made for practical reasons: to ensure that the scope of the analysis was manageable and consistent with the focus to report on the effects of video on learning.

Another limitation of the overview is a result of the nature of the systematic review. Our analysis offered an overview of the trends and patterns. However, the weight of evidence that, for instance, supports the effect of particular presentation manipulations on the recall, does not outweigh the evidence to show support for the effect of content manipulations on transfer. Rather the overview reflects the popularity of certain types of manipulations.

4.3 Implications for Practice

The high-level overview of the evidence presented to describe the effect of video in learning through this systematic review supports practical implications outlined by Hansch and colleagues [10]. The authors conducted semi-structured interviews with practitioners producing video to obtain a set of recommendations. Results of their study suggest that practitioners should think carefully about whether video is the most appropriate medium for the stated learning objectives, to be mindful of the strength and weaknesses of videos, be deliberate in the choice of video production style, and consider both lightweight and DIY approaches to video production. Our findings offer much evidence to unpack the first recommendation. This involves careful alignment between learner prior knowledge, consequent adjustment of the presentation of the video, accompaniment of the video with tasks that help learners spend time paying attention to particular elements presented. We have also seen evidence of the second recommendation put out by the authors - consideration if the medium offers the best content delivery for the information to be learnt (i.e. procedural, declarative knowledge, comprehension or recall, focus on details, or situational analysis, etc.). In some cases, the video may be weak in helping learners familiarize themselves with that particular knowledge. Finally, studies within the dataset also demonstrated that basic technical requirements are key to video quality, as clear video, medium-size screen or instructor personalizing the message impact learner motivation and satisfaction. However, there is evidence of effect from what is being said when presented in the video, and recording discussions or case studies may be a cheaper DIY option.

Given the plethora of decisions to be made around learning with video, it is a challenge to offer a more concise one-size-fits-all recommendation. Our preliminary analysis suggests that immediate quizzing and clearly presented information helps learners recall video content. However, more compelling ways of offering content that can challenge prior knowledge or present problem-solving activities can impact overall long-term understanding, even though this may not be ideal for recall. Evidence also supports the theory of active learning [5], with tasks helping learners engage with the content. Further applications of learning analytics can help understand particular elements that learners are having trouble with during their engagement with the content.

4.4 Future Research

This study has focused on identifying the commonly used metrics and summarizing the overall findings observed in the dataset. Our review suggests that understanding learning with videos is an underexplored area within the learning analytics field. Learning analytics and educational data mining can contribute to further theories of learning with media.

There is a need to advance learning analytics research beyond capturing the trends and visualizing them through video engagement activities, to contribute and refine existing theories. For instance, Koedinger and colleagues [S160] conducted a large correlational study combining academic achievement data and clickstream data with particular interest on how learners with differing language ability engage with videos. Their findings, interpreted through multimedia principles, demonstrated that such principles did not affect learners with different language abilities in the same way. Framing and interpreting grade and video engagement data through cognitive multimedia theory [6], active learning theory [5], or a more recent cognitive-affective theory of media learning that integrates learner motivation [19] can help refine their premises.

Another growing area within the studies refers to multimodal analytics, where clickstream data is combined with physiological data and learner self-reports. Our review has shown a variety of psychological constructs measured through established instruments, such as types of cognitive load, mental effort, task complexity, perceived difficulty, among others. Propelled by its relative availability, studies have adopted gaze tracking to measure visual attention [S98, S126, S112, S166]. For instance, Philips et al. [S126] used gaze tracking to capture the impact of distraction on attention. However, there is potential for more integration of wearables to capture physiological data (i.e. heart rate variability as predictor of self-regulation in [22]), or using multimodal affect detection systems to detect mind-wandering [8]. Triangulation of these more sophisticated approaches with widely used psychological instruments can offer new understandings of how learning unfolds with video.

Finally, in line with a gap noted by Hansch and colleagues from a practitioner's point of view, there is limited understanding around the effect of collaborative tasks for video viewing in asynchronous mode. Prior work has in part addressed the potential of viewing videos alone or together, as well as examined learning from videos when viewing in groups [4, 15]. However, exploring that potential to learn together around the collaborative tasks, such as social annotation, is still in its infancy.

REFERENCES

[1] Allen, I.E. and Seaman, J. 2017. *Digital Learning Compass: Distance Education Enrollment Report 2017.* Babson Survey Research Group, e-Literate, and WCET.

[2] Bearman, M., Smith, C.D., Carbone, A., Slade, S., Baik, C., Hughes-Warrington, M. and Neumann, D.L. 2012. Systematic review methodology in higher education. *Higher Education Research & Development.* 31, 5 (2012), 625–640.

[3] Brown, S.A., Upchurch, S.L. and Acton, G.J. 2003. A framework for developing a coding scheme for meta-analysis. *Western Journal of Nursing Research.* 25, 2 (2003), 205–222.

[4] Chi, M.T., Roy, M. and Hausmann, R.G. 2008. Observing tutorial dialogues collaboratively: Insights about human tutoring effectiveness from vicarious learning. *Cognitive science.* 32, 2 (2008), 301–341. https://dx.doi.org/10.1080/03640210701863396

[5] Chi, M.T. and Wylie, R. 2014. The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist.* 49, 4 (2014), 219–243. http://dx.doi.org/10.1080/00461520.2014.965823

[6] Clark, R.C. and Mayer, R.E. 2016. *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning.* John Wiley & Sons.

[7] Cohen, J. 1960. A coefficient of agreement for nominal scales. *Educational and psychological measurement.* 20, 1 (1960), 37–46. http://dx.doi.org/10.1177/001316446002000104

[8] D'mello, S.K. and Kory, J. 2015. A review and meta-analysis of multimodal affect detection systems. *ACM Computing Surveys (CSUR).* 47, 3 (2015), 43. http://dx.doi.org/10.1145/2682899

[9] Giannakos, M.N. 2013. Exploring the video-based learning research: A review of the literature. *British Journal of Educational Technology.* 44, 6 (2013).

[10] Hansch, A., Hillers, L., McConachie, K., Newman, C., Schildhauer, C. and Schmidt, P. 2015. *Video and Online Learning: Critical Reflections and Findings from the Field.* Technical Report #HIIG Discussion Paper Series No. 2015-02.

[11] Höffler, T.N. and Leutner, D. 2007. Instructional animation versus static pictures: A meta-analysis. *Learning and instruction.* 17, 6 (2007), 722–738.

[12] Kay, R.H. 2012. Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior.* 28, 3 (2012), 820–831. http://dx.doi.org/10.1016/j.chb.2012.01.011

[13] Lang, A. 2000. The limited capacity model of mediated message processing. *Journal of communication.* 50, 1 (2000), 46–70.

[14] Leppink, J., Paas, F., Van der Vleuten, C.P., Van Gog, T. and Van Merriënboer, J.J. 2013. Development of an instrument for measuring different types of cognitive load. *Behavior research methods.* 45, 4 (2013), 1058–1072. https://dx.doi.org/10.3758/s13428-013-0334-1

[15] Li, N., Verma, H., Skevi, A., Zufferey, G., Blom, J. and Dillenbourg, P. 2014. Watching MOOCs together: Investigating co-located MOOC study groups. *Distance Education.* 35, 2 (2014), 217–233. https://dx.doi.org/10.1080/01587919.2014.917708

[16] Major, L. and Watson, S. 2017. Using video to support in-service teacher professional development: the state of the field, limitations and possibilities. *Technology, Pedagogy and Education.* (Sep. 2017), 1–20. https://doi.org/10.1080/1475939X.2017.1361469.

[17] Mayer, R.E. 2006. Ten research-based principles of multimedia learning. *Web-based learning: Theory, research, and practice.* (2006), 371–390.

[18] Mirriahi, N. and Vigentini, L. 2017. Analytics of Learner Video Use. *Handbook of Learning Analytics.* Columbia University, USA, C. Lang, G. Siemens, University of Texas at Arlington, USA, A. Wise, New York University, USA, D. Gasevic, and University of Edinburgh, UK, eds. Society for Learning Analytics Research (SoLAR). 251–267. https://dx.doi.org/10.18608/hla17.022

[19] Moreno, R. and Mayer, R. 2007. Interactive Multimodal Learning Environments. *Educational Psychology Review.* 19, 3 (Sep. 2007), 309–326. https://doi.org/10.1007/s10648-007-9047-2.

[20] O'Callaghan, F.V., Neumann, D.L., Jones, L. and Creed, P.A. 2017. The use of lecture recordings in higher education: A review of institutional, student, and lecturer issues. *Education and Information Technologies*. 22, 1 (2017), 399–415. https://dx.doi.org/10.1007/s10639-015-9451-z

[21] Papamitsiou, Z.K. and Economides, A.A. 2014. Learning analytics and educational data mining in practice: A systematic literature review of empirical evidence. *Educational Technology & Society*. 17, 4 (2014), 49–64.

[22] Spann, C.A., Schaeffer, J. and Siemens, G. 2017. Expanding the scope of learning analytics data: preliminary findings on attention and self-regulation using wearable technology. *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (2017), 203–207. https://dx.doi.org/10.1145/3027385.3027427

[23] Witthaus, G.R. 2016. Lecture capture: what can business schools learn from the recent literature? (2016).

[24] Yousef, A.M.F., Chatti, M.A. and Schroeder, U. 2014. Video-based learning: A critical analysis of the research published in 2003-2013 and future visions. *eLmL 2014, The Sixth International Conference on Mobile, Hybrid, and On-line Learning* (2014), 112–119.

APPENDIX: LIST OF STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

[S1] Rahim, A., Noor, M., Zaid, N. (2015). Development of video based on cognitive conflict strategies in learning information technology application and communication subject.

[S2] Adams, A.J., Wasson, E.A., Admire, J.R., Gomez, P., Babayeuvski, R.A., Sako, E.Y., Willis, R.E. (2015). A comparison of teaching modalities and fidelity of simulation levels in teaching resuscitation scenarios.

[S3] Altan, T., Cagiltay, K. (2015). An eye-tracking analysis of spatial contiguity effect in educational animations

[S4] Ando, M., Nagamori, M., Songmuang, P., Ueono, M., Okamoto, T. (2007). An analysis using eye-mark recorder of the effectiveness of presentation methods for e-learning.

[S5] Ando, M., Ueno, M. (2008). Cognitive load reduction on multimedia e-learning materials.

[S6] Andrade, J., Huang, W., Bohn, D.M. (2014). Multimedia's effect on college students' quantitative mental effort scores and qualitative extraneous cognitive load responses in a food science and human nutrition course

[S7] Andrade, J., Huang, W., Bohn, D.M. (2015). The impact of instructional design on college students' cognitive load and learning outcomes in a large food science and human nutrition course.

[S8] Arguel, A., Jamet, R. (2009). Using video and static pictures to improve learning of procedural contents.

[S9] Beale, E.G., Tawater, P.M., Lee, V.H. (2014). A retrospective look at replacing face- to- face embryology instruction with online lectures in a human anatomy course.

[S10] Beege, M. Schneider, S., Nebel, S., Rey, G.D. (2017). Look into my eyes! Exploring the effect of addressing in educational videos.

[S11] Berger, E.J., Pan, E.A. (2015). Video resources and peer collaboration in engineering mechanics: impact and usage across learning outcomes.

[S12] Bhat, S., Chinprutthiwong, P., Perry, M. (2015). Seeing the Instructor in Two Video Styles: Preferences and Patterns

[S13] Blomberg, G; Sherin, MG; Renkl, A; Glogger, I; Seidel, T. (2014). Understanding video as a tool for teacher education: investigating instructional strategies to promote reflection

[S14] Bolkan, S., Goodboy, A.K., Kelsey, D. (2016). Instructor clarity and student motivation: academic performance as a product of students' ability and motivation to process instructional material.

[S15] Boutell M. (2017). Choosing face-to-face or video-based instruction in a mobile app development course.

[S16] Box M.C., Dunnagan C.L., Hirsh L.A.S., Cherry C.R., Christianson K.A., Gibson R.J., Wolfe M.I., Gallardo-Williams M.T. (2017). Qualitative and Quantitative Evaluation of Three Types of Student-Generated Videos as Instructional Support in Organic Chemistry Laboratories.

[S17] Breimer E., Conway M., Cotler J., Yoder R. (2011). A study of video-based versus text-based labs for a management information systems course.

[S18] Bristow, E.C., Bruhl, J.C., Klosky, J.L. (2014). Effect of supplemental instructional videos on student performance in engineering mechanics class.

[S19] Carpenter S.K., Toftness A.R. (2017). The Effect of Prequestions on Learning from Video Presentation.

[S20] Carpenter S.K., Wilford M.M., Kornell N., Mullaney K.M. (2013). Appearances can be deceiving: instructor fluency increases perceptions of learning without increasing actual learning.

[S21] Cattaneo A.A.P., Boldrini E. (2017). You learn by your mistakes. Effective training strategies based on the analysis of video-recorded worked-out examples.

[S22] Chang W.-H., Yang J.-C., Wu Y.-C. (2011). A keyword-based video summarization learning platform with multimodal surrogates.

[S23] Chen D.-W., Catrambone R. (2014). Effects of multimedia interactivity on spatial task learning outcomes.

[S24] Chen Y.-T., Chen L.-F. (2012). Integrating thematic strategy and modularity concept into interactive video-based learning system.

[S25] Chen, Q., Chen, Y., Liu, D., Shi, C., Wu, Y., Qu, H. (2016). PeakVizor: Visual analytics of peaks in video clickstreams from Massive Open Online Courses.

[S26] Chen, Y.T. (2012). A study of learning effects on e-learning with interactive thematic video.

[S27] Cheng, P.Y.; Huang, Y.M.; Shadiev, R.; Hsu, CW; Chu, S.T. (2014). Investigating the effectiveness of video segmentation on decreasing learners' cognitive load in mobile learning.

[S28] Cheon, J; Crooks, S; Chung, S. (2014). Does segmenting principle counteract modality principle in instructional animation?

[S29] Chung S., Cheon J., Lee K.-W. (2015). Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation.

[S30] Cleeren, G; Quirynen, M; Ozcelik, O; Teughels, W. (2014). Role of 3d animation in periodontal patient education: a randomized controlled trial.

[S31] Colasante M., Lang J. (2012). Can a media annotation tool enhance online engagement with learning? a multi-case work-in-progress report.

[S32] Conard M.A., Marsh R.F. (2014). Interest level improves learning but does not moderate the effects of interruptions: an experiment using simultaneous multitasking.

[S33] Corrias, A., Cho Hong J.G. (2015). Design and implementation of a flipped classroom learning environment in the biomedical engineering context.

[S34] Costley J., Lange C. (2017). The effects of lecture diversity on germane load.

[S35] Craig, SD; Chi, MTH; VanLehn, K. (2009). Improving classroom learning by collaboratively observing human tutoring videos while problem solving.

[S36] Cummins S., Beresford A.R., Rice A. (2016). Investigating engagement with in-video quiz questions in a programming course.

[S37] Davis J., Crabb S., Rogers E., Zamora J., Khan K. (2008). Computer-based teaching is as good as face to face lecture-based teaching of evidence based medicine: a randomized controlled trial.

[S38] de Boer, J; Kommers, PAM; de Brock, B. (2011). Using learning styles and viewing styles in streaming video.

[S39] Delen E., Liew J., Willson V. (2014). Effects of interactivity and instructional scaffolding on learning: self-regulation in online video-based environments.

[S40] DelSignore, L.A.; Wolbrink, T.A.; Zurakowski, D; Burns, J.P. (2016). Test-enhanced e-learning strategies in postgraduate medical education: a randomized cohort study.

[S41] Dey E.L., Burn H.E., Gerdes D. (2009). Bringing the classroom to the web: effects of using new technologies to capture and deliver lectures.

[S42] Diaz, D; Ramirez, R; Hernandez-Leo, D. (2015). The effect of using a talking head in academic videos an EEG study.

[S43] Dindar, M; Akbulut, Y. (2016). Effects of multitasking on retention and topic interest.

[S44] Doolittle P.E., Bryant L.H., Chittum J.R. (2015). Effects of degree of segmentation and learner disposition on multimedia learning.

[S45] Dousay T.A. (2016). Effects of redundancy and modality on the situational interest of adult learners in multimedia learning.

[S46] Dupuis, J., Coutu, J., Laneuville, O. (2013). Application of linear mixed-effect models for the analysis of exam scores: online video associated with higher scores for undergraduate students with lower grades.

[S47] Endres T., Carpenter S., Martin A., Renkl A. (2017). Enhancing learning by retrieval: Enriching free recall with elaborative prompting.

[S48] Fiorella L., Mayer R.E. (2016). Effects of observing the instructor draw diagrams on learning from multimedia messages.

[S49] Gasevic D., Mirriahi N., Dawson S., Joksimovic, S. (2017). Effects of instructional conditions and experience on the adoption of a learning tool.

[S50] Gasevic, D., Mirriahi N., Dawson S. (2014). Analytics of the effects of video use and instruction to support reflective learning.

[S51] Ganier F., de Vries P. (2016). Are instructions in video format always better than photographs when learning manual techniques? The case of learning how to do sutures.

[S52] Garcia-Rodriguez, JA; Donnon, T. (2016). Using comprehensive video-module instruction as an alternative approach for teaching IUD insertion

[S53] Garland, TB; Sanchez, C.A. (2013). Rotational perspective and learning procedural tasks from dynamic media.

[S54] Giannakos, M., Chorianopolous, K., Chrisochoides, N. (2015). Making sense of video analytics: Lessons learned from clickstream interactions, attitudes, and learning outcome in a video-assisted course.

[S55] Gross, S.P., Dinehart, D.W. (2016). Pre- and post-class student viewing behaviors for recorded videos in an inverted sophomore mechanics course.

[S56] Grunewald, F; Meinel, C. (2015). Implementation and evaluation of digital e-lecture annotation in learning groups to foster active learning.

[S57] Guo, P., Kim, J., Rubin, R. (2014). How video production affects student engagement: An empirical study of MOOC videos.

[S58] Guttormsen Schor S., Zimmermann P.G. (2007). Investigating means to reduce cognitive load from animations: applying differentiated measures of knowledge representation.

[S59] Horst W., Lauer T., Nold E. (2017). A study of algorithm animations on mobile devices.

[S60] Hakala I., Laine S., Myllymaki, M., Penttila, J. (2009). The effect of time and place dependence when utilizing video lectures.

[S61] Hakala, I., Myllymaki, M. (2011). The use of lecture videos: attendance and student performance.

[S62] Han, I; Eom, M; Shin, W.S. (2013). Multimedia case-based learning to enhance pre-service teachers' knowledge integration for teaching with technologies

[S63] Hartland, W., Biddle, C., Fallacaro, M. (2008). Audiovisual facilitation of clinical knowledge: a paradigm for dispersed student education based on Paivio's dual coding theory.

[S64] Hibbert E.J., Lambert T., Carter J.N., Learoyd D.L., Twigg S., Clarke S. (2013). A randomized controlled pilot trial comparing the impact of access to clinical endocrinology video demonstrations with access to usual revision resources on medical student performance of clinical endocrinology skills

[65] Hoffler, T.N.; Schwartz, R.N. (2011). Effects of pacing and cognitive style across dynamic and non-dynamic representations.

[S66] Holzinger A., Kickmeier-Rust M., Albert D. (2008). Dynamic media in computer science education; content complexity and learning performance: is less more?

[S67] Homer B.D., Plass J.L., Blake L. (2008). The effects of video on cognitive load and social presence in multimedia-learning.

[S68] Hoppe D.J., Denkers M., Hoppe F.M., Wong I.H. (2014). The use of video before arthroscopic shoulder surgery to enhance patient recall and satisfaction: a randomized-controlled study

[S69] Huff M., Schwan S. (2012). The verbal facilitation effect in learning to tie nautical knots.

[S70] Huk, T; Steinke, M; Floto, C. (2009). The educational value of visual cues and 3d-representational format in a computer animation under restricted and realistic conditions

[S71] Ibrahim M., Antonenko P.D., Greenwood C.M., Wheeler D. (2012). Effects of segmenting, signalling, and weeding on learning from educational video

[S72] Ibrahim M., Callaway R., Bell D. (2014). Optimizing instructional video for preservice teachers in an online technology integration course

[S73] Izmirli S., Kurt A.A. (2015). Effects of modality and pace on achievement, mental effort, and positive affect in multimedia learning environments.

[S74] Jamet, E. (2014). An eye-tracking study of cueing effects in multimedia learning.

[S75] Johnson C.I., Mayer R.E. (2009). A testing effect with multimedia learning.

[S76] Jolley D.F., Wilson S.R., Kelso C., O'Brien G., Mason C.E. (2016). Analytical Thinking, Analytical Action: Using Prelab Video Demonstrations and e-Quizzes to Improve Undergraduate Preparedness for Analytical Chemistry Practical Classes.

[S77] Jordan J.T., Box M.C., Eguren K.E., Parker T.A., Saraldi-Gallardo V.M., Wolfe M.I., Gallardo-Williams M.T. (2016). Effectiveness of student-generated video as a teaching tool for an instrumental technique in the organic chemistry laboratory.

[S78] Jung J., Kim D., Na C. (2016). Effects of woe presentation types used in pre-training on the cognitive load and comprehension of content in animation-based learning environments.

[S79] Koßler F.J., Nitzschner M.M. (2015). Learning online: a comparison of different media types.

[S80] Karsenti T., Collin S. (2011). The impact of online teaching videos on canadian pre-service teachers.

[S81] Kearns S.K. (2010). Guided mental practice: an instructional strategy for asynchronous e-learning of pilot safety skills.

[S82] Kelly M., Lyng C., McGrath M., Cannon G. (2009). A multi-method study to determine the effectiveness of, and student attitudes to, online instructional videos for teaching clinical nursing skills.

[S83] Khan T.M., Hassali M.A., Rasool S.T. (2013). A study assessing the impact of different teaching modalities for pharmacy students in a cardio-pulmonary resuscitation (CPR) course.

[S84] Khan, N.; Nguyen, D.H.; Chen, Z.Z.; Rebello, N.S. () Comparing the use of multimedia animations and written solutions in facilitating problem solving.

[S85] Kim, J., Guo, P., Seaton, D., Mitro, P., Gajos, K., Miller, R. (2014). Understanding In-Video Dropouts and Interaction Peaks in Online Lecture Videos.

[S86] Kim, Y; Thayne, J . (2015). Effects of learner-instructor relationship-building strategies in online video instruction.

[S87] Kizilcec R.F., Bailenson J.N., Gomez C.J. (2015). The instructor's face in video instruction: evidence from two large-scale field studies.

[S88] Kizilcec R.F., Papadopoulos K., Sritanyaratana L. (2014). Showing face in video instruction: effects on information retention, visual attention, and affect.

[S89] Koedinger K.R., McLaughlin E.A., Kim J., Jia J.Z., Bier N.L. (2015). Learning is not a spectator sport: doing is better than watching for learning from a mooc

[S90] Kovacs, G. (2016). Effects of in-video quizzes on mooc lecture viewing

[S91] Kuhl, T; Scheiter, K; Gerjets, P; Gemballa, S (2011) Can differences in learning strategies explain the benefits of learning from static and dynamic visualizations?

[S92] Kwon B.C., Lee B. (2016). A comparative evaluation on online learning approaches using parallel coordinate visualization.

[S93] Lantz M.E., Stawiski A. (2014). Effectiveness of clickers: effect of feedback and the timing of questions on learning.

[S94] Lee, D.Y.; Shin, D.H. (2011). Effects of spatial ability and richness of motion cue on learning in mechanically complex domain

[S95] Lehtola W.I., Gemignani S.M., Sutherland J.T., Jeon M. (2014). "Not all visual media are helpful": an optimal instructional medium for effective online learning

[S96] Lei C.-U., Gonda D., Hou X., Oh E., Qi X., Kwok T.T.O., Yeung Y.-C.A., Lau R. (2017). Data-assisted instructional video revision via course-level exploratory video retention analysis.

[S97] Leiner M., Krishnamurthy G.P., Blanc O., Castillo B., Medina I. (2011). Comparison of methods for teaching developmental milestones to pediatric residents

[S98] Leng J., Zhu J., Wang X., Gu X. (2016). Identifying the potential of danmaku video from eye gaze data.

[S99] Li, N., Kidzinksi, L., Jermann, P., Dillenbourg, P. (2015). How do in-video interactions reflect perceived video difficulty?"

[S100] Li, N., Kidzinski, L., Jermann, P., Dillenbourg, P. (2015). MOOC video interaction patterns: What do they tell us?

[S101] Lin H. (2011). Facilitating learning from animated instruction: effectiveness of questions and feedback as attention-directing strategies.

[S102] Lin L., Atkinson R.K. (2011). Using animations and visual cueing to support learning of scientific concepts and processes.

[S103] Lin, L.J., Atkinson, R.K. (2013). Enhancing learning from different visualizations by self-explanation prompts.

[S104] Lin, L.J.; Atkinson, R.K.; Savenye, W.C.; Nelson, B.C. (2016). Effects of visual cues and self-explanation prompts: empirical evidence in a multimedia environment.

[S105] Mahdjoubi L., A-Rahman M.A. (2012). Effects of multimedia characteristics on novice cad learners practice performance.

[S106] Maniar N., Bennett E., Hand S., Allan G. (2008). The effect of mobile phone screen size on video based learning.

[S107] Mayer, R.E.; Deleeuw, K.E.; Ayres, P . (2007). Creating retroactive and proactive interference in multimedia learning.

[S108] Mayer, R.E.; Griffith, E.; Jurkowitz, I.T.N.; Rothman, D (2008). Increased interestingness of extraneous details in a multimedia science presentation leads to decreased learning.

[S109] Meyer, K.; Rasch, T.; Schnotz, W. (2010). Effects of animation's speed of presentation on perceptual processing and learning.

[S110] Mirriahi N., Liaqat D., Dawson S., Gasevic D. (2016). Uncovering student learning profiles with a video annotation tool: reflective learning with and without instructional norms.

[S111] Moreno, R.; Ortegano-Layne, L. (2008). Do classroom exemplars promote the application of principles in teacher education? a comparison of videos, animations, and narratives.

[S112] Mu X. (2010). Towards effective video annotation: an approach to automatically link notes with video content.

[S113] Mukala P., Buijs J., Leemans M., Van Der Aalst W. (2015). Learning analytics on coursera event data: a proceb mining approach.

[S114] Muller D.A., Sharma M.D., Eklund J., Reimann P. (2007). Conceptual change through vicarious learning in an authentic physics setting.

[S115] Muller D.A., Sharma M.D., Reimann P. (2008). Raising cognitive load with linear multimedia to promote conceptual change.

[S116] Nagy J.T., Bernschutz M. (2016). The impact of webinar-webcast system on learning performance.

[S117] Nesbit J.C., Adesope O.O. (2011). Learning from animated concept maps with concurrent audio narration.

[S118] Nielson K.A., Arentsen T.J. (2012). Memory modulation in the classroom: selective enhancement of college examination performance by arousal induced after lecture.

[S119] Ogan A., Aleven V., Jones C. (2008). Pause, predict, and ponder: use of narrative videos to improve cultural discussion and learning.

[S120] Ozdemir D., Doolittle P. (2015). Revisiting the seductive details effect in multimedia learning: context-dependency of seductive details.

[S121] Ozdemir, M.; Izmirli, S.; Sahin-Izmirli, O. (2016). The effects of captioning videos on academic achievement and motivation: reconsideration of redundancy principle in instructional videos.

[S122] Paik E.S., Schraw G. (2013). Learning with animation and illusions of understanding.

[S123] Pal Y., Iyer S. (2012). Comparison of english versus hindi medium students for programming abilities acquired through video-based instruction.

[S124] Pardo A., Zhao Y., Mirriahi N., Zhao A., Dawson S., Gasevic D. (2015). Identifying learning strategies associated with active use of video annotation software.

[S125] Pfeiffer V.D.I., Scheiter K., Gemballa S. (2012). Comparing and combining traditional teaching approaches and the use of video clips for learning how to identify species in an aquarium.

[S126] Phillips N.E., Ralph B.C.W., Carriere J.S.A., Smilek D. (2016). Examining the influence of saliency of peer-induced distractions on direction of gaze and lecture recall.

[S127] Pohl L.M., Walters S. (2015). Instructional videos in an online engineering economics course.

[S128] Rias R.M., Zaman H.B. (2010). Investigating the redundancy effect in multimedia learning on a computer science domain.

[S129] Rias R.M., Zaman H.B. (2013). Looking at the effects of various multimedia approach in student learning: a case study.

[S130] Rias R.M., Zaman H.B. (2008). Multimedia learning in computer science: the effect of different modes of instruction on student understanding.

[S131] Rias R.M., Zaman H.B., Norhana, (2011). Modality effects in multimedia learning: a case study.

[S132] Rias, R.M.; Zaman, H.B. (2011). 3-D versus 2-D animation in multimedia application: is the extra effort worth it?

[S133] Rias, R.M.; Zaman, H.B. (2011). Different visualization types in multimedia learning: a comparative study

[S134] Rias, R.M.; Zaman, H.B.; Manap, A.A. (2014). Applying redundancy and animation in a multimedia learning application on a computer science domain.

[S135] Ritzhaupt A.D., Pastore R., Davis R. (2015). Effects of captions and time-compressed video on learner performance and satisfaction.

[S136] Rivera-Nivar, M; Pomales-Garcia, C. (2010). E-training: can young and older users be accommodated with the same interface?

[S137] Rose E., Claudius I., Tabatabai R., Kearl L., Behar S., Jhun P. (2016). The flipped classroom in emergency medicine using online videos with interpolated Questions.

[S138] Ryan T.J. (2010). Assessment & efficacy of an m-learning course in industrial hygiene and occupational safety.

[S139] Schonwetter D.J., Gareau-Wilson N., Cunha R.S., Mello I. (2016). Assessing the impact of voice-over screen- captured presentations delivered online on dental students' learning.

[S140] Schofler A., Scheiter K., Gerjets P. (2013). Is spoken text always better? investigating the modality and redundancy effect with longer text presentation.

[S141] Scheiter, K; Gerjets, P; Huk, T; Imhof, B; Kammerer, Y. (2009). The effects of realism in learning with dynamic visualizations.

[S142] Schmid, S.; Yeung, A.; George, A.V.; King, M.M. (2009). Designing effective e-learning environments - should we use still pictures, animations or interactivity?

[S143] Schroeder, N.L. (2016). A preliminary investigation of the influences of refutation text and instructional design.

[S144] Schweppe J., Rummer R. (2016). Integrating written text and graphics as a desirable difficulty in long-term multimedia learning.

[S145] Schworm S., Stiller K.D. (2012). Does personalization matter? the role of social cues in instructional explanations.

[S146] Seaton, D., Nesterko, S., Mullaney, T., Reich, J., Ho, A. (2014). Characterizing video use in the catalogue of MITx MOOCs.

[S147] Shi, C.L.; Fu, S.W.; Chen, Q.; Qu, H.M. (2015). VISMOOC: visualizing video clickstream data from massive open online courses.

[S148] Singh S., Verma H.K., Singh J. (2013). CD-ROM as an instructional device for dairy farmers.

[S149] Sinha, T, Jermann, P., Li, Nan, Dillenbourg, P. (2014). Your click decides your fate: Inferring information processing and attrition behavior from MOOC video clickstream interactions.

[S150] Smart D.A., Castillo M., Bruya M., Dekker L. (2010). Outcomes of teaching baccalaureate nursing students about mastitis utilizing a multimodal teaching tool.

[S151] Szpunar, K.K.; Jing, H.G.; Schacter, D.L. (2014). Overcoming overconfidence in learning from video-recorded lectures: implications of interpolated testing for online education.

[S152] Topper J., Glaser M., Schwan S. (2014). Extending social cue based principles of multimedia learning beyond their immediate effects.

[S153] Tantrarungroj P., Lai F.-Q. (2011). Effect of embedded streaming video strategy in an online learning environment on the learning of neuroscience

[S154] Thomas, AO; Antonenko, PD; Davis, R. (2016). Understanding metacomprehension accuracy within video annotation systems.

[S155] Todorovic M., Johnston A.N.B., Fenwick C., Williams-Pritchard G., Barton M.J. (2016). Enriching biosciences in undergraduate nursing programs: establishment and assessment of online video resources.

[S156] Trevisan M.S., Oki A.C., Senger P.L. (2010). An exploratory study of the effects of time compressed animated delivery multimedia technology on student learning in reproductive physiology.

[S157] Triay J., Minguill<f3>n J., Sancho-Vinuesa T., Daza V. (2015). Exploring the effectiveness of video viewing in an introductory x-mooc of algebra.

[S158] Tsekleves E., Aggoun A., Cosmas J. (2013). Investigating the use and effectiveness of diverse types of materials in the delivery and support of lab sessions for multimedia subjects and students.

[S159] Turkay S. (2016). The effects of whiteboard animations on retention and subjective experiences when learning advanced physics topics.

[S160] Uchidiuno J., Hammer J., Yarzebinski E., Koedinger K.R., Ogan A. (2017). Characterizing ELL students' behavior during mooc videos using content type.

[S161] Urao, A; Miwa, K. (2007). Effects of cognitive load in acquisition of assembly skills

[S162] van Marlen T., van Wermeskerken M., Jarodzka H., van Gog T. (2016). Showing a model's eye movements in examples does not improve learning of problem-solving tasks.

[S163] Verliefde, N; Stevens, L; D'haenens, B; Vermeyen, A; Kaat, R; De Gendt, M; Van Caelenberg, C; Stifkens, K; Van Rampelberg, S; Neijens, T; Van Den Bossche, J. (2011). Comparing the efficiency and effectiveness of different learning media designs for the preparation of skills training in a blended learning context.

[S164] Viswasom A.A., Jobby A. (2017). Effectiveness of video demonstration over conventional methods in teaching osteology in anatomy.

[S165] Vural, O.F. (2013). The impact of a question-embedded video-based learning tool on e-learning.

[S166] Wang J., Antonenko P.D. (2017). Instructor presence in instructional video: Effects on visual attention, recall, and perceived learning.

[S167] Wang, Chen, & Wu (2015). Effects of Different Video Lecture Types on Sustained Attention, Emotion, Cognitive Load, and Learning Performance.

[S168] Weeks B.K., Horan S.A. (2013). A video-based learning activity is effective for preparing physiotherapy students for practical examinations

[S169] Weng T.S., Hsu M.-H. (2011). Dancing mathematics: exploration and application of 3D calculus instruction.

[S170] Wise, A.F.; Padmanabhan, P.; Duffy, T.M. (2009). Connecting online learners with diverse local practices: the design of effective common reference points for conversation.

[S171] Yang, J.M.; Tao, Y. (2015). Effects of different video types about procedural knowledge on cognitive load, learning flow and performance.

[S172] Yong P.Z., Lim S.W.H. (2016). Observing the testing effect using coursera video-recorded lectures: A preliminary study.

[S173] Young-Jones, A; Cara, KC; Levesque-Bristol, C. (2014). Verbal and behavioral cues: creating an autonomy-supportive classroom.

[S174] Yu, P.T.; Liao, Y.H.; Su, M.H. (2013) A near-reality approach to improve the e-learning open courseware.

[S175] Zee T.V.D., Admiraal W., Paas F., Saab N., Giesbers B. (2017). Effects of subtitles, complexity, and language proficiency on learning from online education videos.

[S176] Zha X., Bourguet M.-L. (2016). Experimental study to elicit effective multimodal behaviour in pedagogical agents.

[S177] Zhang J., Yu K. (2016). Application of a ppt presentation system in the course of overall city planning under multimedia teaching context.

[S178] Zottmann J.M., Goeze A., Frank C., Zentner U., Fischer F., Schrader J. (2012). Fostering the analytical competency of pre-service teachers in a computer-supported case-based learning environment: a matter of perspective?