# Instructors' and Students' Needs for Next Generation Video in Education

by

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# Abstract

As education moves towards a more digital experience, teachers and students are increasingly using video technology. This dissertation is composed of three studies that explored the use of video from both sides of the teaching and learning paradigm: an Instructor study, a Student study, and a Video Highlighting study.

In the Instructor study, 16 instructors who teach with video were interviewed. Instructors use video because students are more likely to watch videos before class than read textbooks. Further, using a flipped classroom model and moving lectures into pre-class video enables active learning during class time. However, creating videos is not a trivial task, and there are limited ways that instructors can assess if their students have watched and/or understood the videos. Instructors are eager to leverage digital data from students' video use to generate both aggregate and individual level data about how students are using video for learning.

In the Student study, we deployed a custom video player to five cohorts of an undergraduate chemistry class across three years. Students (n=248) used the video player to view nine videos per semester. Data were collected through activity traces generated from logs and a subset of students were interviewed. Students *familiarised* themselves with the content by watching sequentially and *clarified* their knowledge by re-watching. When students *reviewed* a video in preparation for a test, they searched through the video to find what they needed. Students optimised their use of video by spending more time on parts of the videos that were tied to their grades.

Finally, in the Video Highlighting study, we introduced a method for highlighting a transcript and a filmstrip series of thumbnails of a video. A controlled laboratory study with 11 students revealed that for search tasks in video, users were able

to find previously highlighted parts of video quickly, but transcripts were preferred over the filmstrip highlighting.

The use of video in education is continuing to grow. Instructors use video to promote student engagement, yet future work is needed to make video easier to produce, evaluate, search and organise.

# Lay Summary

In this work, three studies that explore how instructors teach with video, and how students learn from video are presented. Instructors assign video for students to watch before class as an alternative to textbooks, so they can more effectively use face-to-face time in class. However, instructors face difficulties in determining whether their students actually watch the videos. We created a video player for five groups of students to use in a chemistry class and found that students spend more time on parts of video that affect their grade; students often re-watched and searched for summarising conclusion slides in the videos. Finally, we investigated a novel technique for highlighting in video by allowing users to quickly annotate video much like highlighting in a textbook. We found that highlighting helped users quickly find relevant parts of video.

# Preface

All the research presented in this dissertation was conducted in the Human Communication Technologies Laboratory (HCT) at the University of British Columbia, Point Grey campus. All user studies and associated methods were approved by the University of British Columbia Behavioural Research Ethics Board [Certificate Number: H13-01589]. The user studies and associated methods presented in Chapter 4 were approved by the British Columbia Research Ethics Board [REB Number: 2016-19].

An earlier version of Chapter 3 has been published at Learning @ Scale 2019 [Fong, M., Dodson, S., Harandi, N., Seo, K., Yoon, D. Roll, I., Fels, S. Instructors Desire Student Activity, Literacy, and Video Quality Analytics to Improve Video-based Blended Courses. *Proceedings of the Sixth (2019) ACM Conference on Learning @ Scale.* 1-10]. I was the lead investigator, responsible for concept formation, literature review, interview construction, interviewing instructors, interview analysis, and manuscript composition. D. Yoon was involved in the interview construction and peer debriefing. S. Dodson, N. Harandi, and K. Seo were involved in peer debriefing. S. Fels was the supervisory author and provided feedback on the analysis and the manuscript.

A version of Chapter 4 is being prepared as a manuscript for conference submission. I was responsible for concept formation, literature review, interface design and development, data collection and analysis, and manuscript composition. G. Miller, X. Zhang, I. Roll, C. Hendricks and S. Fels were involved with interface design discussion. G. Miller, X. Zhang, I. Roll, S. Sunani, S. Dodson, K. Seo, N. Harandi, D. Yoon and S. Fels were involved in peer debriefing. L. Currie and S. Fels were involved in manuscript writing and editing.

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# Glossary

**BCIT** British Columbia Institute of Technology

**CMS** Content Management System

**ICAP** Interactive, Constructive, Active, Passive, different levels of learning

**MOOC** Massively Open Online Course

**NSERC** Natural Sciences and Engineering Research Council

**PRS** Personal Response System, such as clickers

**TLEF** Teaching and Learning Enhancement Fund

**UBC** University of British Columbia

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# Chapter 1

# Introduction

Video is becoming one of the many tools instructors use to present learning content to their students. One of the ways instructors use video is to integrate it into the lecture to visually illustrate concepts that would otherwise be difficult to explain with still pictures and dialogue. In early iterations of the flipped classroom, instructors would assign students textbook pre-readings as preparatory learning. More recently, instructors have adopted the *blended* style of learning [30] by incorporating video, instead of textbooks. In both models of the flipped classroom, the goal is to have students come to class with some background information, allowing the instructor to use the face-to-face time for supervised activities that promote *active learning* [10], where students are encouraged to be "interactive, constructive, or active" [18]. Active learning has been shown to improve learning outcomes [19], making it a valued teaching strategy. Using video also has its challenges, including creation, distribution, and efficacy evaluation. To illustrate some processes that an instructor executes to implement a flipped classroom using video, I present a scenario about an instructor, Pat.

*Pat teaches an undergraduate chemistry class. In the past, each week, Pat assigned readings about laboratory experiment procedures for students to read in preparation to performing the experiment the following week. However, Pat found that very few students completed the pre-reading and most came to class with no prior knowledge of the background material, making it difficult for them to perform the experiment. Pat hopes by that assigning videos for the students to watch, there* *is a greater likelihood that they will have a baseline understanding of the material before class. Pat creates a video for each experiment, ten in total detailing the procedures for each experiment, for example experiments that demonstrate chemical Separation Techniques, Titrations, and Volumetric Techniques. Each video is about 10 minutes long, and after completing each experiment, students are to submit a written laboratory report detailing the hypotheses, procedures, findings and conclusions to each experiment.*

*Pat uploads the videos to YouTube so that the students can access them. The morning of the first laboratory experiment on Separation Techniques, Pat wants to look at the class's* ***aggregate activity*** *to see if there are any parts of the video with peaks in viewing time. Pat's goal is to look for peaks in activity which might indicate difficult concepts that could be reinforced before the students begin performing the experiment. Pat looks at the video analytics on YouTube to see which parts of the video had peak activity, but the data are sparse and difficult to interpret. During class, before the students perform the experiment, Pat asks the students whether they watched the video, and if they found anything difficult. Ten out of the 25 students raise their hands, however, none indicated that they found anything difficult. The following week, for the Titrations experiment, Pat implements a class-wide quiz using a Personal Response System (*PRS*) (clickers) to gauge the students* ***literacy*** *of the material, and finds that five students got every question wrong, possibly indicating that these students did not watch the video at all. Pat also finds that 20 of the 25 students did not understand how to balance the acid-base chemical equation, and decides to provide an overview and help the students understand the concept before letting them perform the experiment. Pat also wants to* ***evaluate the quality of the videos*** *to understand if the videos themselves were useful to the students. At the end of the semester, Pat hands out a class survey asking about the videos. The responses were not constructive, with answers like "The videos were good".*

In this scenario, Pat exerted a large effort to create videos for the class, but found it difficult to discover how the students were using the videos. While Pat would be able to spend more time in class with the students ensuring that they understand the material better, Pat also makes a significant effort attempting to evaluate the students understanding of the material. Due to the students' reticence to answer questions in front of a group, Pat also has difficulty knowing whether the videos were appropriate for teaching the concepts, and whether the videos were effective for learning. Video, being a digital medium, has the potential to gather the viewing behaviour of Pat's students easier than what is possible with analogue textbooks. However, the coarse nature of the analytics provided to them by YouTube did not help. In the next scenario, the video strategies of one of Pat's students, Kris, is explored.

*Kris is in Pats class and was just assigned the Titration video. Kris is studious, and decides to watch the video to* ***familiarise*** *himself with the material ahead of the experiment. Kris comes across the point of the video explaining how to balance the acid-base chemical equation and is having difficulty following the example because some steps were skipped in the video. He* ***pauses the video*** *and then* ***rewinds*** *it so that he can and re-watch part of it to try to* ***clarify*** *the concept. He eventually gives up and searches the internet to find a similar equation balancing example to* ***reinforce*** *his understanding. As he watches the class video, he takes notes in which he writes down key concepts as well as timestamps in the video so that he can find it again if needed. Kris goes to class and Pat (the instructor) asks the class if they found anything difficult in the pre-class video lecture. Not wanting to be the only person to raise his hand, Kris stays quiet.*

*A cumulative midterm exam on Separation Techniques and Titrations is coming up. Kris refers to his notes to* ***review*** *the material. Kris comes across the difficult acid-base chemical equation balancing, and opens the video and searches through video he had noted earlier. Kris re-watches it and rereads his notes and understands the concept. Kris comes across a different concept in the notes on the Separation Techniques video that is difficult but forgot to write down the corresponding timestamp. Kris spends extra time searching through the video to find the explanation.*

Kris' use of video is typical of a studious student. He watched the videos in full, *familiarising* himself with the contents each video, often re-watching confusing parts of the video as *clarification* to make sure he understands the concepts. While Kris was mostly organised and kept track of the content in the video, he expended a significant effort by writing notes to ensure that he could quickly find and *review* the information that he had trouble understanding. Students who are less organised would likely spend more time searching in the video to find what they need to review and understand for exams. Video viewing interfaces available to students often do not facilitate search, and users are left to manually index the videos themselves.

These scenarios are provided to demonstrate typical thought processes, actions, and issues that were identified for both instructors and students in the three studies presented in this dissertation. Instructor's motivations for teaching with video as well as the challenges in obtaining feedback from the students were examined. From the students' perspective, challenges in watching videos, and the strategies used to ensure effective learning experiences with video were explored. Finally, aspects of how the design of video viewing interfaces that can help students with their learning goals was investigated.

## 1.1 Overview of Studies

This dissertation is composed of three studies, an Instructor study, a Student study, and a Video Highlighting study. In the first study, the Instructor study, we investigate the role of video in the flipped model of teaching, as well as instructors' perceived strengths and weaknesses of teaching with video. We found that there are several reasons instructors use videos instead of traditional text-based media:

- video is more engaging (and higher engagement leads to higher learning outcomes),
- video is more accessible,
- students are more likely to watch video before class, thereby coming to class better prepared, and
- video makes the content more personable and attractive.

Instructors also find that video is a better medium to present animations and dynamic diagrams because video can illustrate concepts better than static images. However, producing a good quality video is not a trivial task, and as was touched upon in the scenario with Pat, it can also be difficult to get feedback from students, such as metrics of understanding, performance, and overall quality of the videos. For example, in order to gauge the effectiveness of the videos, Pat tried to use pop quizzes, PRSs or clickers, and assignments to see how well the students understood the material. The main purpose of using a flipped classroom is to maximise classroom time for active learning. However, as we saw in the scenario, Pat needed to implement extra steps to verify student literacy. Thus the primary advantage of the flipped classroom methodology (i.e., spending more time running interactive activities), is negated. Instructors are in need of a system that can provide them with the insight to quickly evaluate their classroom. This includes assessing their students, but also assessing the efficacy of the videos. Instructors' main questions are: "Are the videos appropriate for teaching these topics, and how can the videos be improved?". In the Instructor study, the granularity of the video analytics systems currently available to instructors are not detailed enough to satisfy instructors' information needs. All 16 instructors wanted to know how the students watched and studied from video. For example, instructors asked: "What parts are students having trouble with?", "How do they re-watch the videos?", and "Do they review the videos?"

In the second study, the Student Study, we describe how the knowledge learning context plays a key role in determining students' behavioural patterns. That is, their behaviours and strategies for watching the video depends on *why* they are watching the video. We found three knowledge learning contexts that correspond to classroom activities:

- *Introduction*, where students watch a video for the first time,
- *Reinforcement*, where students re-watch video to strengthen their understanding of the material, and
- *Demonstration*, where students re-watch video to prepare for an assignment, laboratory experiment, or testing situation.

Within these knowledge learning contexts, three learning behaviours emerge:

- Familiarisation, analogous to *Introduction*, where students are first introduced to the material,

- Clarification, where students return to certain parts of a video to solidify their understanding, and
- Review, where students return to a part of a video after having watched the video for the first time.

Referring back to the scenario, Kris first watched the video and familiarised himself to the material by watching it and writing notes. As Kris watched the video, he flipped between *Introduction* and *Reinforcement* contexts, then he performed clarification behaviours when he went back and re-watched parts of the video. Then, as Kris needed to study for a midterm exam where he needed to demonstrate his knowledge of the material, Kris exhibited reviewing behaviours, going back to the video using his notes as bookmarking tools.

In the Student study, a common strategy that students employed in all knowledge learning contexts was searching for information throughout the video. Students look for strategies to optimise their study time with video, and much like Kris, who created bookmarks by noting down points in the video where he had difficulty. During the *familiarisation* stage, students watched the videos in two different ways: from beginning to end, or by skipping to the concluding slides. During *clarification* and *review*, students performed a number of searching techniques, including using visual search, textual search, and taking notes. Students also frequently searched for parts of the video that they found important; the concluding slides were among the most visited slides in all videos.

In the third study, the Video Highlighting study, the focus was on creating an interface to aid video organisation for students. In the scenario, Kris implemented a bookmarking mechanism by writing down timestamps for parts of the video that he identified as difficult or confusing. We drew inspiration from highlighting functions in text-based mediums and implemented and tested an interface that allowed students to highlight video, much like they would do in text. In this study, we explored if students employed different highlighting and searching strategies when using a filmstrip compared to a transcript. We found that having access to the transcript allowed students to make highlights ahead of the video, and students who were only given the filmstrip only highlighted the video after having watched it.

## 1.2 Summary of Contributions

This dissertation provides three main contributions in the research domain of Human Computer Interaction (HCI) and education. These contributions include studying instructors' needs for video in teaching (Chapter 3), understanding the video studying behaviours of students (Chapter 4), and developing and evaluating a novel highlighting technique for video (Appendix A).

1. *A list of motivations for teaching with video and desires for video analytics to improve video for blended course learning.* (Chapter 3) I interviewed 16 instructors who taught using video and found the advantages and disadvantages of using video in their teaching as well as the different requirements for analytics and feedback to enhance their existing practices. The instructors stated the strengths of video included increased accessibility for students compared to textbooks, increased flexibility which allowed students to more easily re-visit information compared to traditional lectures, and increased student motivation, where students were more likely to watch videos that were created specifically for their class. Disadvantages of video stem from the increase in preparation effort; scripting, filming, and editing a video is more labour-intensive and difficult than writing text, or filming a prepared lecture or presenting an unscripted lecture. Furthermore, instructors found it difficult to elicit feedback from the students about the video; they wanted to see if their students have watched their videos, how much they understood in those videos, and how useful the videos were to the students.

2. *A set of descriptors of how students use and watch video to complete assignments and study in a blended college science class.* (Chapter 4) I report on students video watching behaviour during a three-year study (five semesters; five student cohorts) of a single-semester first-year college chemistry class that used video as a teaching resource. I found that when students watch video, they use strategies to reduce the amount of time they need to watch it. Students behaviours occurred in three knowledge learning contexts: *Introduction* to new material, *Reinforcement* of recently learned material, and *Demonstration* or application of the material for an assignment. In these contexts, we found different sets of behaviours: *familiarisation* by watching

sequentially, skipping through, or reading the transcript; *clarification* by re-watching the video or re-reading the transcript; and, *review of material* by re-watching the video. Qualitative-content-analysis of video activity traces for 248 students confirmed several strategies for optimizing studying time with video, such as searching behaviour to important parts of video like including question slides and conclusion slides.

3. *A novel interaction technique for highlighting in video.* (Appendix A) We created a novel interaction technique for highlighting discrete time intervals in video, and observed and described four different strategies students used to highlight video intervals when given a highlightable transcript, and a highlightable filmstrip, i.e. a series of thumbnails representing the video. We also identified seven different strategies students used to search for content within video. We asked the students if our design for highlighting worked well for saving intervals and found that highlighting is a useful addition to viewing instructional video. The familiar interaction of highlighting a textual transcript was preferred, with the filmstrip used for intervals that are more visually distinctive.

## 1.3 Study Chronology

This dissertation presents the studies in a different sequence than they were performed. The study timeline can be found in Figure 1.1, where the studies were performed in the following order: Video Highlighting (blue), Student (cyan), and Instructor (green). In this dissertation, they are presented as Instructor (green, Chapter 3), Student (cyan, Chapter 4), and Video Highlighting (blue, Appendix A). An informal exploration of instructors needs guided the design of the longitudinal Student study. Therefore, while the formal Instructor study was carried out last, it is presented first because the informal data informed the design of the Student study. The Instructor study was published in 2019. The Student study is the most substantive contribution from this dissertation. To date, no studies have been identified that examined the video viewing behaviour of students in a blended classroom with flipped elements over several semesters with multiple different student cohorts. Therefore the Student study fills a significant gap in the literature. A

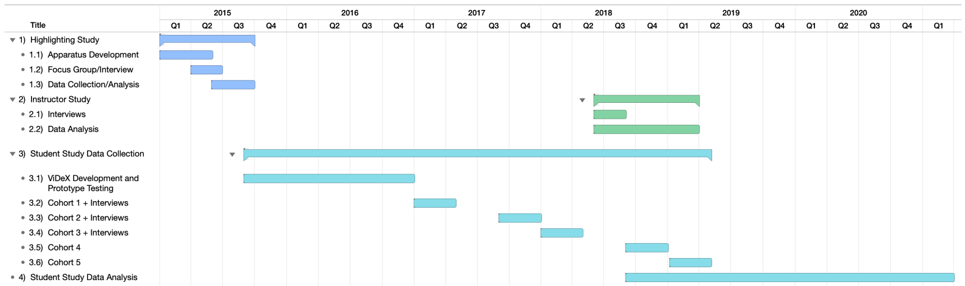



**Figure 1.1:** Gantt chart of the three studies: a Video Highlighting study (blue), an Instructor study (green), and a Student study (cyan).

manuscript is in preparation for the Student study.

The Video Highlighting study was completed first. This study began as an extension to the work our research group did for my master's thesis [36] on simple video authoring with video interval selection and Al Hajri's thesis [2] on video viewing behaviour and using video histories for navigation. These two works focused on general entertainment video. We received a grant from the Teaching and Learning Enhancement Fund (TLEF) at University of British Columbia (UBC), which directed our attention towards educational video. This led to an idea for a novel approach to video interval selection using transcripts, which was inspired by textbook highlighting. We developed a prototype interface and ran a controlled laboratory study in 2015 to determine the usability of such an interaction. The Video Highlighting study was published in 2016.

## 1.4 Technology Development

The Video Highlighting study demonstrated that highlighting video was an effective method in allowing users to select, save, and play back intervals of video. We then wanted to test our video watching interface outside a lab setting by setting up the multi-cohort descriptive Student study in the field. This would ensure that we had a large sample size, and that the data would be gathered in a natural ecologically valid environment with real students studying for a real course. This required that our video interface, ViDeX, was developed to a high enough fidelity, almost product-like, for students to use so that it would not hinder their studying. Furthermore, ViDeX would also have to be instrumented to collect anonymised behavioural data from the students. We deployed several prototypes of ViDeX to several classes during the development phase to ensure the application ran smoothly. After ViDeX proved to be stable, we partnered with instructors at the British Columbia Institute of Technology (BCIT), who developed videos to use specifically with ViDeX. This required them to create videos complete with transcripts for their lectures. We then deployed ViDeX to the chemistry classes at BCIT for five semesters: January 2017, September 2017, January 2018, September 2018, January 2019. After the first three semesters, we interviewed a subset of the students about their experience with ViDeX.

Throughout these studies, we were able to explore video in education from both the instructor and student perspectives. We took our interface, ViDeX, from a controlled laboratory study, and deployed it to a live classroom to investigate behavioural patterns exhibited by students in a blended chemistry class.

## 1.5 Thesis Outline

In this thesis, a survey of the related work is first presented. This includes topics about video in education, video analytics, video navigation and video annotation. Chapters 3, 4, and A present the three studies: the Instructor study, the Student study, and the Video Highlighting study. Finally, in Chapter 5, we summarise the dissertation contributions, describe directions for future work and provide some concluding remarks.

# Chapter 2

# Related Work

In this chapter, I review the literature for video in an education context, such as the use of video in teaching, learning, analytics, and behaviour modelling. I start with a brief history of how video has been used over the years, and proceed to discuss the use of video in specific learning models such as the blended learning model, the flipped classroom, and Massively Open Online Course (MOOC). I then survey the use of analytics in modelling student behaviour, as well as the interfaces available to instructors to view said analytics. Finally, I survey a number of interfaces designed for individuals to annotate video, both for general video such as Netflix and YouTube, as well as video interfaces designed with a focus on learning.

## 2.1 Approaches to Teaching with Video

Video can be used as a centerpiece of the lecture, or as supplementary material, to illustrate certain points. The pedagogical advantages of using video to teach have been well covered; video is often found to be a useful revision and assessment tool [52, 96], and allows students to have "stimulated factual recall and highlights knowledge gaps" [52].

As early as the 1950s, many college campuses used video as a tool for distance learning [33, 78]. At that time, due to growing enrolment, financial distress and shortage of large lecture halls, instructors recorded lectures and then broadcast the videos to students at smaller remote classrooms via closed circuit television. Given that televised lectures were typically a substitute for regular in-person instruction, there was a concern about the lack of instructor-student interaction. However research that examined pedagogical outcomes of televised instruction compared to conventional instruction yielded no significant differences [21, 40, 60, 90].

### 2.1.1 Blended Learning Model

With the growing stability of video technology and ubiquity of computers, instructors and researchers began experimenting with blended learning. Blended learning is the combination of "face-to-face instruction with computer-mediated instruction" [49]. Computer-mediated instruction can take many forms and there are different levels of blended learning, including activity-level, course-level, or program-level. For example, activity-level blended learning may use internet conferencing to "bring experts at a distance into the classroom" [49]. Course-level blended instruction may utilise a Content Management System (CMS), and program-level blending may use fully online courses. In this dissertation, I focus on the use of video specifically as a technology in activity-level blended instruction.

### 2.1.2 Flipped Classroom Model

Before video was commonplace, instructors implemented the flipped classroom model by assigning textbook pre-reading for students to complete before class. In this model, students would then perform active face-to-face learning activities with the instructor in class. The same model can be employed with video to replace or supplement pre-class readings. The flipped classroom model that uses blended learning "employs asynchronous video lectures and practice problems as homework, and active, group-based problem-solving activities in the classroom" [9, 24, 35]. Table 2.1 illustrates activities in the flipped classroom compared to the traditional classroom, with and without blended learning. Bishop and Verleger [9] found student perceptions of the flipped classroom to be generally positive; while students preferred in-person lectures to video lectures, they enjoyed the interactive classroom activities over traditional lectures. De Grazia et al. [24] found that when courses used video, students were far better prepared compared to when students had been given reading assignments. Further, Sappington et al. [87] showed that

| | **Flipped classroom** | **Traditional classroom** |
|---|---|---|
| **Blended learning** | Pre-class lecture videos<br>Face-to-face activities | Face-to-face lectures<br>Mix of online/offline homework |
| **Non-blended learning** | Pre-reading textbooks or handouts<br>Face-to-face activities | Face-to-face lectures<br>Offline homework |

**Table 2.1:** Activities in the flipped classroom compared to the traditional classroom, with and without blended learning. Blended learning is the combination of face-to-face instruction with computer mediated instruction. One variation of the flipped classroom model uses blended learning extensively by implementing video to teach students before class.

college students generally do not complete pre-class reading assignments. The theoretical foundations used for justifying the flipped classroom model rely on reasons for using classroom time for student-centred learning, which look to the constructivist and cooperative learning theory from Vygotsky [95]. Vygotsky's zone of proximal development [95] states that when a student is in the zone of proximal development for a task, providing external assistance will aid the student in achieving said task. This constructivist view is considered the source of active learning [48]. In the flipped classroom model, activities that students perform in the class are intended to promote active learning, where students are encouraged to be more "interactive, constructive, and active" in their learning by "engaging in higher-order thinking tasks as analysis, synthesis and evaluation" [10]. These learning activities are designed to allow students to learn through experience, which is the basis for Kolb's theory of experiential learning [62], where students undergo concrete experience, reflection observation, abstract conceptualisation, and active experimentation.

### 2.1.3 The Role of Video in Active Learning

There are several frameworks that describe active learning (problem based learning [97], peer instruction [22], discovery learning [15], to name a few). Chi [18] provided the most operationalised framework that identified and delineated different levels of active learning and the effectiveness of learning in different types of learning activities. Chi [18] proposed a framework for three types of learning processes: active, constructive, and interactive learning, and derived a hierarchy of different types of activities that improve learning. Her later work focused on the Interactive, Constructive, Active, Passive (ICAP) Framework [19], which suggests that as learning activities go from "passive to active to constructive to interactive, students undergo different knowledge-change processes and, as a result, learning will increase." In her work, she provides examples of the four "modes of engagement": listening to a lecture without doing anything else is *passive*, taking notes in a lecture is *active*, asking questions and reflecting on the concepts is *constructive*, and defending or arguing positions is *interactive*. In the flipped classroom model, instructors make more effective use of face-to-face time with the students; students are to perform the passive activity of watching a pre-recorded lecture on video prior to class and more time can be spent in class doing interactive activities that ensure the concepts they learn before class are reinforced effectively.

However, due to conditioning from decades of watching cinema and television, watching video is a fundamentally passive activity. This default behaviour runs counter to the Interactive, Constructive, Active, Passive (ICAP) framework which says that more active approaches to learning are more effective. Work by Dodson et al. [27] extends the ICAP framework to video by introducing the Active Viewing Framework, which categorises video viewing behaviours for studying into ICAP behaviours. Examples of the behaviours in each category are shown in Table 2.2, which were drawn from literature and activity stream logs from a custom video player, similar to the one we will cover in Appendix A. To understand these behaviours would enable the design of videos and interfaces that promote a more engaging video learning experience.

### 2.1.4 Video in Massively Open Online Courses

A relatively recent approach to distance learning is online courseware, commonly called Massively Open Online Courses, or MOOCs. In 2001, MIT announced its OpenCourseWare initiative[1], prompting the beginning of many similar online

[1] https://ocw.mit.edu/about/milestones/

| Interactive Behaviours |
| --- |
| Communicating with others. |
| Cooperating with others. |
| Collaborating with others. |
| **Constructive Behaviours** |
| Making connections between learning objects. |
| Taking notes to record sense making. |
| Highlighting video content for future use. |
| Tagging video content for future use. |
| **Active Behaviours** |
| Browsing for general information. |
| Searching for specific information. |
| Triaging between learning objects, such as a video and a textbook. |
| Re-watching specific video content. |
| Pausing video content to reflect on the video content or engage in another viewing behavior. |
| **Passive Behaviours** |
| Playing video content. |

**Table 2.2:** The Active Viewing Framework by Dodson et al. [27] and the types of video viewing behaviours categorised by the ICAP framework by Chi and Wylie [19].

course systems such as edX[2], Khan Academy[3], Coursera[4], and Udacity[5]. In Khan Academy, for example, short educational videos were the main presentation method; instructors would record videos to be posted on YouTube, compiled together in a course format, and students would complete the course material asynchronously. Online learning made substantial disruptions in the way we teach, leading to a shift towards using new technologies for learning. In 2019, 23% of students surveyed by Kaltura, a video cloud platform, stated that more than half of instructors used video regularly in their curriculum[6]. Additionally, 58% of students in that study

[2] https://www.edx.org
[3] https://www.khanacademy.org
[4] https://www.coursera.org
[5] https://www.udacity.com
[6] https://corp.kaltura.com/wp-content/uploads/2019/07/The_State_of_Video_in_Education_2019.pdf

stated that they had used video for flipped classrooms, and 66% stated that they had used video in remote learning.

## 2.2 Analysis of Video Viewing Behaviour for General Video

There has been a significant effort in exploring video viewing patterns. For general entertainment video, Al Hajri [2] explored the viewing patterns of students watching YouTube videos in categories such as music, science and technology, entertainment, and sports. She categorised user actions into six different specific patterns: skip, re-watch, drop-off (not watching the video in its entirety), uninterrupted viewing, replayed the entire video during the same session, and revisited the video in another session. Zen et al. [99] took a machine-learning based approach and analysed mouse movements to predict the interesting-ness of a video (which was collected via an annotation task). For general entertainment video, they found that users often revisit and re-watch videos and are often searching specifically for parts of the video that they found engaging.

### 2.2.1 Behaviour Analysis Applications

There are many applications for understanding how users consume video. For example, some have used the viewing patterns of specific videos to detect important parts of video to create summaries [6, 81, 98]. Similarly, the use of video hot spots, searches, and drop-off points can be used to generate short accurate summaries of video [56].

## 2.3 Video Viewing Behaviour Analysis for Educational Video

Since 2010, a substantial amount of research has investigated MOOCs to promote distance education. With the courses being offered online, MOOCs have become a popular source of data for video behaviour research given the wide reach of MOOCs and their readily available datasets on user behaviour. The research on MOOCs fits into three broad categories: video viewing behaviour analysis, predicting performance based on behaviour, and visualisations for behaviour.

### 2.3.1 Video Viewing Behaviour

In most of the literature, researchers collect viewing behaviour data in one of two ways: leverage existing MOOC infrastructure which is already collecting data, or developing their own interface (which we do in Chapter 4).

Brooks et al. [8, 12, 14] discovered five types of learners: minimal activity, high activity, disillusioned (students who watch videos at the beginning of the course but will stop using it), deferred (students who watch videos near the end of the course), and just-in-time (students who watch only during exam review). Surveys with students revealed several reasons why students did not watch the videos: technical issues, unawareness that the videos existed, perceived lack of need, discomfort with online materials, or they only used it if they missed a class. Over 79% of survey respondents indicated that they did not "need" the video learning system, stating that the other resources provided were sufficient.

Giannakos et al. presented an investigation into clickstream activity peaks and their relationship to learning performance [42, 43]. In a small study with eleven students, they found that perceptually important video (as determined by a single question in a post-experiment survey) had more repeated views. Students who perceived that video to be important scored higher on tests. Oppositely, perceptually unimportant videos had lower viewing time and students who had lower viewing time scored lower on tests. Giannakos et al. also found that activity peaks were often associated with parts of the video with questions where higher-order cognitive skills were required. On a larger scale, their later work [44] analysed the behaviours of a flipped computer science classroom, and found video activity to correspond to video releases, assignment dates, and final exams. In Chapter 4, we investigate further into the students' perceptions of their studying behaviour as well as their exhibited behaviours during each phase of a course, and link behaviour to specific examples related to the contents of the video.

More recent works studying viewing behaviour have generally relied on MOOCs that have already been developed and are collecting students' behavioural data. Kim et al. [57], for example, investigated the drop-out rates and interaction peaks of students on edX. They found that in longer videos, students were less likely to watch the entire video, leading to higher drop out rates; according to Guo et al. [50], videos should be approximately 6 minutes long to maximise engagement in a MOOC environment. This is in contrast to Lagerstrom et al. [64], who found that based on viewing behaviours of standard college course videos, videos should be 12 to 20 minutes long. Kim et al. [57] also investigated peak interaction behaviours, and found five activities associated with peak interaction: (1) starting from the beginning of new material, (2) returning to missed content, (3) following a tutorial step, (4) replaying a brief segment, and (5) repeating a non-visual explanation. From these activities, Kim et al. [56] developed LectureScape, an interface that shows students' interaction peaks from other learners, as well as students' personal interaction peaks. The researchers tested LectureScape in a 75-minute study with 12 students and found that in all search tasks, LectureScape did not improve participants' speed in finding content they were looking for. However, participants indicated that they liked some of the extra features, such as visual previews and transcripts, but found the interface to be visually complex.

While Kim et al. [57] made some distinction between lectures and tutorial type videos, Ozan and Ozarslan [79] extended it further by examining how lecture length and lecture type, such as talking head videos, slide presentations, and interview-style videos, affected viewing behaviours. They found that for videos under 10 minutes, 58% of students watched the entire video, for videos between 10 and 30 minutes, the completion rate was 40%, and for videos longer than 30 minutes, the completion rate was 2%. They also found that students were less likely to skip around in interview-style videos compared to talking head or presentation style videos. Ozan and Ozarslan speculate that non-verbal information that can be gleaned from the body language of two people conversing may have been preferential to students, and also may hold more importance in courses on social sciences.

Another factor that affects viewing behaviour is the perceived difficulty of the content. Li et al. [69] looked at patterns of viewing and correlated students' thoughts on the difficulty of the material. The difficulty level of the videos was determined by placing a single survey question at the end of each video asking "How easy was it for you to understand the content of this video?". They analysed in-video interactions and found that for videos with more difficult content, students would play video slower at 0.75x speed, pause more frequently, pause for longer, search less often, seek longer distances forward, and replay more of the video. However, the contents of the video were not taken into account. In their later work [68], they found that stronger students skip and pause less frequently than weaker students.

### 2.3.2 Applications of Viewing Behaviour

There have been many approaches to analysis of MOOC behaviour using machine learning algorithms. Brinton and Chiang [11], Lemay and Doleck [66], Li et al. [68], Sinha et al. [93] utilised the abundance of data available from MOOCs (Coursera, edX, Coursera, Coursera respectively) to generate computational models that predict various aspects of video learning. Brinton and Chiang [11] used video-watching clickstream data (play, pause, rate change, seek) from Coursera to correlate behaviours with performance, which they then used to cluster similar students together. Lemay and Doleck [66] also used eight video viewing behaviours (videos watched per week, average fraction spent watching, average fraction completed, average fraction played, total pauses, average fraction paused, average playback rate, total fast forwards) to predict student assignment completion using several classification algorithms. They were able to generate a model that predicted whether a student would complete an assignment with 80% accuracy based on the eight viewing behaviours. However, due to the nature of these 'black-box' models, little explanation of the specific patterns of behaviour that predict assignment completion is reported.

Sinha et al. [93] took sequences of actions (playing, pause, seeking, etc.) to predict engagement, in-video dropout, and course dropout. They sequenced actions into n-grams of 4 to 5 and categorised them into actions such as re-watch, skipping, and increasing and decreasing playback rate. These features then characterised each of the three predictions. For example, high engagement was characterised by low skipping, high re-watching. Using these features to determine engagement and whether students were bored or challenged, they were able to predict engagement, in-video dropout and course dropout rates. This work brings more transparency to the types of behaviours that contribute to engagement levels of students.

### 2.3.3 Visualisations of Viewing Behaviour

Several researchers are exploring the creation of visualisations that can communicate students' video viewing information in a format that is understandable by instructors.

VisMOOC, by Qu and Chen [83], Shi et al. [91] aimed to help instructors analyse user learning behaviours by showing visualisations of clickstream data from Coursera. In particular, they found that instructors were interested in the following information: overall statistics for a video, interesting parts of a video to re-search, differences in behaviour between different user groups, and changes in learning behaviour over time, and factors that affect user viewing behaviour. Their task analysis revealed some information instructors wanted to know from the data collected by the online MOOCs. However, the report did not indicate why instructors wanted to perform these tasks, and how they would use the information to improve their teaching. The researchers then created several visualisations to address the tasks and presented them to MOOC instructors. The instructors commented that the system was easy to use, and they appreciated being able to more easily understand online learning behaviour from clickstream data. PeakVizor, by Chen et al. [16], further examined clickstream peak analysis. They produced a visualisation where instructors would be able to visually cluster different students by looking for a correlation between learner groups based on dropout time, grades and country, video activity, and forum activity. Brooks et al. [13] presented three separate visualisations to show how students watch videos throughout a course (temporal patterns), as well as compared groups of students (high scorers and low scorers). These visualisations showed that students exhibited certain patterns when watching video, specifically regarding increased skipping behaviour and increased watching activity as exam time approached.

### 2.3.4 Existing Video Feedback Systems

Other work has been done to incorporate methods for students to either discuss the videos or provide explicit feedback to the instructor about their learning. Monserrat et al. [74] presented an education environment called L.IVE (Integrated Interactive Video-based Environment for Learning), which provided students with the ability to discuss parts of the video with temporal comments (marked at a single time in the video). The L.IVE environment also included assessments included within the video. Kim et al. [58] introduced RIMES (Rich Interactive Multimedia Exercise System), which explored the use of interactive multimedia exercises embedded within lecture videos, with student feedback recorded using video, audio and sketching for the instructor to review later. Each video had self-contained exercises, and students used an annotation feature to answer questions, but no mechanisms were present for students to later review. Other researchers have explored student feedback about the videos. Glassman et al. [46] introduced Mudslide, a tool in which students to could identify which slides in a video they found confusing. Using this system, instructors would then review the feedback provided by students and alter their lecture accordingly. Instructors were provided with heatmaps denoting which slides students found confusing, and found the heatmaps to be more helpful than typical comments from students as part of class evaluation.

## 2.4 Video Navigation

The video player that students use to watch video is equally as important to consider as the video itself. The YouTube video player (Figure 2.1) is the most commonly used video player in current use. The YouTube video player is very simplistic with two essential parts: the main video view and the timeline. The purpose of the timeline is to allow the user to navigate to different parts of the video (e.g. to move forward to skip certain parts, or move backwards to re-watch parts of the video). These navigation tools allow users to watch videos non-linearly. In order to provide users with a preview of the video, YouTube incorporates dynamic thumbnails, similar to those found in work by Girgensohn et al. [45]. When a user moves the cursor over the timeline, the content of the thumbnail corresponds to the position of the cursor. This dynamic preview thumbnail provides the user with a good indication of where they would arrive if they clicked without actually having to search.

One of the primary uses of a video player is to support users' navigation of

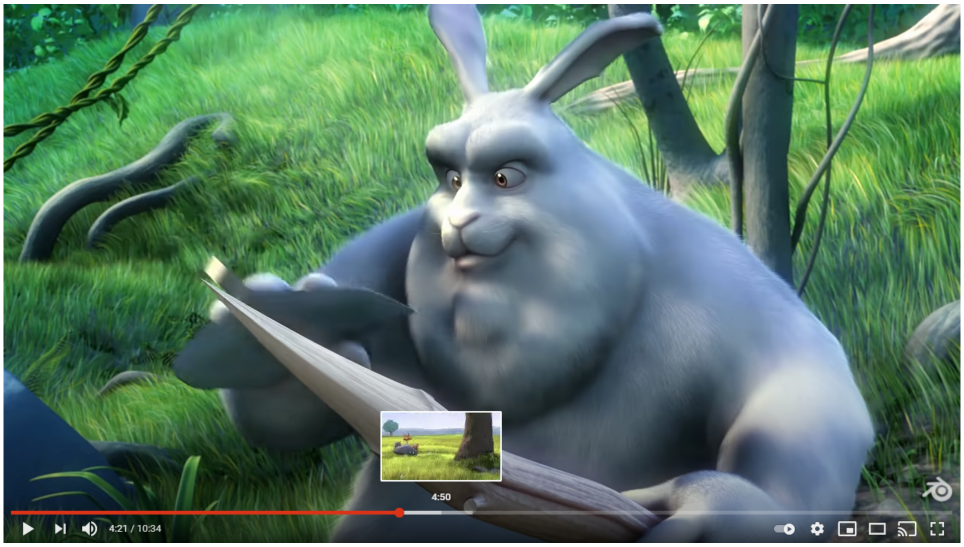



**Figure 2.1:** The YouTube video player shows the main video, and a timeline that includes a preview for users to know where they are searching. Screenshot © copyright 2008, Blender Foundation / www.bigbuckbunny.org. Used with permission.

the content. Navigating a video space, specifically for searching, can be mentally demanding and time-consuming, particularly with longer videos. There have been many interaction techniques proposed in the literature to support quick navigation and search of video content. The standard navigation tools used in most video systems use VCR-like (video cassette recorder) controls. These controls provide the user with the ability to move video time against its natural progression (forwards or backwards), which in turn supports the ability to search faster, rather than by watching at regular speed. As this method only allows users to go sequentially throughout the video, it is unsuitable when quick video search is needed.

An improvement to VCR controls is the chapter based system found in interactive DVDs. This menu-like system allows users to skip ahead to time points predetermined by the video creator. In most cases, chapters are represented by thumbnails showing the most important scene of the chapter. These thumbnails or previews, provide the users with a better snapshot of the contents of the video, allowing users to preview the video. This system is used in conjunction with the

VCR controls and helps reduce the amount of time that a user has to search linearly. Due to the reliance on the VCR-like controls, menu-like controls suffer the same problems; searching within chapters is cumbersome as it requires users to go through the video sequentially and otherwise provides no previews for the rest of the chapter. Furthermore, chapter locations are placed at the discretion of the video creator, which may or may not be useful for the user.

An improvement to the chaptering system was developed by Li et al. [67]. They allow users to create their own annotations in the video, thus creating a customised table of contents. This allows users to bookmark interesting parts of the video and create a chapter system that makes sense for them. Self-created bookmarks inherently make more sense to the user and the temporal location of such bookmarks is easier to remember, making non-linear search easier. We make use of manual annotations in video in the Video Highlighting study. The mechanism proposed in Li's work, however, intrudes on the video viewing experience and requires users to provide written descriptions for each of the bookmarks. Furthermore, there is no visual representation of the bookmarks, which requires the user to search through each bookmark to identify the actual contents. An improvement to this would be to give thumbnail previews for each bookmark, similar to the DVD chapter system described above.

Since video is a visual medium, providing visual previews can be an important part in enhancing video navigation. In the video systems developed by Christel and Moraveji [20] and Drucker et al. [31], thumbnail previews were heavily used to aid the user in search tasks. The system by Christel and Moraveji used thumbnails to display a storyboard of the video to aid in a search task. These thumbnails were keyframes extracted from the video automatically using text metadata already present in the video to separate clips from one another. This system relied heavily upon metadata to be previously embedded within the video, and made it an unlikely tool for searching in newly captured, or homemade video. Drucker et al., in their SmartSkip video player, allowed users to skip regular 30 second intervals, which were previewed to the user via thumbnails along the timeline. This extended the functionality of the skip-ahead button and allowed users to visually discern their destinations. We adopt this interface element design in ViDeX, allowing users to preview the sections of the video without needing to interact with it.

As the length of video becomes longer, traditional methods of displaying timelines has inherent problems. For example, in a very long timeline, representation of each particular time-step becomes too small to see, and by extension to use. Work by Hurst et al. [53, 54] introduces the ZoomSlider, which shows only part of the timeline, and allows users to shift the slider across the screen to search the video. The timeline is zoomable, and the granularity of search is dependent on the vertical mouse position, allowing for higher accuracy when searching in longer videos. Commercially, this multi-level searching functionality can be found in the Apple iOS (since iOS 3 [7]) default player. The zooming functionality, however, is not well liked as it hides portions of the timelines, impeding access to the entire video.

Another interesting method of manipulating the timeline was introduced by Kimber et al. [59]. They developed a system that allowed users to use direct mouse manipulation (i.e., dragging) to manipulate objects directly within the scene along their natural flow. They achieved this by preprocessing video using computer vision techniques to enable object tracking. Using background/foreground segmentation they were able to extract objects, and allow them to be draggable. For example, users could drag a moving car across the screen to control the flow of time in the video. In an example application, they showed objects with motion trails to indicate the direction of movement to allow for dragging. Dragicevic et al. [29] and Karrer et al. [55] used optical flow to accomplish the same task. Goldman et al. [47] set upon to improve the systems described above by providing support for partial occlusion in objects, motion grouping, and long-range accuracy of object tracking.

Divakaran et al. [26] proposed a method for quick video browsing by dynamically adjusting video playback rate. They used the compression information found in the video codec to evaluate motion. In places with low motion, the playback rate was increased. In places with high motion, the playback rate was decreased. Further work by Peker and Divakaran [80] introduced the same adaptive playback rate and included spatial-temporal complexity to the evaluation of scenes. High complexity resulted in lower playback rates, and lower complexity resulted in higher playback rates. Cheng et al. [17] extended the work, introducing SmartPlayer.

[7] https://en.wikipedia.org/wiki/IOS_version_history#iPhone_OS_3

They expand the previous works to include scene complexity, predefined scenes of interest, as well as users' preferences with respect to playback speeds. In addition, their system can also learn the users' preferred event types and the preferred playback speeds specific to the event type through manual intervention from the user.

Some research focuses on allowing users to utilise their navigation histories in video, much like those found in web browsers. Al Hajri et al. investigated the use of visualisations for navigational history made by users. For example, when users re-watch an interval of video, the interval is saved and shown to users as a possible interval of interest [3, 5]. This is a form of video annotation that relies on implicit behaviour of users. An application of timeline navigation is the work by Mertens et al., who introduced a histogram which overlayed onto the timeline. This system allows users to quickly discern parts of the video by the number of times the user viewed it personally and the number of times the part of the video had been viewed by the rest of the class [71, 72]. Results showed that with this option, students paid more attention to the parts of video that other students had previously visited [73].

## 2.5 Video Annotation

Several video annotation tools are available which allow users to mark-up video. Some video annotation tools are available commercially, while others are open source[8]. In general, video annotation tools can use many different methods of annotation, such as text, free-drawing, audio, or video. In research,video annotation tools have been designed for various devices, such as mobile [23], where a fingertip would interact with the video, and stylus based [84, 92], where the annotations would be carried out with a stylus. Others have studied collaborative annotation tools [1, 34, 85], and yet others have studied automatic annotation via computer vision techniques [47, 77]. However, the focus of the research in video annotation has been for general video. No literature was identified that described the implications of such video annotations systems in an educational context.

[8]https://atg.fas.harvard.edu/supported-technologies

## 2.6 Summary

The use of video in education extends back to the 1950s [21, 33, 40, 60, 78, 90] as a means for distance learning. Recently with widespread internet access, some instructors adopted the flipped classroom format [9, 24, 35] and used a blended learning approach [49], incorporating video with traditional assignments. The flipped classroom format encourages active-learning [18, 19] and active viewing [27], where students can be more engaged with video, potentially increasing learning outcomes [18]. The analysis of how the video is being consumed is an important aspect of using video for teaching and learning. In the non-teaching context, researchers have categorised different types of viewers based on re-watching behaviour [2], and identified level of engagement through mouse movements [99]. In the education sector, MOOC are a major driving force behind the adoption of video in education. The majority of analysis research on video viewing behaviour in education has been carried out using data from MOOCs [50, 56, 57, 66, 68, 69, 79, 93]. In these works, a significant effort has been made to categorise, predict, and simulate student viewing behaviour in an online environment. Yet, the students are anonymous and the classes are largely completely asynchronous. Prior to initiation of the Student study in this dissertation, no literature was found that analysed the studying and viewing behaviour of students interacting with video in a flipped classroom context.

From the instructor's perspective, researchers have studied visualising the data through analytic dashboards [13, 14, 42, 43, 61, 83, 91], with specific task analysis to understand what data instructors would like to see. Yet, no studies were identified that measure the information needs of the instructors. Finally, many methods have been developed to navigate in video: thumbnail previews [20, 31, 45], sliding timelines [53, 54], colour bars [7], content focused searching [29, 47, 55, 59], dynamic playback rates [17, 26, 80], and behaviour history navigation [3, 5, 56, 71–73]. These features are important to consider in understanding how students use video in their coursework.

The related work shows that there is a broad range of work on educational video, but there are gaps that are addressed in this dissertation. This dissertation contributes to three areas of research in this thread: (1) an analysis of the instructors' current practices of using video in their teaching, including strategies for creation, maintenance, and mitigation of the shortcomings of video, (2) an analysis of the different knowledge learning contexts and strategies students employ to study from video, and (3) a video annotation interaction that employs highlighting.

# Chapter 3

# Motivations for and Challenges with Teaching with Video

In this study, I explore why instructors choose to teach with video, the challenges they face when adopting video technology, the methods they used to ascertain video quality and determine if students have watched the videos, and the desired features for video analytics[1]. I targeted instructors who have used video to teach in a face-to-face classroom, rather than those teaching in fully online courses. Participants' ranged from new instructors to experienced instructors who have taught for more than 30 years across a variety of disciplines. Participants' continued use of video has given them insights about strategies for increasing engagement with the course content in, and outside the classroom. While instructors see many pedagogical advantages to using video, there are still aspects about learning with video they desire. For example, instructors find it difficult to obtain feedback about student perceptions of video effectiveness. Further, instructors are largely unable to view behavioural patterns in video use, which they believe could be used to improve their teaching. While instructors attempt to supplement these shortcomings with tools like personal response systems (PRSs), such as clickers, and end-of-term surveys, they still want to know more about how their students use videos. I interviewed 16

[1] In this study, I conceived of the study and carried out the interviews, D. Yoon (DY) supported creating interview questions, D. Yoon (DY), S. Dodson (SD), N. Harandi (NH), K. Seo (KS) were involved in peer debriefing and S. Fels (SF) provided feedback on the analysis and the manuscript.

instructors who have used video in their teaching, and thematically analysed the types of student feedback and analytics instructors want to see.

This study aims to answer the following research questions:

- What are instructors' experiences of using video for teaching? (Section 3.2.1)
- What do instructors want to know about their students' video viewing behaviours? (Section 3.2.2)

The purpose of this study was to document the current practices of teaching with video at a post-secondary level, including how instructors elicit feedback about their students' use of video and the impact of their videos on student learning. The findings were then used to identify the implications for designing a video learning analytics system for instructors that would satisfy their needs.

## 3.1 Study Design

I performed an interpretive descriptive study [94]. I used a phenomenologic approach [82] and interviewed 16 instructors to explore their perspectives on teaching with video. I used inductive content analysis [32] to analyse the interview transcripts, and identified three reasons instructors choose to teach with video, and three categories of evaluation of their videos that instructors desire.

### 3.1.1 Participants

I used both a purposive and convenience sampling technique to recruit instructors. In particular, I used typical case sampling [82], to highlight a typical instructors perspective on teaching with video. Participants were eligible for participation in this study if they had taught a post-secondary level course and used video in their teaching. I was previously in contact with P1, P2, P3, P4, P8, and P9 (where *P* stands for *participant*) for another project, and recruited them by email and word-of-mouth. The remaining participants (P5, P6, P7, P10, P11, P12, P13, P14, P15, P16) were found in a directory that listed instructors using in flipped classroom activities at UBC. I recruited the participants in that list by sending them an email invitation. If they agreed to participate, I set up a time during working hours to meet in their office. After interviewing approximately thirteen participants, I reached

| ID | Age | Subject | Teaching Experience | Class size | Source of videos |
|---|---|---|---|---|---|
| P1 | 50–60 | Chemistry | 28 years | 10–30 | Self created |
| P2 | 50–60 | Chemistry | 15 years | 10–30 | Self created |
| P3 | 40–50 | Chemistry | 4 years | 25–50 | Online, self created |
| P4 | 40–50 | Chemistry | 18+ years | 10–30 | Self created |
| P5 | 30–35 | Computer Science | 1 year | 80–100 | Premade course videos |
| P6 | 40–50 | Electrical Engineering | 20+ years | 30–50 | Self created |
| P7 | 40–50 | Computer Science | 10+ years | 80–100 | Self created |
| P8 | 50–60 | Electrical Engineering | 20 years | 80–100 | Self created |
| P9 | 40–50 | Philosophy | 20+ years | 100–150 | Self created |
| P10 | 40–50 | Physics | 16 years | 80–100 | Self created |
| P11 | 30–40 | Biology | 9 years | 100–150 | Online, Self created |
| P12 | 40–50 | Nursing | 30 years | 100–150 | Online, Self created |
| P13 | 50–60 | Computer Science | 33 years | 220–325 | Self created |
| P14 | 50–60 | Business | 18 years | 100–125 | Self created |
| P15 | 40–50 | Political Science | 25 years | 100–150 | Self created |
| P16 | 50–60 | Linguistics | 24 years | 150–200 | Self created |

**Table 3.1:** Summary of the participants' information.

data saturation where the data became repetitive with no new codes emerging [75, 88]. I interviewed three more participants to ensure that data saturation had been reached [82]. Participant demographics are listed in Table 3.1.

P1, P2, P3, and P4 all taught introductory chemistry at a local post-secondary institute, where class sizes ranged between 10 and 30 students. These courses had videos that consisted of step-by-step directions on determining the number of significant figures in a calculation, laboratory demonstrations, laboratory techniques, directions on how to write-up laboratory reports. In these classes, the instructors encouraged students to watch the laboratory report videos; other videos were optional and treated as extra material. One of the instructors used three additional videos that students watched instead of attending a live lecture. The instructor assigned a worksheet to go along with the video that the students were to complete and hand in for participation marks. The videos were designed so that students could go through example problems including suggestions to the viewer that they pause the videos and work through the problem themselves. All videos in the courses had been created by the instructors themselves within the two years prior to the interview.

P5, P7, and P13 taught an introductory computer programming course that used an entirely *flipped classroom* style, with class sizes of around 100 students. Using the *flipped classroom* approach, instructors would assign a lecture video to be watched before class, and the face-to-face class time was devoted to active learning exercises. During the face-to-face class, the instructors would use Personal Response Systems (PRS), or clickers, and ask students questions about the videos. They would then distribute exercise worksheets for the students to complete during class. During the exercises, the instructors and teaching assistants would walk around the class to gauge the students' understanding of the material. At the completion of the exercise, students submitted their worksheets for grading.

P6 and P8 taught electrical engineering courses with class sizes of around 40 students and 80 to 100 students, respectively. The students in the class taught by P6 had a weekly video to watch before class, and they attended class where the instructor would go through example problems from the videos. P6 would also use the PRS and ask students simple problem questions in order to get an understanding of students' comprehension of the concepts. P8 asked students to watch his lecture-style videos before class. The instructor would then use face-to-face time to review through the material again, giving students a second exposure to the content. P8 used an online PRS system to both keep the class time interactive and as a way to gauge topics that were confusing to the students.

P9, P15, and P16 taught arts classes with up to 200 students. The instructors used video to introduce materials, and the students would come to class and perform activities like writing a position essay, writing a speech, or participating in a debate. The videos were used mainly as a supplement to better explain any materials that were "*not that easy to read.*" P9 and P16 also used a PRS system as well as slides to carry out classroom activities or lecture.

P10 and P11 taught science courses (physics and biology), with class sizes of around 100 to 120 students. P10 used videos that were problem based and the students were expected to watch the videos before class. The lecture time was then structured with short introductory explanations, and the rest of the class time would be structured around completing problems. P11 used video in lieu of pre-reading material, where she had previously used scientific articles that students could access through the online library. She indicated that she would first look for videos online, and if there were no appropriate videos, she would create them herself. She would then make extensive use of PRS systems, quizzes, and class discussion of problems during the class time.

P12 taught in the nursing program, and videos were used to demonstrate clinical nursing skills. Students were expected to watch the videos before class, but they were also allowed to watch them immediately before performing the clinical skills in the labs as a method of referencing the material.

P14 taught marketing courses with class sizes of around 100 students. Students were assigned to watch one video and read two articles before class, which were then used for individual or group activities.

### 3.1.2 Procedures and Data Collection

Prior to recruitment and data collection, the research procedures were approved for use with human subjects by the UBC Behavioural Research Ethics Board [Certificate #: H13-01589]. Informed consent was obtained from all participants. All interviews were audio-recorded and transcribed verbatim. The interviews were conducted in the instructors' office, as the settings were mostly quiet and the risk of interruptions was minimal which allowed for better audio recording. The interviews lasted between 25 and 60 minutes. The interview was semi-structured, with a set of questions that were generated by myself and DY. We generated the questions by decomposing the research questions into more easily answerable components. We asked the instructors how they taught with video, how they obtained feedback from students about their videos, and the challenges they faced when teaching with video. See Appendix D for the questions.

### 3.1.3 Data Analysis

I used inductive content analysis [32] to analyse the data. I read the first two transcripts and coded each statement from the participants in a spreadsheet. These codes were then used to name categories of summarised statements, for example, the code "I rarely get feedback about the videos afterwards" was sorted into a category named “Evaluation of Video Quality”. These categories were then used to identify the overarching themes. After open coding of the first two transcripts, I coded the next five transcripts (and recoded the original two) using these codes and added new codes when the data did not fit into an existing code. This process was then repeated for transcripts of the last nine participant interviews. Once all transcripts had been coded, I summarised and described each category and theme.

### 3.1.4 Rigour and Validity

During data collection, instructors were asked to elaborate on their experiences as well as verify my interpretations of their explanations as a form of member checking [82]. Additionally, I had weekly peer debriefing [82] sessions with the research group (DY, KS, SD, SF) to verify and validate my interpretations of the emergent themes and categories from the interviews.

## 3.2 Results and Discussion

Several patterns and themes emerged about why instructors taught with video, as well as how they evaluated how the students watched the videos including how instructors evaluated the quality of the videos themselves. While there was a mix of experience in using video to teach amongst participants, the reasons for using video and activities for evaluation of video converged into two main themes: Why instructors teach with video, and How instructors evaluate students and video quality. These are summarised in Table 3.2 and discussed in the following subsections.

| Themes | Categories | Prototypical Statements |
|---|---|---|
| Why instructors teach with video | Effective use of classroom time | “*...so that they’re not just looking at it cold [and] we’d rather the time that they’re standing in the lab be time that they’re actually [doing] hands-on [work].*” |
| | In-class engagement | “*They are asking me questions about the topics that before I would get only from the very best students.*” |
| | Personalisation and motivation | “*But I found actually, that students like the grittiness ... This isn’t slick, it’s just the professor at home or in the office, and they’re shooting a video for me.*” |
| How instructors evaluate students’ use of video and video quality | Evaluation of Student Activity | “*Sometimes it’s like, ‘So, did you watch the video?’ and they’re like ‘Yup.’*” |
| | Evaluation of Student Literacy | “*I would be able to look at the worksheet and see how far they got.*” |
| | Evaluation of Video Quality | “*What would be helpful probably is to know whether it was better than reading it in a book, or whether it amplified what they read in a book or an article.*” |

**Table 3.2:** Summary of the types of themes, categories, and prototypical statements made by instructors about teaching with video.

### 3.2.1 Why instructors teach with video

There are several reasons for instructors to use video in their teaching over text-based alternatives. Instructors perceive that video is more engaging to students and that higher engagement levels lead to higher learning outcomes. They perceive that video provides the ability to use animations, which can illustrate some content better. Video can be more easily accessed compared to textbooks. For example, students are less likely to carry a heavy textbook to class, and therefore forego the opportunity to study while commuting, whereas with video, a student could watch the video while on the bus or train. Videos support students who are learning English because students can replay a part that is difficult for them to understand. Finally, video is perceived to be better than a lecture because of its permanence; P12 stated "*the advantage of the video is it is a permanent thing... you can watch that as many times as you want.*"

Instructors indicated that when used in a blended learning/flipped classroom format, video is advantageous because class time can be used for students to perform activities that promote active learning. These activities enable students to apply knowledge that was acquired outside the classroom (i.e., in the pre-class video), onto the discussions, simulations, and scenarios that occur in-class; that is, they are able to apply the experiential learning model popularised by Kolb [62]. However, instructors indicated that this model is sometimes met with resistance from the students. P16 states that they "*were really skeptical about it, because... they felt... 'I'm paying, and you're supposed to instruct me'. And they didn't see the benefit of learning by discussion. So they thought, well, we paid for this, and now we have to do something outside the classroom.*" Over the years, however, students have become more accepting of this style of teaching and video has become more commonplace.

#### 3.2.1.1 Effective use of classroom time

As mentioned above, one of the more powerful aspects of using video for pre-class lectures instead of in-class lectures is that class time can be spent on activities that require an instructor's guidance. These activities vary for different disciplines. In their chemistry courses, P2, P3, and P4 used videos to increase the amount of time that students could perform their laboratory activities by limiting the amount of time spent on pre-lab activities. P3 states that "*it would be most useful... preparing before they come to the lab, and so that they're not just looking at it cold [and] we'd rather the time that they're standing in the lab be time that they're actually [doing] hands-on [work].*" These instructors used videos instead of providing a demonstration, because they believed that not only would each student see the same thing, but video allowed students to re-watch it if they desired. Unfortunately, instructors had no way of enforcing students to watch the videos, and given the safety implications in the chemistry laboratory setting, live demonstrations were still being performed in class.

#### 3.2.1.2 In-class engagement

In addition to being able to spend classroom time more effectively, instructors also found that students tended to have a better understanding of the material if they watched the videos. Several instructors found that students had more in-depth questions about the material. P15 stated that "*it just takes their learning to a higher level, and then the instructor's satisfaction to a higher level because now I can speak <u>with</u> them, not <u>to</u> them, at a much higher level. ... It's a conversation that, is much more sophisticated and developed because I'm not spending my time in the class giving them the basics.*" P8, who assigned videos to be watched prior to class and repeated his lecture in class, found that the students "*develop way deeper questions [and] are not asking basic understanding questions anymore. ... They are asking me questions about the topics that before I would get only from the very best students.*"

#### 3.2.1.3 Personalisation and motivation

While the alternative to video is getting students to read articles, books, or book chapters, instructors indicated that video is a more motivating activity for students to do at home due to the humanizing aspect of being taught by an instructor. "*This is the instructor, and I'm learning from the instructor while I'm watching this video. There's something human about that, that you don't get if you read the book.*" P8 stated that a very important part of teaching is establishing trust between instructor and student. To do so, P8 would "*use [their] face in front of a camera to establish the personal link with the viewer, to gain their trust, to sell the importance of what [they were] going to teach. After [they] have done that selling part, show only the content.*" This presents the students with a face to attach to the voice of the narrator. P8 further elaborates that once that trust has been established, the talking head can be removed.

One of the instructors stated that students are more likely to watch videos that are personable. P16 stated: "*But I found actually, that students like the grittiness. It's more authentic. They kind of get, oh okay, there's no production values here. This isn't slick, it's just the professor at home or in the office, and they're shooting a video for me.*" The fact that the instructor had created the videos motivated the students to watch the videos. P15 described that professionally created videos are less authentic, and students tend to "connect" more to a video that was purposely created for the students. "*[The professionally-created videos are] just not as approachable. It's not as informal, it's not like this is my professor, this is like someone shooting a video it could be for anybody. Right? But the other videos, no, it's clearly for me. He's shot this for me. And they're right, I have. And I think that's something the students picked up on.*" The finding that personable, self-made videos are more engaging, complements existing work on how video production affects students' interaction with instructional video [50].

### 3.2.2 How instructors evaluate students' use of video and video quality

While instructors had many motivations for teaching with video, it was difficult for them to fully assess the use and usefulness of their videos. The types of questions that instructors have about their videos can be separated into three categories: Have the students have watched the video? Did students comprehend the content in those videos? And how useful are the videos? There are various ways that instructors have attempted to answer these questions.

#### 3.2.2.1 Evaluation of Student Activity

One of the most common questions instructors have in regard to their students is "Did my students watch the videos I assigned?" Student viewing activity can be divided into two groups: aggregating and summarising all student activity, and examining individual students-level activity.

*3.2.2.1.1 Aggregate Student Activity* Summarising and aggregating student activity can be a very useful tool and would allow instructors to quickly gauge how their students are performing in the class, and what the instructor needs to focus on during the lecture. Instructors currently employ three different methods for determining if the students watched the assigned videos: simply asking the students during in-class time, assigning worksheets for students to complete while watching the video, or polling the class and testing their knowledge using PRS. The first method typically results in a small proportion of the students responding and has generally not been useful in determing whether or not students watched the video. P3 stated "*Sometimes it's like, 'So, did you watch the video?' and they're like 'Yup.' And I can't tell if they're telling the truth or not.*" The PRSs were similarly ineffective; P5 stated that with "*the clicker questions where you get a fraction of students that are getting it right. Like I get a general fraction of students who are watching the videos, but I don't know if that's consistent, I don't know how they're watching them.*"

Students' assignment scores gave instructors not only an indication of how many students had watched the video but also gave insight into how the video was consumed by students and answers the questions "Where did the students have trouble?" and "Where do I need to focus more on the lecture?" The answers to these questions are indicators of difficult areas in the video, which was of interest to the instructors. For instructors who have been teaching their material for a long time like P1, this only serves as an affirmation that some parts of their courses are challenging for students to comprehend. P1 stated, "*the years I've been teaching the same course outline [helped] a lot. ... I learned how to pace the course. I learned how to deliver the concept year after year. ... You understand where students will not understand or [where they will] make mistakes.*" For newer instructors, such information would be invaluable.

*3.2.2.1.2 Individual Student Activity* There were two main reasons that instructors wanted to look at individual student activity. First, an instructor may be interested in the amount of effort that a student is putting into the course. Similar to where instructors may provide leniency on marking examinations by looking at the amount of effort a student has put forth in their prior assignments, an instructor can add criteria to further evaluate a student. P6 stated that "*if you get a student who is having some problems and so on or is, there's academic concession request or there's something like that, I look to see, 'Has the student been active in the course?'*"

Similarly, some instructors were interested in whether individual students were having difficulties with the material. P2 mentioned the use of an analytic dashboard for online assignments that he used to evaluate individual student performance. Using this system, he was able to look at individual questions on each assignment to see which questions were done well and which were not. P2 then found that sometimes questions were not written well by him and contributed to poor performance by the students. By interpreting data like these, instructors can draw conclusions about their own teaching and find ways to improve. Similarly, analytics on how students are viewing a video can be interpreted by instructors to improve their videos or notify less experienced instructors about issues in the course.

#### 3.2.2.2 Evaluation of Student Literacy

In a flipped classroom, students are expected to have completed the pre-class activities prior to class. Instructors hoped that the students had some previous literacy in the topics at hand, which would help the students participate in more in-depth discussions of the topic. By measuring students' literacy of topics, instructors can utilise time more efficiently and focus on more complex topics. Several of the instructors in this study used worksheets that accompanied the video, clicker systems, discussions, as well as in-class assignments.

A common method for gauging student comprehension and literacy is through the use of PRSs which allowed instructors to pose questions to the class. In this format, each individual student is tasked with both discussing a solution to the problem with a neighbouring student, and then providing their own answers using the PRS. When instructors use PRSs, they can see the proportion of correct answers in the class. This served not only as a way to increase visibility about where students were having difficulties but also increases engagement with the material [70]. For example, P5, P8, P13, and P16 used PRSs to assess how well students understood the pre-lecture material. Instructors would then look at the results of the question and decide whether or not they needed to review the material during class time.

Other instructors used worksheets as a way to gauge students' understanding of the video content. P1 paired the videos with worksheets that students completed while viewing the videos. The videos were designed to guide students through the worksheet on a step-by-step basis. The worksheets themselves did not count towards the students' grades, but the instructor provided feedback on the worksheets so that students would have a sense of how well they understood the material. The instructor, in turn, was also able to identify which students had actually watched the video and applied the knowledge, as well as identify topics that needed further reinforcement. Instructors would also frequently stage discussions during which students were asked to break into groups to discuss a problem posted by the instructor. While students were in break out groups, the instructors and teaching assistants would walk around the classroom and answer questions or coach students who were having difficulties with the problems.

With these practices, instructors must pay close attention to the students' activities during the class and must devote class time evaluating students' literacy of the material. Although instructors are teaching with video, data related to viewing the videos were not being used to help instructors understand how their students are consuming the material and whether students understood the content in the video.

#### 3.2.2.3 Evaluation of Video Quality

Most instructors were interested in the students' opinions of the videos, more so if the instructor made the videos themselves. Instructors are interested in the comparison of video to textual mediums, especially with the students' perceived effectiveness of video as a learning tool.

There were two main methods that instructors in this study employed to evaluate video quality: end-of-semester surveys distributed by the institution, and informal conversations with the students. Institutional end-of-semester student evaluations of teachers are voluntary at the two institutions where participants worked. Unfortunately, only a small proportion of students complete the institutional surveys and are therefore not a valid and reliable form of feedback. Furthermore, some students feedback is not constructive. For example, P8 stated that some students complained about his voice in his videos. P14 received feedback from the students "*that they liked the t-shirt I was wearing, or that my accent was strange*". Feedback that the instructor thought was nonconstructive was disregarded by instructors.

Instead, instructors wanted feedback about the following: (1) Did the video present the topic clearly? (2) Did students comprehend the complex topics? (3) Is video better than text for this topic? (4) Do the students take video as seriously as lecture? (5) Did the videos spark the students' curiosity? (6) What are ways to make the video more interesting and more engaging? In order for video to be useful in teaching, the students need to find value in watching it. P14 described that "*there is a level of edu-tainment in here. We're trying to engage and excite people in a way which means that it's not purely about knowledge transmission*". By creating a video that is entertaining and engaging, instructors hoped that students would be more intrinsically interested in the topic at hand.

Every instructor stated that they would take student feedback into consideration when doing subsequent teachings of the course. The level of action could include: editing the video, completely remaking the video, changing the activities associated with the video, and completely replacing the video with other learning materials if they found that using video was not appropriate. All instructors also emphasised that creating the videos was not a trivial task. Yet, all stated that, should the need arise, reworking the video would be something that would be worth the effort.

### 3.2.3 Design Implications

In this section, design implications of interfaces that could aid instructors with the questions that they have about their students and their video viewing activities is presented. A summary of these design implications can be found in Table 3.3.

#### 3.2.3.1 Aggregate Student Activity

Questions like "Are my students watching the videos?" and "Where are my students getting stuck?" could be answered with analytics that would show whether students are watching the video, how active they are, as well as areas of interest in the video which could be indicated by an excess or lack of activity (e.g., amount of watches, pauses, or searches at a particular point in the video). This concept is similar to the kind of dashboard P2 described which allowed them view averages of student performance on online assignments.

#### 3.2.3.2 Individual Student Activity

Similar to showing aggregate student activity in analytics, allowing instructors to drill down to see individual student activity would also be an option to help instructors evaluate their students.

#### 3.2.3.3 Evaluation of Student Literacy

Since instructors are already evaluating student literacy by implementing quizzes in class, a simple solution would be to embed the quizzes within the video, similar to work by Kovacs [63]. This would allow instructors to offset the evaluation of student literacy to pre-lecture, thus creating more time for in-class active learning activities. The behaviours that students exhibit while watching video could also be summarised, which would provide insight into difficulty of the video content. For example, parts of the video that are frequently re-watched might indicate content that is either confusing, complex, or interesting. Areas of the video where students pause frequently may be portions of video that are difficult to understand, and require students to spend more time processing. Simple counts of how often a section of video has been viewed could indicate which topics to focus on during the face-to-face time.

| Categories | Questions | Design Implications |
|---|---|---|
| **Evaluation of Student Activity (Aggregate)** | Did the students watch the video? | Show number of students who have watched the video |
| *How much time do I have to spend on each topic in the lecture, and where should my focus be?* | Where did students watch the video the most? | Show parts of the video that students watched most [57] |
| **Evaluation of Student Activity (Individual)** | Is this student putting effort into the course? | Show if a student has watched videos, and how much |
| *Does this student need extra help, and why are they having trouble?* | Are students having trouble with the material? | Show irregularities in watching behaviour per student |
| **Evaluation of Student Literacy** | Did the students learn the material? | Have in-video questions and quizzes |
| *Do the students understand the material, and which topics are most confusing for students?* | Which topics in the video were confusing? | Automatically summarise and interpret video viewing behaviour |
| **Evaluation of Video Quality** | Were the videos useful for students? | Show video watching behaviour across time [51] |
| *Are the videos appropriate for teaching these topics, and how can they be improved?* | What can be improved in the videos? | Have students submit feedback directly on the video [28, 46, 74] |

**Table 3.3:** Summary of the types of questions instructors have and design implications for each question.

#### 3.2.3.4 Evaluation of Video Quality

Being able to see the chronology of when students were watching the videos might allow instructors to better interpret whether the videos were useful. For example, videos that are watched twice (e.g., once when the video is released, and once just before the final exam), could be considered more useful than videos that have been watched once and never again. Similarly, a video that has been watched and re-watched many times might be considered as more engaging than a video where the majority of students skip around. The ability to view data like these could be used to guide decisions about when to use video, and which videos appear most useful to the students.

### 3.2.4 Summary

To summarise, video can be powerful tool that shifts the basic learning from inside to outside the classroom, thus allowing more effective use of classroom time with more interactive learning activities. While the flipped classroom model is not a new concept and has been previously used with textbooks, the medium of video provides a more engaging experience and students are more likely to watch a video lecture before class than read a book. The challenges with effectively using video lie in determining how students are using the videos, whether the students understood the material, and determining whether the videos were appropriate for teaching the material. Instructors have a number of workarounds to determine if videos are effective, most of which involve using classroom time to evaluate the videos and the students. Some of the information desired by instructors could be obtained by creating analytic systems to help summarise students' use of video learning.

However, the ability to look at students' individual viewing patterns and behaviours would currently require access to students' browser data, which opens a host of privacy issues. While instructors are privy to student behaviours within a classroom, or student performance on assignments and examinations, being able to closely observe students working at home may violate privacy laws. However, some possible solutions might be to create a permissions system, where students would be able to control the visibility of their own behavioural patterns, or an anonymizing system that allows instructors to see behaviours but not be able to pinpoint which student is responsible.

## 3.3 Limitations of the Study

The instructors we interviewed are from two Canadian post-secondary institutes (UBC and BCIT) who have used video. As such, these observations are strictly from the views of instructors in the educational sector. Participants were also experienced in teaching at a post-secondary level, and the observations and conclusions may not apply to kindergarten to grade 12 education.

The majority of instructors' videos were self-created. Most instructors found videos on the internet to be insufficient for their classrooms and thus opted to create their own videos. Due to budget constraints, except for P14 and P15 (who were able to have the university studio aid in creating one or two videos), the videos were largely created by screen-capture of a slide presentation with a voiceover recording. However, it should also be noted that P15 preferred the non-studio quality approach, citing that the students "connected" more with the videos that were produced with low production values.

Finally, except for P9, P14 and P16 who taught philosophy, business, and linguistics, respectively, the majority of the instructors interviewed taught science-based subjects that were practical and much of the video content was based on demonstrating procedures (i.e., problem-solving examples, scientific experiment procedures). Further work would include instructors from more varying disciplines where the videos are more information-based or theoretical.

This work summarises the perceptions that instructors have regarding their needs on teaching with video in the classroom. Further work should be done to associate these perceptions with the observed practices and effects of teaching with video.

## 3.4 Conclusion and Future Work

We studied and articulated several reasons why instructors use video to teach and the strategies they use to evaluate their students and the videos. The use of video is advantageous because instructors are able to take a hands-off approach to introduce material and shift it to the students' "homework" time. The extra time spent in class can then be spent performing activities that demonstrate deeper learning. Instructors who teach with video are also looking for information about the students' use and perceptions of video, which we split into activity, literacy, and video quality. Instructors are interested in each of these to create strategies about how best to teach their topics. If instructors were able to gain an in-depth analysis of student video watching behaviour through an analytics dashboard, and accompanied by some careful interpretation, they would be able to answer many of the questions about the status of their students' behaviour with the material.

The task of increasing the visibility of student learning behaviours using video and simplifying the data down to "Did the student understand the concepts in the video?" does not have an easy solution. To further investigate video viewing behaviour, we developed a video player interface for students to use, to not only aid students in studying with video, but also allowed us to record their behaviour for further analysis (Chapter 4).

# Chapter 4

# Student Video Navigation Patterns in a Blended Chemistry Class

In this chapter, we[1] investigate the video viewing strategies students employ when studying from video in a post-secondary level chemistry course. In Chapter 3, we found that instructors were interested in understanding how their students watched videos to prepare for class. In this study, I collected students' video viewing behaviour in a multi-cohort descriptive study to determine how students watch videos, such as the specific strategies they employ in different learning contexts. To do so, I developed a custom video viewing application (which is described in Appendix B), that recorded students' video viewing behaviours, which I deployed to a post-secondary level chemistry course for five semesters over three years.

Previously, Al Hajri [2] investigated the viewing behaviour of videos available on YouTube, and identified various behavioural patterns, the most prominent of which was liberal use of rewinding and skipping to find and re-watch content. For

[1] In this study, I was responsible for concept formation, literature review, interface design and development, data collection and analysis, and manuscript composition. G. Miller (GM), X. Zhang (XZ), I. Roll (IR), C. Hendricks (CH), and S. Fels (SF) were involved with interface design discussions. G. Miller (GM), X. Zhang (XZ), I. Roll (IR), S. Sunani (SS), S. Dodson (SD), K. Seo (KS), N. Harandi (NH), D. Yoon (DY), and S. Fels (SF) were involved in peer debriefing. For the purpose of this study, I will use the term 'we' when others were involved in the project.

educational video, Kim et al. and Guo et al. studied the interaction peaks of video and found that many peaks occurred at visual transitions [50, 56, 57], most notably when instructors change slides in their presentations. However, no studies were identified that reported on how viewing strategies relate to content and knowledge learning contexts. In this study, I investigated how students watched videos in a post-secondary class with the following research questions:

1. What are the knowledge learning contexts associated with learning from video? (Section 4.2)

2. What behaviours do students exhibit in each context and what specific strategies do students use? (Section 4.4)

3. Do students focus on specific parts of the video when watching? (Section 4.5)

In the investigation of the behavioural patterns of students using video in a post-secondary single semester chemistry class, I identified three knowledge learning contexts:

1. *Introduction*: The first time students are presented new material.

2. *Reinforcement*: The subsequent visits that students make to material to ensure their understanding of the material.

3. *Demonstration*: The subsequent visits that students make to the material because of external goals such as completing an assignment or reviewing for an examination.

I then explored whether students exhibit different behaviours when they are in different knowledge learning contexts. I confirmed that students' viewing goals and strategies are often affected by the classroom context, such as the amount of effort that they want to put into an assignment and the course in general. I also found that students spend their video activity towards the extrinsic goal of achieving a good grade rather than towards an intrinsic desire to learn the material. This motivational dichotomy impacts how students optimise their video activity strategies within different contexts, for example, non-linear viewing through video search becomes more prevalent when students are in a *Demonstration* context.

## 4.1 Study Design and Overview

I performed a three-year multi-cohort descriptive study where I observed the video viewing behaviour of students in a post-secondary single semester chemistry classes during 2017 to 2019. I used an exploratory sequential [82] design with two data collection methods. First, the students were provided with ViDeX, a custom video player described in Appendix B, which could log the actions they performed while watching videos assigned for their class. Then, during a qualitative phase, a subset of students who had used the ViDeX system in their class were interviewed to provide contextual understanding of their video studying strategies. For quantitative analysis, I created activity trace data by using the log files captured during the students' use of ViDeX. Finally, I qualitatively analysed the activity trace data to characterise students' video use patterns based on the findings from the qualitative interviews.

### 4.1.1 Course Structure

The chemistry course that was studied is part of the Technology Entry (TE) program[2] at the BCIT. The students in the TE program took introductory chemistry, physics, mathematics, and computer applications courses. The chemistry course covered topics such as "Separation Techniques", "Energy Accompanying Reactions", and "Acid-Base Titrations", among others. Each semester (from January to May for the spring semester and September to December for the fall semester), two concurrent sections were offered. In the years that we ran the study (2017, 2018, and 2019), the courses were co-taught by three instructors; each had at least 15 years of teaching experience teaching chemistry at a post-secondary level (P1, P2, P4 from Table 3.1 in Chapter 3), except for the second term in 2019, which was taught by a fourth instructor who had four years of teaching experience (P3 from Table 3.1 in Chapter 3). The instructors created the videos in 2016 for use with ViDeX. For each video, a transcript was created by the instructors. Contact hours

[2] https://www.bcit.ca/programs/technology-entry-te-full-time-0020nobcit/

with the students were as follows: each week, students were expected to attend three hours of lecture, one hour of tutorial, and two hours of laboratory experiments. There were a total of nine laboratory experiments, and each had a corresponding video that students were given to watch the week before they performed the experiment. Students also had online calculation-focused assignments due two days after each lab experiment, and two midterm exams: one after Experiment 5, and one after Experiment 8.

The laboratory and video schedule was as follows: the video for Experiment 1 was released on ViDeX two weeks into the course (which we designate as day 0). Seven days later (day 7), students performed Experiment 1, and video for Experiment 2 was released to the students. Seven days after that (day 14), the report for Experiment 1 is due, students perform Experiment 2, and the video for Experiment 3 was released, and this pattern continues for nine experiments. The course format is cumulative; concepts presented in the course build upon each other as the semester progresses and students are expected to utilise the laboratory techniques, problem-solving skills, and calculations they learned earlier, throughout the course. The first four experiments focus on basic laboratory techniques and ask students to answer questions that are qualitative in nature, requiring little to no numerical calculations. After that, the students are taught how to perform more complex experiments that include learning about chemical reactions, how to use the formulas to perform numerical calculations, as well as a focus on the reasoning for certain procedures.

The nine videos of the laboratory experiments were created solely by the three instructors in the year prior to their deployment (i.e. in 2016). The instructors created the slides using Microsoft PowerPoint, created a script that they would read during each video, and screen-recorded a voice over as they went over the presentation. Each video ran between three minutes and 12 minutes and were all similarly structured. They each featured a title slide, an introduction to the topic, concept instruction, practical application, concept questions, a laboratory report writing guide, and a final 'The End' slide. The first four videos presented basic laboratory techniques and were qualitative in nature, showing students how to take measurements using different tools and how to separate chemicals. The last five videos involved computation-based methods for determining percent composition of chemicals, calculating concentrations and percentage error. For each video, the slides were categorised based on their titles ("Review", "Lab Questions", "Observations", "Conclusions"). Slides that did not have those titles were always concept instructions, which were subdivided into two categories: diagram/image-based, and text-based.

### 4.1.2 Participants

Prior to recruitment and data collection, the research procedures were approved for use with human subjects by the UBC Behavioural Research Ethics Board [Certificate #: H13-01589] and British Columbia Research Ethics Board [REB Number: 2016-19] which covers BCIT. In this field study, I used a convenience sampling technique [82] and recruited students from five semesters of the first-year chemistry class described above. I coordinated with the instructors in the course to collect video viewing behaviour from the students by distributing ViDeX for use in their classes. Students were given the option of watching videos using ViDeX or using their standard video player. Upon first opening ViDeX, the students were presented with a consent form describing the nature of the study, the data that would be collected, and the option to withdraw from the study at any time. Thus, students who opted in provided informed consent before any data were collected. In total, I collected data from 248 students: 62 (January 2017), 62 (September 2017), 34 (January 2018), 53 (September 2018), and 37 (January 2019).

In order to be able to separate students from each other, they were each assigned a randomly generated 24-character alphanumeric string, which was not linked their student identity, as per ethics requirements. Ethics requirements also stipulated that the instructor did not have knowledge of which video player the students used and that students remained anonymous so that there was no trace-back from video player usage to the students. This meant that we had no mechanism to link how a student performed in the class (i.e., their grade) with their particular video viewing actions.

For the qualitative part of the study, I recruited 26 students: six in January 2017, 12 in September 2017, and eight in January 2018 through purposive sampling. These students were recruited through a sign-up sheet distributed by the instructor at the end of the semester. Students who expressed interest in participating were contacted via email by the interviewer and a meeting time was arranged. Informed consent was obtained from all participants and all interviews were audio-recorded. After 26 participants had been interviewed, data saturation was reached, where the data became repetitive with no new codes emerging [75, 88]. Therefore, no further interviews were conducted.

### 4.1.3 Video Player Prototype for Capturing Activity Traces

To collect video activity traces, I deployed ViDeX, seen in Figure 4.1, our custom video player, which I developed with feedback from GM, XZ and SF, to the 248 students across the five semesters. At the beginning of each semester, I gave a short presentation demonstrating the features of the player and informed the students that they could opt out of using the player as the course videos were also available online on the course website.

ViDeX is a video player I developed in ActionScript 3 and deployed via Adobe AIR. It featured a video library, which housed the course videos, a player screen, which showed users the video, a searchable transcript, and a set of video thumbnails (i.e., a filmstrip), which provided a mechanism for an at-a-glance visual search of the video, as well as a way to navigate through the timeline of the video. ViDeX was also enabled to support moving five seconds backwards (using the left keyboard arrow), or five seconds forwards (using the right keyboard arrow) to facilitate timeline navigation within the video. A more detailed description of ViDeX can be found in Appendix B.

Students were given a link to download ViDeX onto their computers. Assigned videos were made available to the students according to the instructor's schedule; the laboratory experiment would be performed after the video was released, and the assignment would be due the week after that. As stated earlier, students had nine videos to watch throughout the semester.

ViDeX was instrumented to record actions performed by the user, such as when users loaded a video, paused, resumed playback, navigated in the video timeline, and exited the player. The logs of student activity were uploaded to a secure server located in Canada. The server-side logic was implemented using PHP and stored in

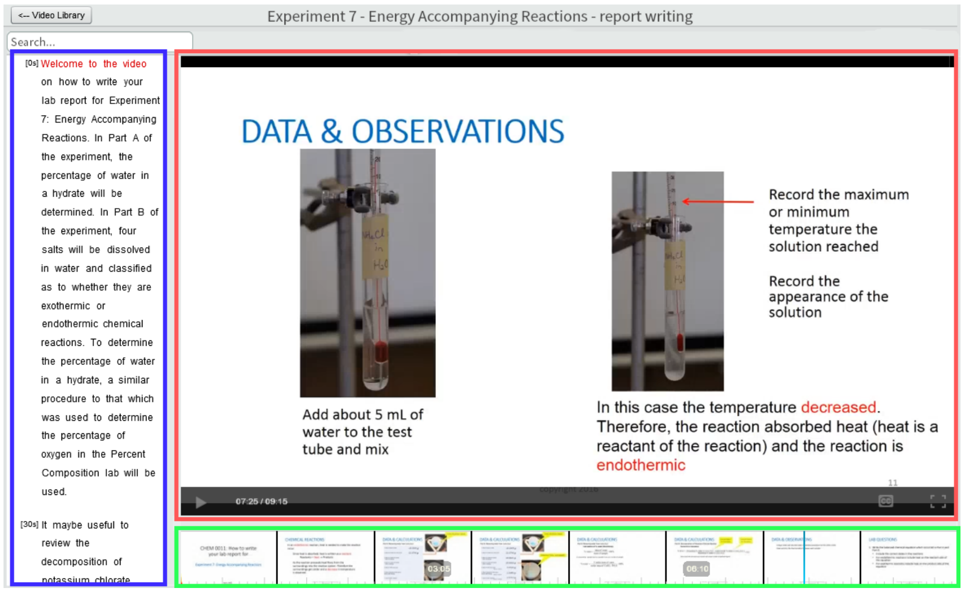



**Figure 4.1:** The video player, ViDeX, that the students used to watch the videos. ViDeX showed students the transcript of the video (blue), a main video viewer (red), and a filmstrip region (green) for visual search and seeking. It was used as the apparatus for capturing student activity traces.

a MySQL database. ViDeX did not record anything outside the application, such as which other applications were active and associated clicks (e.g., applications that students used to take notes), nor did it record the presence of students in front of the computer. The ViDeX logs were used to generate the activity traces, which were used to perform the qualitative content analysis presented in Section 4.4.4. Visualisations of activity traces, for example Figure 4.8, were drawn using JavaScript by querying actions directly from the database. I analysed the activity traces programmatically with respect to the strategies described by the students in the interviews to facilitate categorising the patterns of activity seen in the logs.

### 4.1.4 Interviews

Interview questions were generated by myself and DY, KS, SD, SF. During the interview, the following questions were asked:

1. How did you watch the videos? What was your workflow?
2. Did you take notes while you watched the video? How?
3. How did you study for your tests from the video?

As the students answered the questions, they were asked to elaborate on specifics about their strategies. During the interviews, ViDeX was also open for them to point to if needed to demonstrate their strategies. Each interview lasted approximately 15 minutes and the students were compensated with a $10 gift card at the campus cafeteria. All interviews were audio-recorded and transcribed verbatim by the interviewer to ensure consistency.

### 4.1.5 Data Analysis

I began with inductive content analysis [32] to analyse the interview data. After each set of interviews per semester, I read each transcript and coded each statement from the students by theme in a spreadsheet. These themes captured categories of statements from the students about their practices about using video. Within each theme, the statements were coded as specific strategies for watching video. After coding transcripts from the first semester (January 2017), I coded the twelve transcripts from September 2017 using the codes generated from the analysis of the first set of transcripts. I added new codes when the data did not fit into an existing code. I then recoded the original six transcripts to apply any new codes that were identified. This process was then repeated for the transcripts generated from participant interviews in January 2018. Data saturation was reached, where no new codes emerged [75, 88], which was after the third set of interviews. Once all transcripts had been coded and strategies were discovered, each strategy was mapped to sequences of actions found in the activity traces collected by ViDeX. The activity traces were also analysed for concentrations of activity during the semester by the number of minutes watched by the students and correlated with video releases, assignment due dates, and exam dates. Finally, the activity traces were also qualitatively analysed to find concentrations of activity within the videos by looking at peaks of activity and contents in the videos. These were then mapped to specific contents in each video, where a Poisson regression was performed on video activity and video content. This enabled the evaluation of the relationship in the amount of viewership of specific contents in the video. Differences in patterns were explored with Friedman Test and Wilcoxon signed-ranked analyses where relevant.

### 4.1.6 Rigour and Validity

During the interviews, the students were asked to elaborate on their experiences as well as verify my interpretations of their explanations as a form of member checking [82]. Additionally, I had weekly peer debriefing [82] sessions with the research group (DY, KS, SD, SF) to verify and validate my interpretations of the behaviours and strategies expressed by the students in the interviews, as well as my interpretations of the activity trace data.

## 4.2 Knowledge Learning Contexts

We introduce three learning contexts that correspond to the learning timeline prescribed by the instructors from the scheduling of the video's release, laboratory, and laboratory write-up due dates, as well as the behaviours revealed by the students. In the interviews, the students revealed three distinct stages of learning with video: familiarising themselves with the video for the first time, re-watching and clarifying concepts in the video they found difficult, and re-watching parts of the video in order to complete an assignment or study for a test. These three stages relate closely to Rosenshine [86]'s model of effective instruction, which was composed of six teaching functions: (1) reviewing and checking the previous day's work; (2) presenting new content; (3) supervising initial student practice; (4) providing feedback and correctives; (5) setting up student independent practice; and (6) organising periodic reviews. Mapping Rosenshine's model with the students' stages of learning, the model was simplified into three contexts: *Introduction* of new material (2), *Reinforcement* (3) (4), and *Demonstration* (5) (6).

Due to the way the course was formatted, the three knowledge learning contexts closely correspond with the schedule for the videos and their related assignments and examinations. To reiterate, each week, students were assigned one of nine videos to watch (day 0 for each video) (i.e., *Introduction*). Students then performed a laboratory experiment based on that video one week later (day 7) (i.e., *Reinforcement*), and then one week and one day after, the students were to hand in a laboratory report using the video as a guide (day 14) (i.e., *Demonstration*).

### 4.2.1 Knowledge Learning Contexts Visible in Activity Traces

Students spent varying amounts of time watching the videos that were assigned, based on whether the topics were expected to be tested in an upcoming assessment exam. Figure 4.2 displays the amount of time each student spent watching the videos during each day of each video's cycle. For every video, the students show minimal activity after 28 days (i.e., at 28 days two additional videos would have already been released).

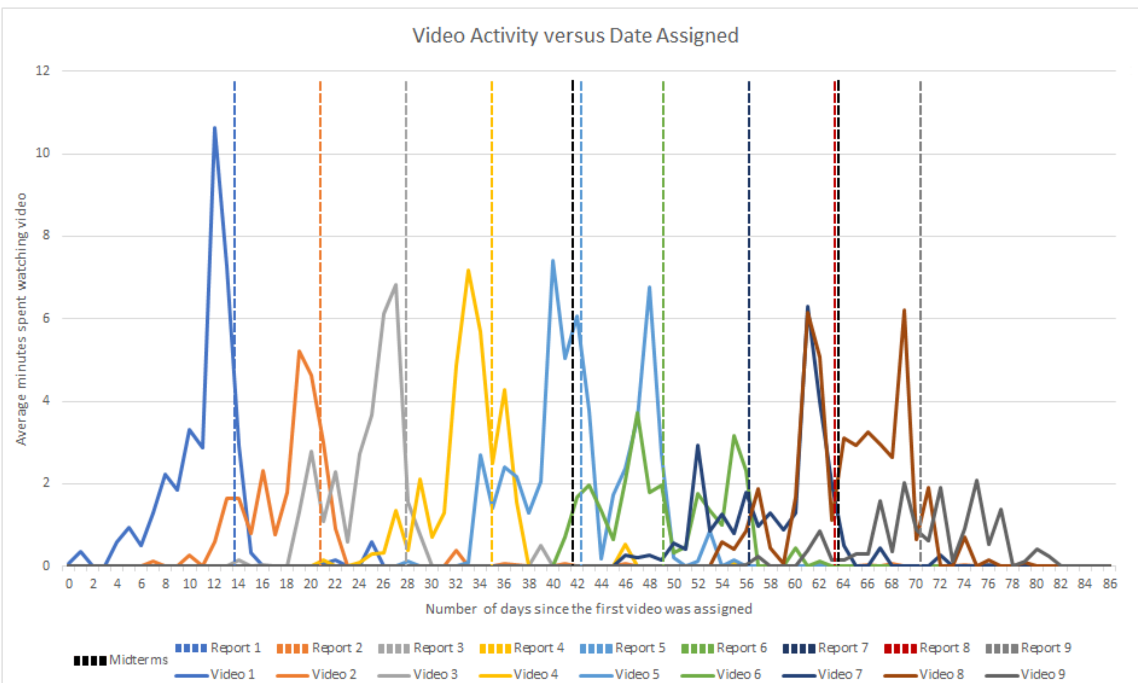



**Figure 4.2:** The relative amount of time students spent watching videos on each day of the semester. Each vertical bar represents the days on which the laboratory reports are due. Most videos see an increase in activity two to three days leading up to the due date.

From the day each video was assigned (day 0) to the day the report was due (day 14), there are approximately three relative increases of activity (local maxima): before the experiment (<= day 7, where day 7 is the morning of the experiment), right after the experiment (day 8, 9), and 1 to 3 days before the report is due (day 12, 13, 14). These maxima are similar to those results found by Giannakos et al. [44].

Again, these mapped well to the learning stages the students described in the interviews. For each video, there was a general outline of the three different stages during the three increases of activity. Students introduced themselves to the material before they performed the experiment, reinforced their knowledge about what they did right after, and watched the video again as they were writing the report as a demonstration that they understood the experiment's processes.

Up until day 15, the observed behaviours were similar and the waves of activity followed the general pattern outlined above. Starting with the video for Experiment 5, the pattern diverged after day 15. Where videos for Experiments 1, 2, 3, and 4 would have little to no activity after day 15, students continued to revisit and rewatch videos for Experiment 5 through 9 for up to 23 days (i.e., until the reports for the immediate subsequent experiments are due). Figure 4.2 illustrates the amount of time that students watched the videos across the semester; each coloured line represents the average total time spent watching per student on each day of the semester, and the vertical bars represent the days on which each report is due as well as the midterm exams throughout the semester. Videos for Experiments 5 (turquoise), 7 (dark blue), and 8 (brown) all had significant increases in viewing activity corresponding to their previous videos' report due dates (4, 6 and 7 respectively).

The timing of the midterm exams also had an effect on how much time the students spent on the videos. Students taking this course had two midterm exams; one on day 42 (the day video 6 was released), and one on day 63 (the day video 9 was released). In the days leading up to each midterm exam, the viewing activity increased among the most recent videos that were covered in the exam. Immediately following each midterm exam, the amount of viewing activity drastically decreased. Figure 4.3 shows the total minutes students spent watching the video on average. Videos 5 and 8, which are the final videos with content covered by the midterms, show an increased amount of time spent (from 32.8 minutes to 52.2 minutes in video 4 to video 5, and 26.8 minutes to 42 minutes in video 7 to 8), particularly during the two or three days before the midterm exam as seen in Figure 4.2. In contrast, students spent under 30 minutes on average watching videos after a midterm (6, 7, and 9), which was a statistically significant difference ($\chi^2 = 36.968, p < 0.001$). A post-hoc analysis with Wilcoxon signed-rank tests revealed significant differences in the number of minutes viewed between videos just before a midterm (5 and 8), and those after a midterm (6 and 9) (V5 and V6: $Z = -3.187, p < 0.01$) (V5 and V9: $Z = -2.838, p < 0.01$) (V8 and V9: $Z = -2.659, p < 0.01$).

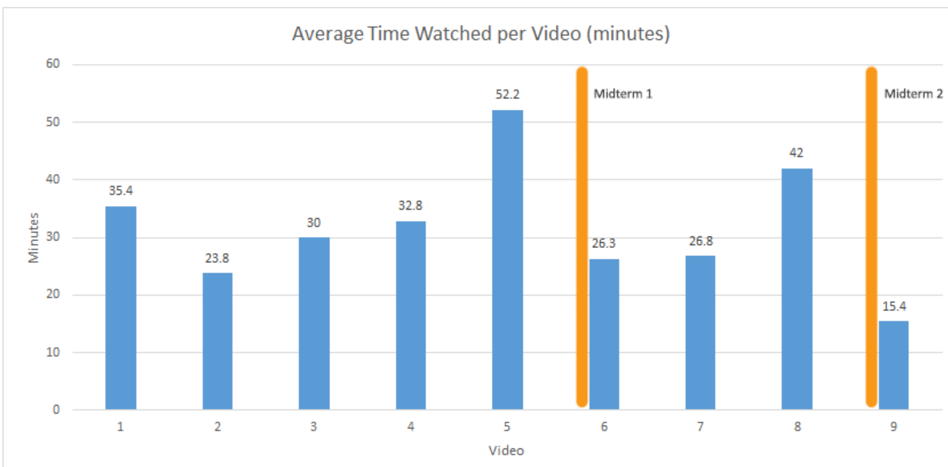



**Figure 4.3:** The average amount of time students spent on each video. One video is released for the students to watch each week. Students often spend less time watching video after a midterm exam.

The three knowledge learning contexts, which were dependent on the video's assignment date and its relevance to any midterm examinations, dictated the amount of time students spent studying from a particular video. By extension, the amount of time students spent studying on a video is proportional to the weight of the assessment on their final grade in the course. This becomes more evident as the answer to research question 2 is presented in the next section.

## 4.3 Overview of Analyses

We performed three analyses to answer the research questions. We first analysed the video learning behaviours outlined by the students in the interviews and extracted seven key strategies that students utilised to learn from video (Section 4.2). The seven strategies indicated by the students informed us of the video navigation patterns to search for in the analysis of the activity trace data collected by ViDeX (Section 4.4). The strategies and activity trace data also indicated the presence of "hotspots" in each video, which prompted the analysis of common video seek and pausing locations (Section 4.5).

## 4.4 Behaviours and Strategies

The varying amount of time students spent studying from a video is a result of amount of importance students place on learning the material and thus the strategies that the students use to learn the material from the videos. Consider for example, Student A, who takes notes from the video on paper and never refers to the video again, and Student B, who always refers back to the video and needs to search for information during the *Demonstration* context. Student A would likely spend less time than Student B studying from video, but not necessarily less time studying overall. Another example of different strategies would be if Student A remained in the *Introduction* context by watching a video playing the entire video without interruption, and Student B transitioned in between *Introduction* and *Reinforcement* contexts by watching a video and re-watching parts of video they did not understand as they were watching.

### 4.4.1 Defining Activities Related to Seeking for Sections in the Videos

As described earlier, the ViDeX application has several video navigation tools that permitted the student to navigate forward or backward in the video. In order to describe the ways that students used this function to look for different sections or slides in the videos, it was necessary to create terms to characterise multiple different searching activities. For the purpose of this study 'searching behaviour' refers to the general activities that students employ when they are using the video navigation tools to move forward or backward in the video with the goal to reach a desired destination in the video. Others have called this 'searching' or 'scanning'. We define a 'seek' as the individual navigational actions (either by clicking on the filmstrip or using the arrow keys) where the video play time is changed. The term 'seek' is used because, in this context, the students are trying to find a very specific thing, rather than general 'browsing', where students are not necessarily trying to find something specific. Thus, the terms 'seek forward, seek backward, seek forward towards and seek backwards towards' were created to capture the more specific nuances of the behaviours. Students in the interviews also used the words 'skip', 'rewind', and 're-watch', which refer to searching behaviours. See Table 4.1 for the definitions developed to articulate these behaviours.

### 4.4.2 Searching Behaviour

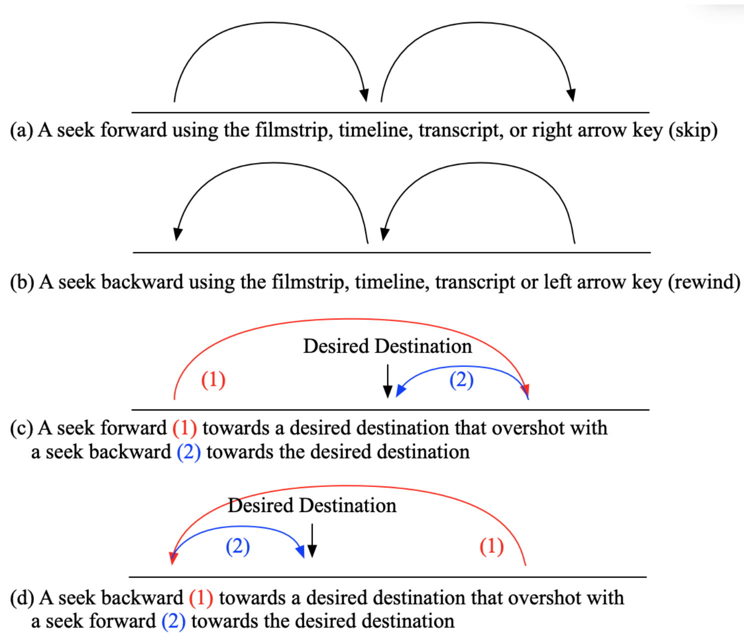
The students utilised the video player's functionality (such as the timeline, filmstrip, transcript, and left and right arrow keys) to navigate the video. Often, the searching behaviour utilised sequences of *seek forward* and *seek backward* shown in Figure 4.4. For example, students would repeatedly perform a *seek forward* to search for specific slides in a video. Similarly, when students reached the end of a video, they might also repeat a *seek backward* to search for concepts that they needed to re-visit. There were also times when students would perform a *seek forward towards* or a *seek backward towards* a specific point in the video, only to seek too far in one direction (c and d). The students would then proceed to seek in the opposite direction towards the desired destination.

### 4.4.3 Student Reports

Through interviews with the students, I found several strategies that students used when studying from video. A summary of the video behaviours and specific strategies are found in Table 4.2, with the number of students (out of 26) who referenced each strategy. The students described three learning behaviours that they had during the video learning process: watching the video for the first time (*familiarisation*), re-watching to reinforce their understanding of the concepts (*clarification*), and revisiting the videos for an assignment or a test (*review*). The students each indicated their video watching strategies (such as watching the entire video from

| Term | Definition | Methods |
|---|---|---|
| Seek Forward | Navigating closer to the end of the video with the intention to move to the next content (e.g. next slide). Can also be referred to as a 'skip'. | Right arrow on the keyboard or clicking on the filmstrip *after* the currently playing time. |
| Seek Backward | Navigating closer to the beginning of video with the intention to move to previous content. Can also be referred to as a 'rewind'. | Left arrow on the keyboard or clicking on the filmstrip *before* the currently playing time. |
| Seek Forward Towards | Seek forward in the video with the intention to search for a destination time or content in the video (e.g. a specific slide). | Clicking on the filmstrip *after* the currently playing time with attention to the content displayed by the filmstrip. |
| Seek Backward Towards | Seek backward in the video with the intention to search for a destination time or content in the video (e.g. a specific slide). | Clicking on the filmstrip *before* the currently playing time with attention to the content displayed by the filmstrip. |
| Seek Towards | Navigating forward and/or backward in the video with the intention to reach a destination time or content in the video (e.g. a specific slide). | Clicking on the filmstrip with attention to the content displayed by the filmstrip. |
| Re-watch | A seek backward in the video to a destination that has already been watched, and resuming playback. | While the video is playing, pressing the left arrow on the keyboard one or more times and pressing play, or clicking on the filmstrip to a destination in the video that has already been watched. |

**Table 4.1:** Searching Behaviours: Students use the video navigation tools to move forward or backward in the video with a goal to reach a desired destination in the video.




(a) A seek forward using the filmstrip, timeline, transcript, or right arrow key (skip)

(b) A seek backward using the filmstrip, timeline, transcript or left arrow key (rewind)

(c) A seek forward (1) towards a desired destination that overshot with a seek backward (2) towards the desired destination

(d) A seek backward (1) towards a desired destination that overshot with a seek forward (2) towards the desired destination

**Figure 4.4:** Common searching behaviours exhibited by students. These are common sequences of *seek forward* and *seek backward* that students employ to search for specific content to re-watch. They can be referred to by students as ‘skip’ or ‘rewind’, respectively.

start to finish, pausing to write notes), and described which learning behaviour these strategies helped them achieve. These learning behaviours could be applied to other contexts of learning as well, for example, traditional paper based learning, problem-based learning [97], or peer instruction [22] as well. Furthermore, in peer instruction, for example, additional learning strategies and behaviours could exist as well, such as research, information synthesis, and presentation, as students will be creating their own material to teach to their peers. However, in our survey of the students, these were the three learning behaviours presented.

| Learning Behaviour | Prototypical Statements | Strategy | # students (%) |
|---|---|---|---|
| Familiarisation | "*I just pretty much watch it from start to finish.*" | Watch entire video | 17 (65%) |
| | "*I just watched it right through.*" | Watch without pausing | 7 (27%) |
| | "*I watch and pause, and watch and pause.*" | Watch with pausing | 10 (38%) |
| | "*I pause and write details.*" | Take notes | 13 (26%) |
| | "*Most of the time I skipped until the last part.* " | Skip through | 8 (31%) |
| | "*I would pause it ASAP and then read through the transcript.*" | Pause and read transcript | 5 (19%) |
| Clarification | "*I usually pause it when I don't get it and re-watched until I got it.*" | Rewind and re-watch | 17 (65%) |
| | "*I just go back and read it.*" | Pause and read transcript | 3 (12%) |
| Review | "*I used the video in combination with my notes to study for tests and assignments.*" | Refer back to notes | 13 (50%) |
| | "*I would look back at my assignments.*" | Review marked assignments | 20 (77%) |
| | "*While writing the report, then I watch it to see if there are any tips in there on how to write it.*" | Go back to the video | 20 (77%) |

**Table 4.2:** Summary of video behaviours and strategies from interviews.

#### 4.4.3.1 Familiarisation with new material

When students were first introduced to new material via video, they stated that they familiarised themselves with the material in one of three ways: watch the entire video from start to finish, skip directly to parts of the video they thought were important by clicking on various sections of the transcript and the filmstrip, or read the transcript without playing the video. Prototypical statements illuminate the types of familiarisation behaviours observed as follows:

**"*I just pretty much watch it from start to finish.*" P7**

Seventeen students stated that they would watch the entire video the first time they were introduced to it. Of those 17, seven stated that they would watch through the entire video without pausing. For example, P5 said that his "*method is just to go through the whole thing. ... I didn't take notes, I just focused on the screen and tried to understand what they're talking about.*" In contrast, ten students stated that they would watch the video and occasionally pause. Pausing allowed students to slow down the pace of the video and reflect on the content. For instance, P9 stated that "*if something doesn't quite make sense to me initially, I usually just go back to the section that I have trouble with to play it over again.*" Similarly, P7 said that "*when I needed to, or when I had questions to clarify, I would go back and stop.*" Pausing also allowed students time to create their own notes and summaries of the video. P6 stated that with videos (in contrast to traditional lectures) "*you can actually pause it and write down stuff. That's what I used it for, I pause and write details.*"

**"*I skipped directly to the important parts.*" P2**

Eight students stated that they would skip directly to the parts of the video that were important, specifically the laboratory question and conclusion slides. These slides were often the cornerstone of their assignments, and understanding them was essential for completing the assignment correctly. P1 stated that "*for the first video, I watched the entire thing, and then after, I just picked out the things I needed to, just write the conclusion, mostly. Most of the time I skipped until the last part.*" Similarly, P2 said "*I already knew what was going on for most of the video* *and because I didn't understand the lab questions as well [as the other parts], I skipped directly to [the lab questions].*" This suggests that as the students watched the videos, they became familiar with the layout of the videos, allowing them to predict where they would be able to find parts of the video that they were interested in. P2 and P3 stated that they already understood the material (P3 stated that they had already taken a similar course and that they were taking this course for the credit rather than for a grade) and that watching the videos in their entirety seemed unnecessary. As such, skipping through the video saved them time. P13 stated that he would utilise the filmstrip to make a *seek forward toward* the slide transitions (this is in agreement with Kim et al. [57]), play the video for a couple of seconds to fine-tune what was being displayed, and screenshot the slides to paste into an external note-taking application (either Microsoft Word or Microsoft OneNote).

**"*I would pause it as soon as possible and then read through the transcript.*" P3** Five students indicated that watching the video was too slow, and going through the video via the transcript was more effective use of their time. P3 specifically said that they would normally play the video and "*just be working in the kitchen doing other stuff. I could listen to it.*" Then, when they "*were actually engaged, like if I was writing up the lab reports and stuff, I would just read [the transcript]. I can read it quicker.*" P14 stated that he would search for specific slides using the transcript, such as lab questions and conclusions, and navigate through the video that way. Similar to the previous method of skipping through the video, these students found a more efficient way to navigate through the video at their own pace.

#### 4.4.3.2 Clarifying information

When students re-watch parts of the new material they are introduced to, they switch to clarifying behaviours. They may also switch back and forth between familiarisation and clarification behaviours as they are watching and re-watching parts of the video as they progress through the video. For example, when students are watching a video and come across a section they do not understand, they will perform a *seek backward* to re-watch as a form of clarification. Clarification strategies emerge when students are looking for specific information during, or after they have familiarised themselves with the content. Again, the flexibility of video compared to traditional lectures allows students to re-watch portions of the video without any restrictions, and many students utilised that advantage, switching contexts from *Introduction* to *Reinforcement* quite often.

We found that when students were watching a video and they encountered a difficult concept, they used one of two strategies to try to understand it: a *seek backward* using the filmstrip or the keyboard arrows keys (the left arrow invokes a *seek backward* by 5 seconds and the right arrow invokes a *seek forward* by 5 seconds) and re-watch it again, or pause it and read the transcript. Prototypical statements illuminate the types of clarification behaviours observed as follows:

**"*I usually pause it when I don't get it and re-watched until I got it.*" P12**

The 17 students who watched the video (rather than skipped immediately to the "important parts") stated that they would go back to the point of the video that they felt they needed clarity. P9 stated that "if something doesn't quite make sense to me initially, I would usually just go back to the section that I had trouble with and play it over again." As we discovered in Chapter 3, from an instructor's point of view, this is one of the major strengths of video; students can replay the video as many times as necessary, and this is a time saver when the alternative would be to contact someone else or find another source for clarification.

**"*Occasionally I would rewind and watch it again, but most of the time I just go back and read [the transcript].*" P7**

The alternative to rewinding and re-watching the video was just to go back and read the transcript, again speeding up the process as they felt their reading speed was faster than the pace of the video. Five of the 26 students indicated they would use this method.

#### 4.4.3.3 Review

The students are often evaluated on their knowledge of the material through assignments, midterm examinations, final examinations, and pop quizzes. Before such evaluations, students can review the material by re-opening the video. Reviewing information consisted of three strategies: skip to sections of the video and re-watch them, review the marked completed assignments, and review the notes that they took while watching the video the first time. These prototypical statements illuminate the types of review behaviours observed:

**"*I used the video in combination with my notes to study for tests and assignments.*" P9**

All the students who made notes while watching the video referred back to them during review sessions. The other methods were to refer back to the video (P23 referred to it as the "source material"), or past completed assignments and tests. The students who did not create notes stated that they were worried that any notes they made would be incomplete or oversimplified, and thus, not representative of what was taught and inappropriate to study from.

**"*While writing the report, then I watch it to see if there are any tips in there on how to write it.*" P6**

P6 went on to say that when reviewing for a test "*I did re-watch the videos, I jumped around*". This strategy is echoed by 19 other students, where students were evaluating whether they already knew the information and searched for information that they needed to study for, or was required of them in the assignment. According to these students, re-watching the entire video was deemed unnecessary and not an optimal use of their time.

#### 4.4.3.4 Noteworthy patterns

The more familiar a student was with the material, the more likely they were to skip through the video to find the parts that they thought were important. This behaviour was seen in the students who skipped through the video on their first view, and subsequently in the students who had already watched the video. Reviewing the entire video took too long and students found it was better use of time to re-watch (or re-read) the parts of the video that were challenging. We also saw a difference in relation to note-taking. Some students decided to take notes while watching the video. While it is not clear if these students spent more or less time studying from video compared to students who did not take notes, it has been shown that constructivist active learning activities increase learning outcomes in science, technology, engineering, and mathematics (STEM) courses [41].

### 4.4.4 Activity Trace Results

I used activity trace data from the 248 student data set to discover patterns of activities that relate to the students' strategies. Using the strategies from the interviews as a basis, I derived six viewing strategies that match activity trace logs: watching at least 70% of the video sequentially (1) with pausing or (2) without pausing, (3) skipping directly to the conclusion, (4) skipping small sections of the video (less than 15 seconds) or (5) skipping large sections of the video (greater than 15 seconds), and (6) re-watching the video. I checked for the presence of each of these strategies in each watching session, where a session is a sequence of actions terminated by exiting the video/application or by two hours of inactivity. In Figure 4.5, the horizontal axis lists the presence of each strategy during each context: during the introduction (before the experiment), during the *Reinforcement* (just after the experiment), and during *Demonstration* (before and after the report is due).

Figure 4.5 also shows the percentage of sessions in which students used each strategy. In the Introduction context of watching video, students were more likely to watch more of the video in sequential order (35% of sessions), and if necessary, use a *seek forward* action (generally by using the left keyboard arrow) (26% of sessions). In contrast, in the *Reinforcement* and *Demonstration* contexts, students were then more likely to perform multiple large *seek forward* actions (greater than 5 seconds) through the video (37% of sessions in *Reinforcement* and 46% of sessions in *Demonstration*) to search for specific content (and quite often, a *seek forward* action directly to the conclusion slide of the video using the filmstrip). During the *Reinforcement* and *Demonstration* contexts, students were commonly searching for content to help them write their report; that is, they were more likely to use a *seek forward towards* action towards the lab questions, calculations, and conclusions slides. Furthermore, it is during these viewing sessions that students were also more likely to spend more time re-watching sections of video (34% of sessions in

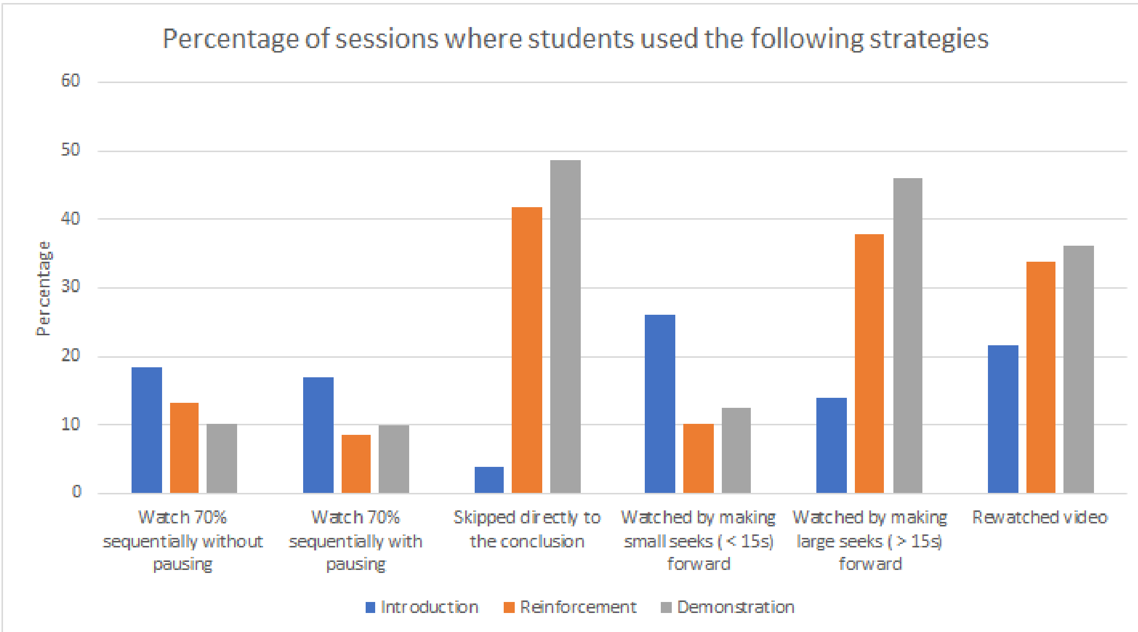



**Figure 4.5:** Percentage of viewing sessions where students watched video using these strategies. During the first viewing sessions, students tend to watch more of the video sequentially. After they have familiarised themselves, they tend to skip large sections of video, where they are searching for specific slides in the video, namely the lab question, calculation, and conclusions slides.

*Reinforcement* and 36% of sessions in *Demonstration*), as they needed to be able to follow the steps to perform the calculations properly, as well as to write a proper conclusion based on the comments from the instructor. In the following section, the different watching behaviours and strategies students employ to watch video are discussed.

### 4.4.5 Visualising Activity Traces

I implemented visualisations for activity traces the students took across a video. Figure 4.6 presents an illustration for how activity traces can be represented. The horizontal axis represents the temporal location in the video the student is watching, and the vertical axis is the timestamp of each action. Playing through the

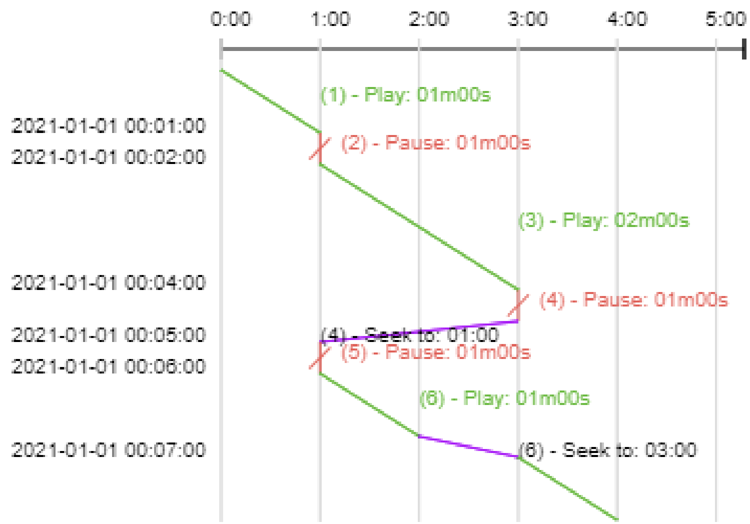



**Figure 4.6:** An example activity trace visualised. The horizontal axis represents the temporal location of the video that the student is watching, and the vertical axis shows timestamps for when the actions (plays, pauses, and seeks). Playing the video is indicated by green lines, seeks in fuchsia, and pauses in red. In this example, the student (1) a play for one minute, (2) a pause for one minute, (3) a play for 2 minutes, (4) a pause for one minute, (5) a *seek backward* to minute one of the video, (6) a pause for one minute, (7) a play for one minute, (8) a *seek forward* to minute three of the video, and (9) a play for one minute.

video is indicated by green lines, searching behaviour in fuchsia, and pauses in red. Pauses and plays are labeled with their duration in their corresponding colour. Seek locations are labeled, and timestamps are also labeled for pause locations.

### 4.4.6 Familiarisation Activity Traces

Figure 4.7 shows some of the patterns (simplified) that were observed in the activity traces, for example, a repeated playing and pausing pattern, skip to the end pattern, and a re-watching pattern. We determined the first time a student views a video to be familiarisation behaviour. When they are first introduced to new material, 65% of students stated that they would watch the entire video from beginning to end. As discussed in the previous section, there are two strategies when students watch

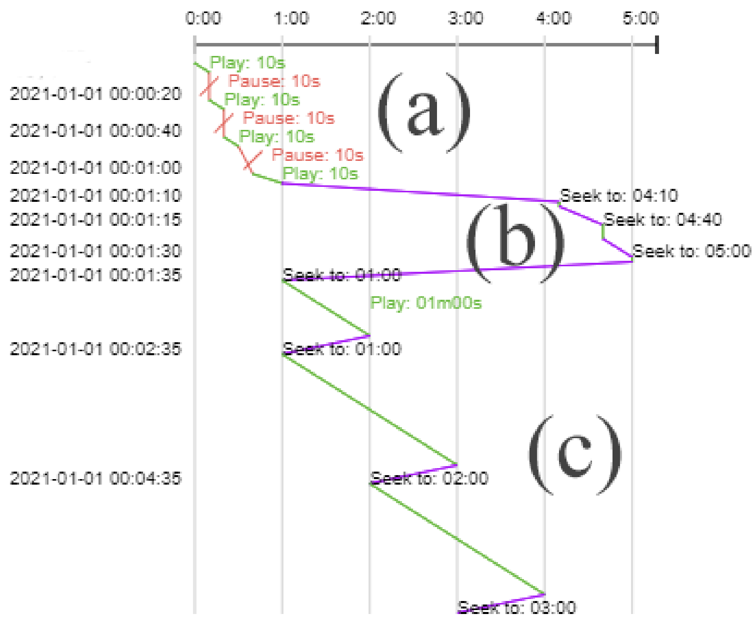



**Figure 4.7:** An example activity trace with simplified patterns that were observed in student activity traces. (a) Repeated playing and pausing pattern characterised by short plays and short pauses. (b) Skip to the end pattern characterised by a relatively large *seek forward* to the end of the video followed by a shorter *seek forward*. (c) Playing and re-watching pattern, characterised by a play and a *seek backward* and more playing.

the video in its entirety: some students will play through the entire video without pausing, mimicking a live, in-person lecture, and others will be more interactive with the video, pausing and re-watching parts of the video.

Complete playthroughs are non-interactive until the student has reached the end of the video. However, it is not often the case that students understood everything they saw in the video, and we observed that once students reached the end of the video, they often returned to certain parts that they had already watched, which is consistent with what they reported during the interviews.

The second method we observed is where students watch the video more interactively. Figure 4.8 displays an example where the student made multiple pauses, re-watched one section of video, skipped a section of video only to perform a *seek* *backward* and watch a portion of the skipped section. Interviews with the students revealed that during these pauses, students were note-taking, re-reading slide contents, as well as reading the transcript.

Complete playthroughs of the video were more likely to occur when students were watching the video for the first time, and in subsequent views, students were less likely to go through the entire video without searching and not watching certain sections, for example, the introduction. While there were instances of students re-watching the video in its entirety again during the *Reinforcement* and *Demonstration* contexts, students were more likely to perform a *seek forward* to specific parts of the video rather than re-watch parts of video that were perceived to be less relevant to their assignments.

The other popular method of watching videos was to 'skip' through a video by either performing *seek forward* actions five seconds at a time (by pressing the right arrow key) or using larger intervals (which can be done using the thumbnail previews in the filmstrip or using the transcript), as in Figure 4.9. This behaviour manifested as a way for students to complete their assignments as quickly as possible by looking for the answers within the video. P1 and P2 in the interviews discussed seeking directly to the conclusions and lab questions slides, which suggests that as students watched more videos during the semester, they became increasingly familiar with the general layout of the video and had developed a sense of which parts of the video were more important, which allowed them to develop strategies for watching the video in a more time-saving manner.

### 4.4.7 Clarification Activity Traces

Students also stated that they would perform a *seek backward* using the filmstrip in the video when they felt that they missed out on the information presented. They either did not understand the information or just needed to watch it again for clarity. We found that of the students who paused while watching the video, about half of them used *seek backward* actions in the video to re-watch segments. Once students finished playing through the entire video, we found that there were many instances where students would use *seek backward* to the middle of the video (where the instructor talks about how to make calculations and observations). Students would

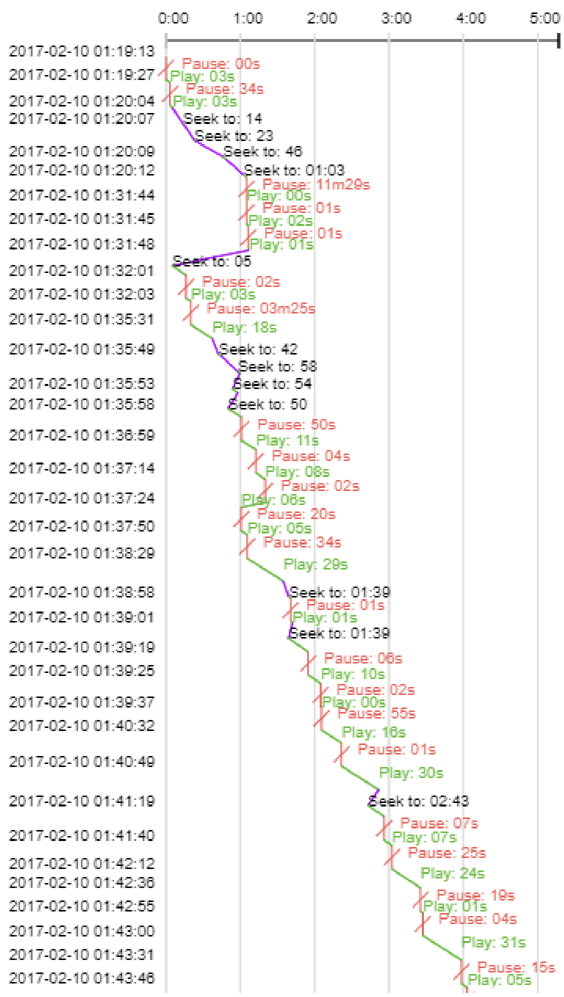



**Figure 4.8:** This is playing and pausing behaviour, often seen in the first sessions of video watching, when students are first familiarising themselves with the material. In this session, the student played small intervals of video, paused frequently, and sometimes a *seek backward* to re-watch certain intervals of video. This behaviour shows up as a short zig-zag pattern.

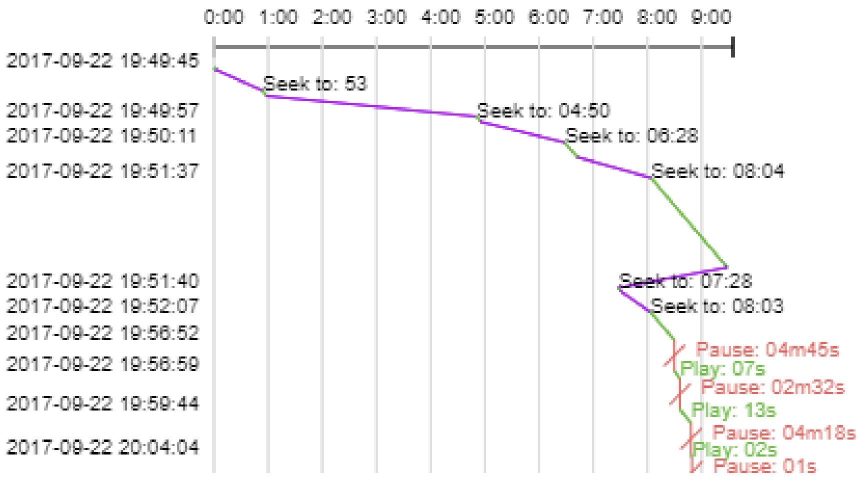



**Figure 4.9:** This student used *seek forward* on most of the video towards the conclusion slides. This was a common occurrence upon repeat views of a video when students are looking for specific content, or in first viewing sessions later in the semester when students are busy with more assignments and exams from other classes.

then either re-watch short segments (either by playing through and pausing periodically, such as in Figure 4.10), or read the transcript (and use *seek forward* through the video while paused).

We also found that students would use *seek backward* during the middle of their first play-through; when coming across a difficult concept, students would use a *seek backward* 10-30 seconds at a time to review that concept. Finally, when students used *seek forward* through a lot the video on their first view, they would sometimes find that they went too far. After playing the video, they would use *seek backward* to the beginning of a slide, suggesting that the student found a concept they did not understand well enough to just read the final contents of that particular slide.

### 4.4.8 Review Activity Traces

After watching the video for the first time, students would refine their viewing optimisations. Some students would attempt to find specific parts of the video through a series of *seek backward or forward*. Other students would then play the

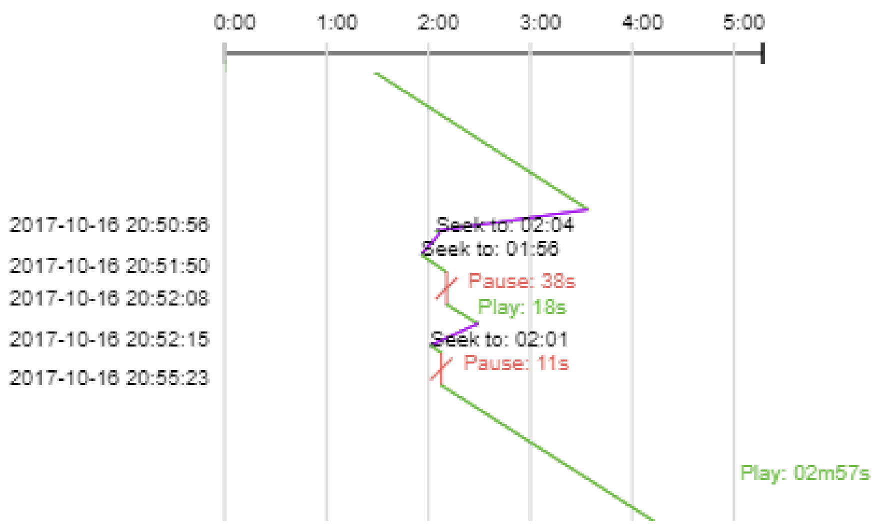



**Figure 4.10:** Activity trace of a student re-watching a section of video.

video in short bursts and then *seek towards* another destination, or stay paused and then seek. Such behaviour can be seen in Figure 4.11, where the student used *seek forward* to the end of the video, only to use *seek backward* and watch the middle of the video. During the pauses, students stated that they were reading through the contents of the slide or the transcript in order to clarify their own understanding of the content.

Each video had hotspots as some parts of the videos were more important (more relevant to their assignments and midterm exams), or confusing than others. As we discovered in Chapter 3, knowing where students are re-watching often can be a useful metric for determining video quality and student literacy.

## 4.5 Video Focus

Each video followed roughly the same structure: introduction, background information, data and calculations, lab questions, and conclusion. The information that is most needed to complete the laboratory report was found in the lab questions and conclusions slides. In this part of the analysis, I investigated how, and how often students were reaching these sections using the video player functions, such as with the preview thumbnails of the video and the transcript.

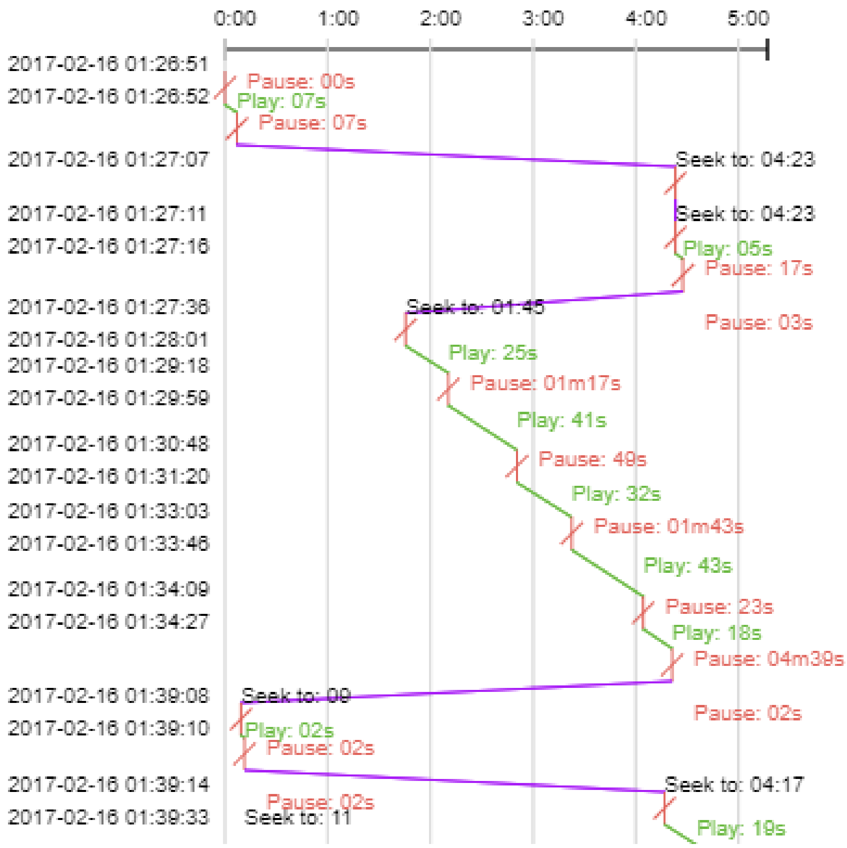



**Figure 4.11:** Activity trace of a student who used *seek forward* and then *seek backward*.

### 4.5.1 Seek and Pause Locations

For each video, I categorised each slide in the video by their title and content, and I also categorised progression of the build state of a slide (the entire content of a slide was usually hidden at the start but was revealed as the presenter talked about it). I performed a poisson regression analysis on each category of slide and slide build states for destinations of *seek backward*, destinations of *seek forward and backward*, as well as pause locations. These actions indicated areas of interest in the video that students would *seek toward*, or otherwise spend more time on. The results for slide type can be seen in Figure 4.12, and the results for slide build states can be seen in Figure 4.13.

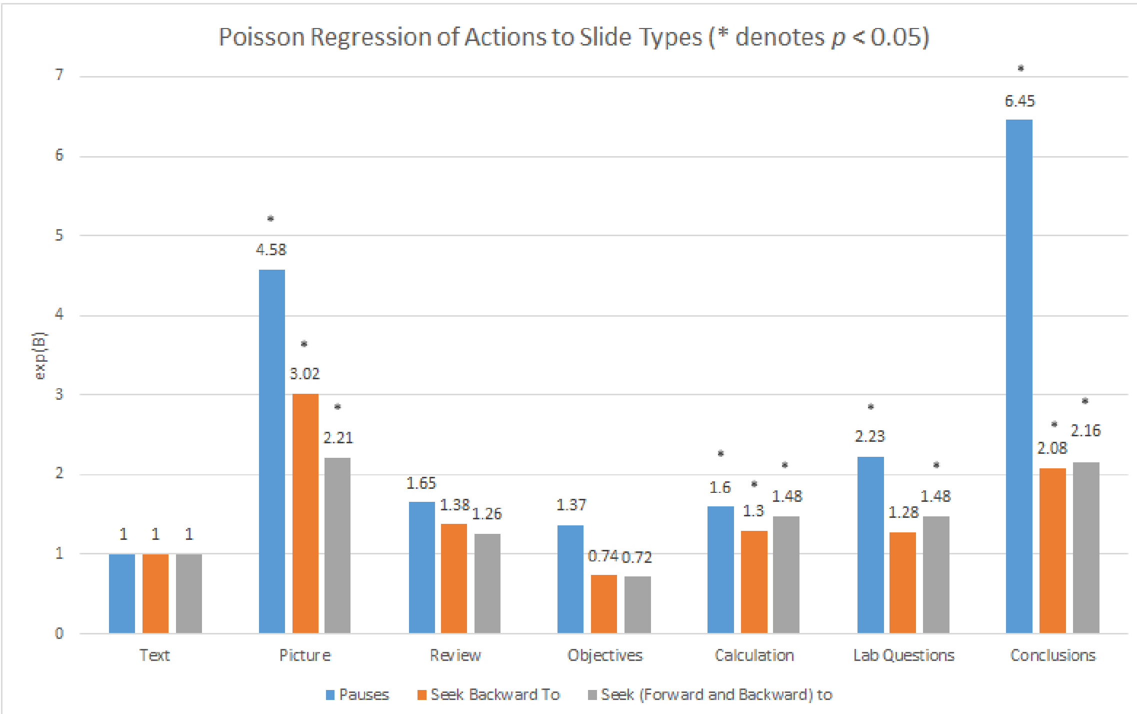



**Figure 4.12:** Poisson regression on pauses, *seek backward*, and combined *seek forward* and *seek backward* in relation to slide types (reference text based slides). Higher values indicate slides with more activity. For example, students pause on the conclusion slides 6.45 times more than on regular text background information slides.

#### 4.5.1.1 Seek backward

When students had trouble with content, they:

(1) stopped at the slide that they needed to understand and re-read the slide,

(2) used the *seek backward* function (using the filmstrip, or the arrow keys) and re-watched that part of the video, or

(3) continued watching the rest of the video and then use *seek backward* to the part they had trouble with.

A large portion of the *seek backward* action and re-watching occurred on conclu-

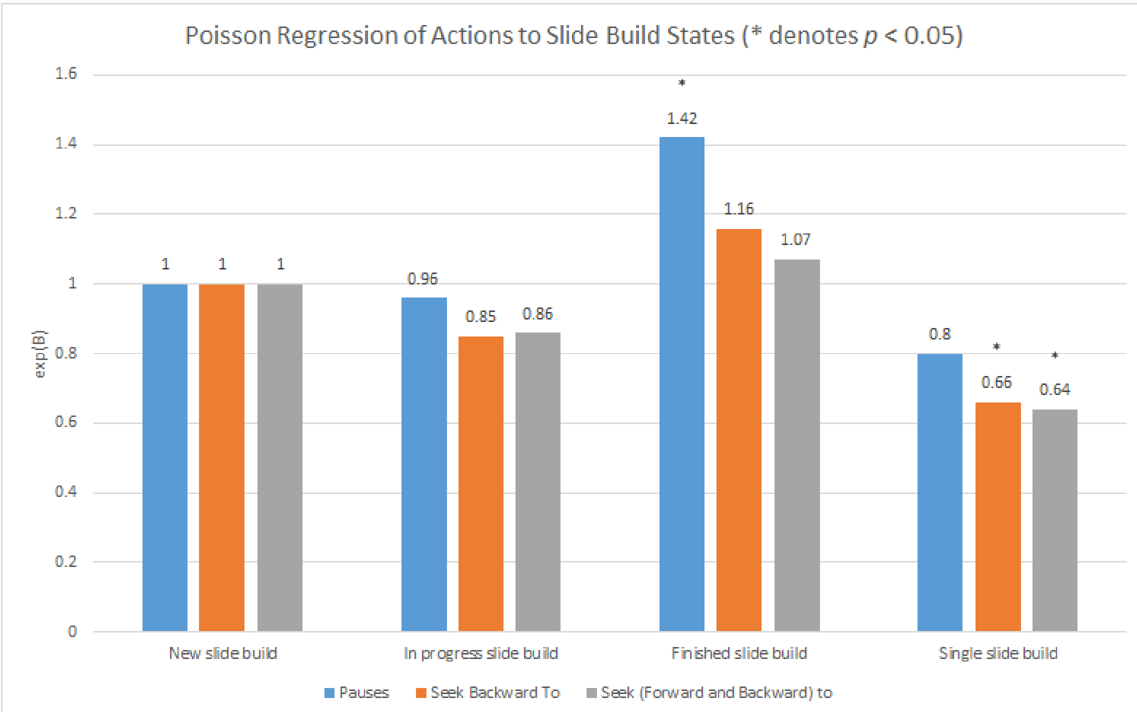



**Figure 4.13:** Poisson regression on pauses, *seek backward*, and combined *seek forward* and *seek backward* in relation to slide build phases (reference newly building slide). Higher values indicate slides with more activity. For example, students pause on the slides that have fully appeared 1.42 times more than slides that have just changed.

sion and lab questions slides (2.08 and 3.02 times more than regular text background information slides), which are both text-heavy and contained substantial information that students needed to complete the laboratory report. These slides in particular drew students' attention as they were not only dense with information, but contained compulsory information. For example, conclusion slides outlined what the instructor expected to see in the conclusion section of the final report for the laboratory experiment. Similarly, the lab question slides asked students questions about that experiment, such as additional calculations for the lab report, or critical thinking questions, and also contained questions similar to those that would be found on an exam. The number of *seek backward* actions were very large for picture-based slides (3.02 times text slides) and conclusions slides (2.08 times text slides), and significantly larger than the other slides (e.g., review (1.38 times text slides), calculation (1.28 times text slides)).

One possible explanation for the large increase in *seek backward* for picture-based slides (3.02 times text slides) could be that the use of pictures and relative lack of text made it difficult for students to follow. With their attention split between the visuals on the screen and the speaking voice, students needed to make sense of both, and doing so required multiple viewings. When we compare with, for example, calculation slides or observation slides that had more text, the information that is being presented visually on the slide and spoken are similar enough that understanding the two forms together was easier. Slides that were mostly text-dominant allowed the student to read along with what was being said. If a student missed something and needed to "go back" and reprocess the information, no *seek backward* was necessary as the information was already on the screen.

When students used *seek backward*, they tended to do it after a visual transition. Much like the results found in [57], students used *seek backward* from the beginning of new slides (right after the explanation of a concept has finished), as well as the final build far more often than during the middle of a slide being built.

#### 4.5.1.2 Pauses

Students spent a significant amount of time on conclusion slides (6.48 times text slides), picture-based information slides, as well as lab question slides (2.23 times text slides) when compared to regular text-based information slides. For picture-based slides, we saw a similar effect to *seek backward* behaviour. Since students were given the transcript to view on the side, they were afforded the ability to re-read what was said in case they missed something. When interviewed, some students stated that they opted to pause the video and read the transcript in order to fully understand the concepts.

Another reason for pausing is that students needed to write their own notes on the videos. In the interviews, many of the students stated that they made their own notes of the information presented in the videos themselves. This was accomplished in one of two ways: writing the main points on paper, or taking screen-shots of the videos and writing notes on top of the video in a separate application. Clearly, a fully completed slide is more important to students as they pause 1.5 times more when a slide has fully appeared on the screen.

#### 4.5.1.3 Seek forward and backward

The seek destinations skew towards conclusion slides (2.16 times text slides), picture slides (2.21 times text slides), calculation slides (1.48 times text slides), and lab question slides (1.48 times text slides). In our interface, the students were given thumbnail previews of the video. Conclusion slides were often colourful, like in Figure 4.14. Similar to picture slides and calculation slides, students are less inclined to *seek toward* slides that were composed mostly of text and devoid of colour. Slides that are visually distinctive from each other, for example through the use of colour or layout, could make search tasks easier, especially in video players with a filmstrip-like preview functionality.

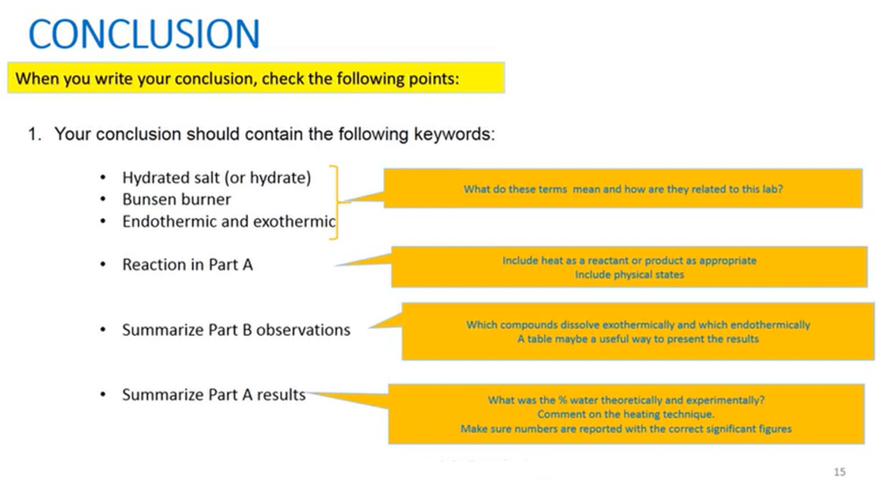



**Figure 4.14:** An example of a conclusion slide, which were colourful and visually distinctive. Used with permission

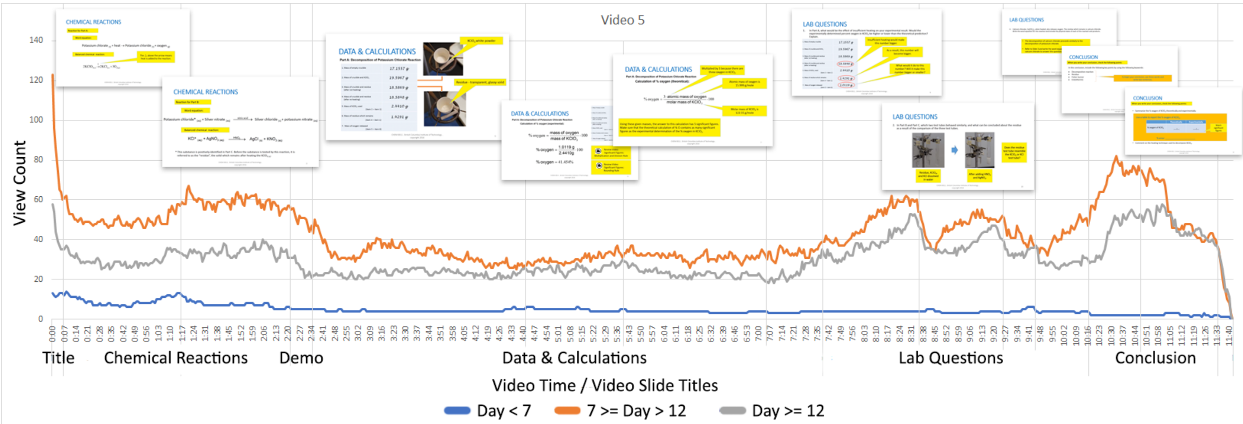



**Figure 4.15:** Students' view counts for video 5. The blue line is view counts before the experiment (*Introduction*), orange is just after the experiment (*Reinforcement*), and grey is just before, as well as after the report (*Demonstration*). There is generally minimal viewing activity leading up to the experiment, and most of the activity happens after the experiment and before the assignment is due. Students most often watched and re-watched lab questions and conclusion slides. Video thumbnails used with permission.

### 4.5.2 Relationship Between Videos

In this part of the analysis, we looked at which parts of each video students revisited and re-watched in relation to the content of the video. In Figure 4.15, we show an example of a graph of the videos for the three knowledge learning contexts: *Introduction* (blue), *Reinforcement* (orange), and *Demonstration* (grey). The heatmaps divide each video into a view count for every one-second segment. For students who watched the video before the experiment (before day 7), the general method was to watch the video to the end with minimal interaction. The graphs for the other videos can be found in Appendix H.

In the first four videos, the students placed priority in re-watching the "Conclusions" slides (Figure 4.16), and for videos 2 and 4, students also revisited the "Lab Questions" slides. The eleven questions in video 2 (Figure 4.17) were detailed conceptual questions and guided the students toward answers, and the 2 questions in video 4 guided the students through a detailed example problem. This is in contrast

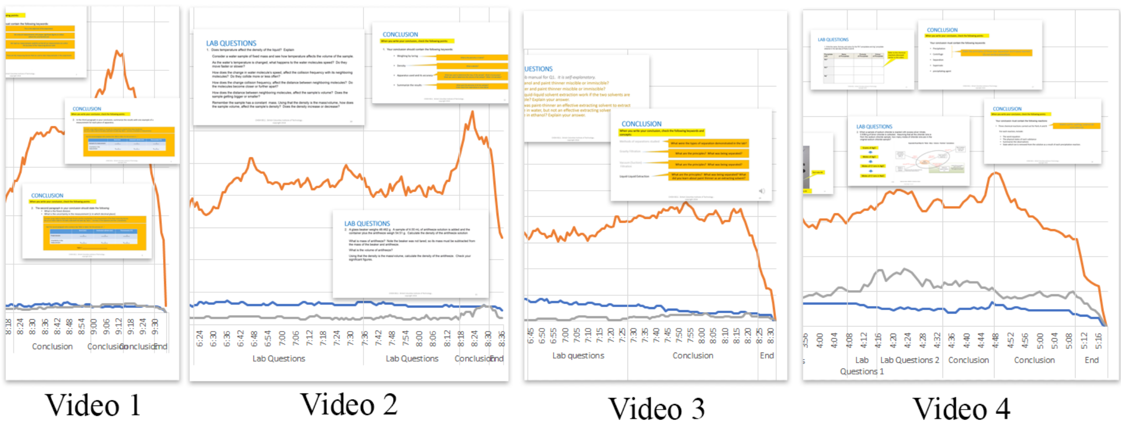
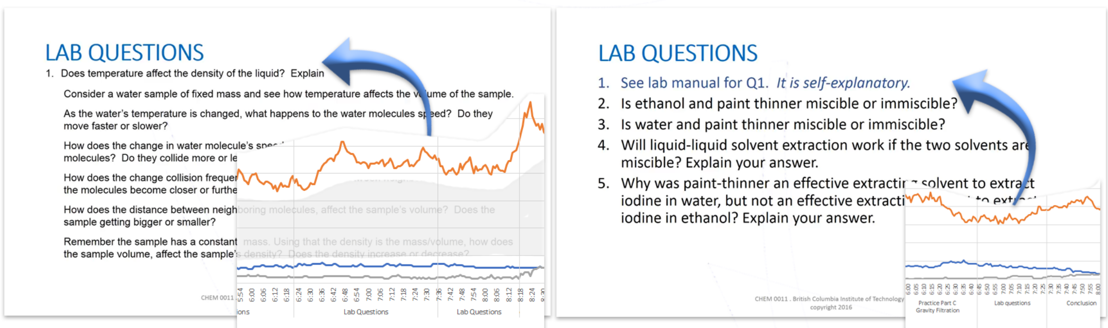



**Figure 4.16:** Graphs of view counts for videos 1, 2, 3 and 4. Students often visited the conclusion slides to determine what was required to be written in their laboratory reports. Used with permission.

to the five questions in video 3 (Figure 4.17), which were yes/no questions or questions that did not guide the student in their thinking. Video 4 also saw increased activity on a slide called “Chemical Reactions”, which showcased illustrations of the reaction that students would be handling during the experiment.

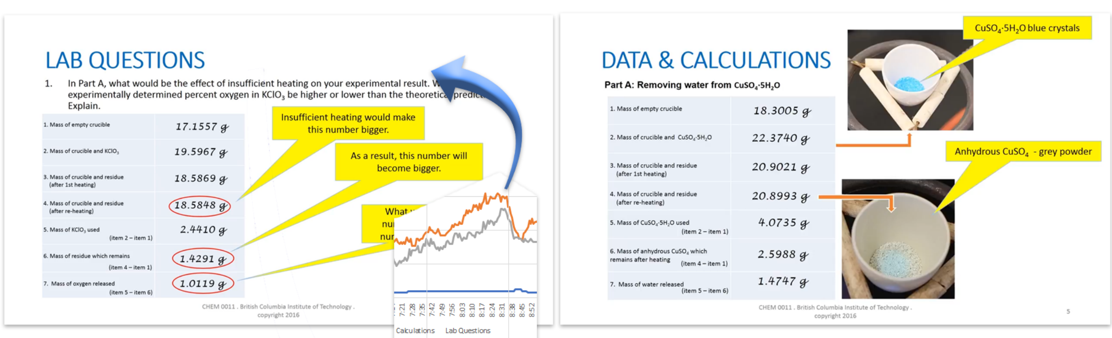
Only the last five videos showed any activity *after* the report was due, therefore, we shift our focus away from the first four videos. In video 5, there was a significant amount of activity *after* the report was due, with several peaks of activity towards the end of the video. The slides with more activity were the first “Lab Questions” slide and the “Conclusions” slide. The “Lab Questions” slide in question contained a table of calculated values. The calculations involved to fill out this table are revisited in video 6. Similarly, the “Lab Questions” slide for video 6 is similar to the “Conclusions” slide of video 5, where instructors asked students to balance chemical reaction equations to the two parts of a decomposition reaction. While the reactants and products of the equations were different, the procedure was the same. The relevant slides in video 5 and 6 and view count for video 5 are shown in Figure 4.18. This suggests that when completing the report for video 6, students are checking to see if the questions are similar enough so that they could refer to their old (marked) work as an example to follow.




Video 2 Lab Questions

Video 3 Lab Questions

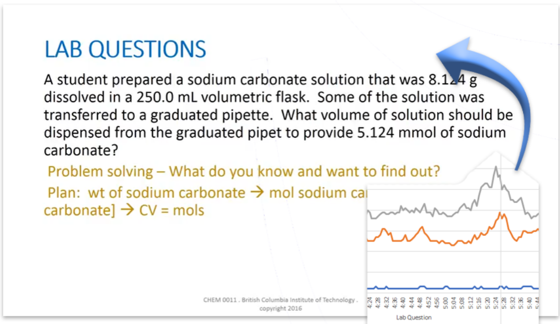
**Figure 4.17:** The detailed guidance questions found in video 2 drew students attention more than the simple yes/no questions presented in video 3. Students revisited the guidance questions in video 2 more often, as signaled by the increase in view count at the lab questions slide, whereas a valley is present in the view count of video 3 during the lab questions slide. Used with permission.



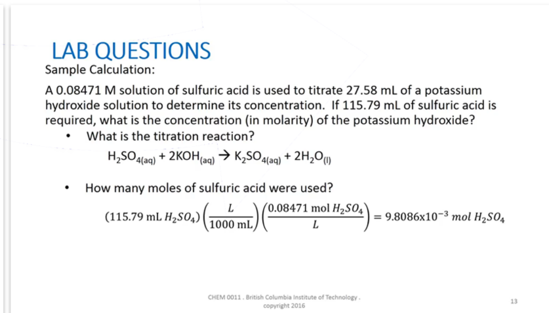

Video 5 Lab Questions

Video 6 Calculations

**Figure 4.18:** The identical table of calculations in video 6 could be the cause for a peak in view count for the lab questions slide in video 5. Students may be referring to their previous videos in order to complete their laboratory reports. Used with permission.



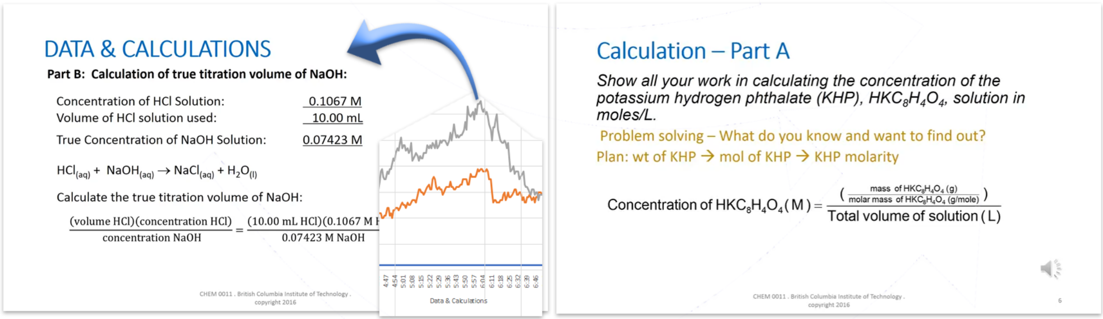

Video 7 Lab Questions




Video 8 Lab Questions

**Figure 4.19:** Video 8 presents a lab question that draws from concepts covered in video 7, which could be the cause for the peak in view count for video 7. Students may be referring to their previous videos in order to complete their laboratory reports. Used with permission.

In video 7, the topic transitioned from the decomposition of substances in water and calculating the percentage of water in a solution, to the preparation of a standard solution and calculating the concentration of that solution based on the amount of a substance dissolved. While the concepts were related, none of the calculation procedures overlapped, and thus, there were no evident activity peaks in video 6. In video 8, the “Lab Questions” referred to the resulting concentration of a solution after two solutions are added together. One of video 7’s lab questions asked the students to calculate the amount of solution to add to create a specific concentration; students were asked to calculate the reverse calculation. The relevant slides in video 7 and 8 and view count for video 7 are shown in Figure 4.19. In video 9, students were asked to calculate titration volumes; the concepts of titrations were introduced in video 8, and again, using the processes for calculating concentrations of solutions, students revisited problems and solutions that they already completed. The relevant slides in video 8 and 9 and view count for video 8 are shown in Figure 4.20.




Video 8 Calculations

Video 9 Calculations

**Figure 4.20:** Video 9 presents calculations that are similar to calculations found in video 8, which could be the cause for the peak in view count for video 8. Students may be referring to their previous videos in order to complete their laboratory reports. Used with permission.

## 4.6 Discussion

In this study, visualising students' activity traces showed that students rarely watch videos from start to finish, but rather, they navigate to parts of the video they feel they do not understand as well, or parts of video that are more relevant to their assigned tasks. Further, students who did watch videos from start to finish only reviewed the relevant the parts. The patterns of behaviour revealed by the activity traces was consistent with the knowledge learning contexts identified via interviews with the students and showed that students spend more of their time on parts of video that are tied to their grades.

### 4.6.1 Implications for Video Player Interaction Design

One strength of using video to teach is that it allows students to repeat the information as many times as needed. We observed that students often pause the video and go back over it. Sometimes they read the transcript in order to get a better idea of what was going on, and other times they re-read the contents of the slide. Students often needed to *seek forward and/or seek backward* in the video several times before finding the point they wanted to get to. A video-content-aware *seek backward* and *seek forward* mechanism would be useful in this scenario. For example, a back button that allows students to go back to the beginning of a slide, or the beginning of the last spoken sentence.

From the behaviours observed in Section 4.4.4, searching in video can be a difficult task, especially due to the time-based nature of video. Students found several ways to alleviate this task: take paper-based notes so that they do not have to re-watch the video, memorise the layout of the video, or perform a text search in the transcript. One way the video player would be able to aid in this search task is by allowing students to temporally annotate the video, much like students are able to do with text through bookmarking or highlighting. Another way to aid search would be for the video player to not only index transcripts, but also index slide contents such as text found on the screen.

### 4.6.2 Implications for Video Design

Subsequent views of video typically involved students searching through the video. In ViDeX, students used both video previews and the transcript to navigate. The inclusion of a searchable transcript allowed students to quickly skim through the content of the video without having to watch it. Similarly, a set of video previews for visual search (the filmstrip) also allowed for quick search. To further aid in visual search, the slides in the video could be made visually distinct from each other. For example, text layouts could vary across different slides to make them more easily recognisable.

From our observations in Section 4.5, students are likely to re-watch videos for at least three reasons: (1) the video referred to topics covered in a previous video, (2) they needed to refer to the videos to complete an assignment, and (3) they needed to study from the video for an exam. The video needs to be easily searchable; it needs to be structured so that students can remember the locations of specific points information. The videos that this set of students used also aided students in search because they had a consistent ordering of slides. Students searching for specific slides were able to "guess" where, for example, the conclusion and lab question slides were, allowing them to minimise the time spent searching. The structured nature of the videos also helped students familiarise themselves with new videos as they would already know what to expect and where to expect it even before they watched it for the first time.

## 4.7 Activity Tracing

The features and functions in the ViDeX application provided a way to show students' interactions with their class videos. Not only did this facilitate students' ability to navigate the video, but the logs supported activity tracing. While the activity tracing was used primarily as a data analytic method for this study, activity tracing might be useful for instructors to view which parts of their videos are being reviewed frequently. This could provide instructors with the information desired in Chapter 3 where they could determine how to focus their in-class activities and or change their course content.

## 4.8 Limitations

Many of the students we interviewed stated that this was their first encounter with a course that utilised video so heavily as a teaching medium, and as such, many were figuring out how best to study from video. Thus, in this study, the novelty of learning from video likely played a role in how students were developing new learning strategies. As video becomes more ubiquitous in the current educational climate, we suspect not only students to be more experienced in learning from video, but instructors to better understand the strengths and nuances of teaching with video.

Furthermore, due to ethics restrictions, we were unable to link performance outcomes with specific viewing strategies, nor were we able to record the activities that students performed with the video outside the video player. For example, students reported note-taking in other apps or on paper which did uncover some strategies through the interviews. However, a detailed account of students' note-taking strategies with video could lead to some significant insights to further allow us to draw more conclusions about how to structure the videos and the video interface to integrate better into their information ecosystem [27].

Finally, our selection of students to study was limited to a first-year chemistry class and the 248 students who agreed to try a new video player that would record their actions. Further studies are needed to expand the range of topics to document different strategies students use in different knowledge learning contexts to fully articulate the range of behaviours that video production and video interfaces need to support. Video is a rich medium that is only beginning to find new roots in education; thus, there is an evolving set of genres, guidelines, tools, and strategies that are tied to specific pedagogical practices that remain to be created and studied. However, this study provides an in depth look at one particular set of experiences over three years of a core class in a post-secondary chemistry class, providing a foundation for the next steps of research.

## 4.9 Conclusion

The manner in which students watch video for their courses depends upon their knowledge learning context. For example, in one strategy, students used note-taking as a means optimising their time and reducing study and review time in the future. However, another student avoided note-taking because they believe they will be revisiting the video in the future anyway. Similarly, instead of reviewing the entire video, students will *seek forward* or 'skip' to find the information that they need for the assignment (i.e., the information they need to know immediately to demonstrate they are correct).

These behaviours, coupled with the students' workload in academic programs, suggest that students are making a trade-off between effective studying techniques (concepts like active watching, which derive from active learning [27]) and quickly finding information. Watching and searching video is a time-consuming task, with students performing significant searching throughout a video to try to reduce the amount of time watching irrelevant sections of video. Thus, there is substantial room for improving video player design and organising video production in a way that aids students in navigating through the information so that they can familiarise, clarify, and review content quickly. Doing so enables video to emerge alongside text to fully exploit its strength as a learning medium.

# Chapter 5

# Conclusion

The goal of this dissertation was to investigate the use of video as a tool in educational contexts from the perspective of both instructors and students. In this chapter, I conclude the dissertation by outlining and summarising the contributions, discuss the limitations and provide directions for future research.

## 5.1 Contributions

The three main contributions of this dissertation are:

1. a list of motivations for teaching with video and desires for video analytics to improve video for blended course learning (the Instructor study in Chapter 3),

2. a set of descriptors of how students use and watch video to complete assignments and study in a blended college science class (the Student study in Chapter 4), and

3. a novel interaction technique for highlighting in video (the Video Highlighting study in Appendix A).

For the Instructor study, we investigated instructors' current strategies and practices for using video to teach in blended learning environments. For the Student study, we investigated viewing behaviours exhibited by students by deploying an application across multiple cohorts in a post-secondary level chemistry course. Finally, for the Video Highlighting study, we designed and evaluated a video viewing interface within a laboratory setting that allowed users to organise their learning. This dissertation provides three main contributions in the research domain of Human Computer Interaction (HCI) and education:

1. *A list of motivations for teaching with video and desires for video analytics to improve video for blended course learning.*
   I investigated the current state of video as a teaching tool at a post-secondary level by interviewing instructors about their perceptions of the strengths and weaknesses of video, and the strategies they used to ensure that the video was being used effectively. We found the strengths of video to be increased accessibility (compared to textbooks), increased flexibility (students can easily re-visit information), and increased personability (videos created by instructors were more personable and students were more likely to be motivated to watch them). The main disadvantages of video were increased preparation time and difficulty in garnering feedback from the students. Creating a video was very time-consuming; instructors found that scripting, filming, and editing a video was more labour-intensive and difficult than writing text or presenting a lecture. Finally, instructors found it difficult to elicit feedback from students about the video; they were looking to see if their students had watched videos, how much the students understood in those videos, and how useful the videos were to the students, but the tools at their disposal were insufficient.

   Instructors used video in a variety of different ways; some instructors used video in a flipped learning format where students watched lecture videos before class and came to class to perform activities. Some instructors chose to use video as supplemental material incorporated into a website. Yet other instructors distributed video with a take-home worksheet to complete. We found that most of the instructors created their own videos. The majority of instructors used screen-recording software to record their slide presentations; some instructors created videos with the help of a professional studio and team, and some used videos they found online. In terms of feedback, instructors would often use PRS such as clickers, pop quizzes, or assignments to gauge literacy on the topics covered in the video. The instructors also asked students directly about whether the videos were adequate in representing the knowledge that the students needed to learn for the course.

The findings from this study suggest that instructors would make use of data about how their students watch video. By answering questions in the four different categories of aggregate student activity ("Did the students watch the video?"), individual student activity ("Are students having trouble with the material?"), student literacy ("Did the students learn the material?"), and video quality ("Were the videos useful for students?"), instructors could be more informed to better adapt to using video as a teaching tool.

2. *A set of descriptors of how students use and watch video to complete assignments and study in a blended college science class.*
   In the Student study, we studied five cohorts of students over three years to understand the different strategies that students used to watch video. Based on the structure of the course and the students' video viewing patterns, we discovered three knowledge learning contexts: *Introduction*, *Reinforcement*, and *Demonstration*. During the *Introduction* context, students *familiarised* themselves with the material by watching the video sequentially, skipping through, or reading the transcript. Subsequent reviewing of information, which we classify as *Reinforcement*, had students *clarifying* confusions they had by re-watching the video or re-reading the transcript. Finally, when assignments were due to be submitted for grading and the students needed to demonstrate their understanding of the material, students would *review* parts of the video to ensure that they had completed the assignment correctly. In this study, we also investigated the students' viewing patterns and found that activity peaks in the videos corresponded to assignment due dates as well as midterm evaluation dates. Further, the searching behaviour during *Reinforcement* and *Demonstration* contexts typically involved looking for problem-solving and informational slides that provided students with instructions on how to complete their assignments. Through activity trace analysis, we found six different methods that students used to traverse video: (1) watching most of the video sequentially with pausing or (2) without paus-

ing, (3) skipping directly to the conclusion, (4) skipping small sections of video, (5) skipping large sections of video, and (6) re-watching video. During *Reinforcement* and *Demonstration* contexts, students were more likely to watch videos by skipping around the video, with regular playthroughs being more common the first time they watched the video.

These findings offer implications for (1) designing videos and (2) designing interfaces for consuming educational videos. For the design of videos (1), our analysis of students' behaviours suggest that videos should be highly relevant to the material that will be on examinations to ensure that students will watch them. The videos should also be easily searchable by ensuring that the structure of a series of videos should be similar (e.g., introduction, objectives, instructional content, review, conclusions), and the different types slides should be made visually distinctive. The video viewing interface (2) should aid students in the searching tasks that they will inevitably perform; allowing students to temporally annotate video through highlighting or bookmarking, providing a searchable transcript or make text within the video searchable would also allow students to find material more quickly.

3. *A novel interaction technique for highlighting in video.*
   In the Video Highlighting study, we developed a novel interaction technique to highlight discrete time intervals in video. We observed and described four different strategies students used to highlight video intervals with two different interfaces (highlighting the transcript versus highlighting a filmstrip of the video) and seven different strategies they used to search for content within video. Highlighting behaviour varied across participants; they would: (1) read ahead in the transcript and highlight ahead as the video played, (2) highlight as they watched, (3) search backwards and then highlight, and (4) highlight the video after having watched it to the end. Participants in the study found that they would highlight parts of the video that they found to be confusing or parts they thought they would need to return to later. When asked to search for content, the participants would make use of highlighting as it worked well for saving intervals, and they found that highlighting was a useful interaction when viewing instructional videos. In general, participants

preferred highlighting a textual transcript over the filmstrip, but they used the highlighted filmstrip to search for intervals with more visual content.

## 5.2 Pandemic Context

The data collection for each study was performed prior to the COVID-19 pandemic. In British Columbia, post secondary institutes transitioned to online classes, suspending in-person classes from March 16, 2020 (UBC[1], BCIT[2]) until September 7, 2021 (UBC[3], BCIT[4]). The data collected in this dissertation presents a description of the experiences of instructors and students before the transition to online classes. At UBC and BCIT, online classes during the pandemic consisted of a mixture of live online lectures and pre-recorded videos and video lectures as instructors adapted to the change in teaching environment. As provincial mandates eased and schools began to reopen, anecdotal reports indicated that classes adopted a hybrid model, with some instructors choosing to remain remote, some returning to in-person classes, and others opting for a mixture of the two.

The pandemic presented instructors and educators with the challenge of finding alternative methods for teaching as they rushed to adapt their teaching material to a fully online environment. Many chose to adopt video, and while some instructors had already been teaching with video (such as those instructors I interviewed in Chapter 3). There are likely to be instructors who would be teaching with video for the first time and would not have adopted the technology under normal circumstances. While there are a myriad of reasons for not using video, the pandemic presented a paradigm shift that forced instructors to at least consider using video. In the Instructor study, we discovered that instructors find it challenging to use video to teach due to the lack of visibility of their students' learning, and that analytics into their viewing behaviour would be beneficial. For example, instructors began using Proctorio [5] to invigilate their students during online assessments, and this suggests that similar analytics on video viewing, such as video watching time

[1] https://president.ubc.ca/homepage-feature/2020/03/13/transition-to-online-classes-at-ubc/
[2] https://commons.bcit.ca/news/2020/03/transition-online-classes-mar18/
[3] https://president.ubc.ca/blog/2021/06/11/weekly-update-7/
[4] https://commons.bcit.ca/news/2021/09/president-update-sept9/
[5] https://www.proctorio.com

and video heatmaps would help instructors determine problem topics within the videos. However, the use of Proctorio revealed a number of privacy issues, for example, Proctorio's collection of student chat logs [6] and a lack of regard for student and instructor privacy. This prompted UBC to discontinue the use of remote proctoring software [7].

Privacy is a delicate issue, and while the mass collection of data is useful in modeling and predicting human behaviour, special care must be taken to ensure that the needs and safety of instructors and students are met. Proctorio presents an example where its users were not protected and exemplifies the importance of research that focuses on untangling the complexities between privacy, learning, and teaching, and the trade-offs that must be made in concession of each. For example, in our studies, we ensured complete anonymity for the students' and their data; instructors were made unaware of which students participated in the study. The technology that implements the use of behavioural analysis in education contexts should ensure that such data is used for formative assessment rather than summative assessment to prevent any biases that instructors may make based on preconceptions about video studying behaviour.

The information presented in this dissertation provides a snapshot of the perceptions of and practices for using video before remote learning became a necessity. The pandemic forced instructors to creatively devise alternatives to in-person classes and disrupted the stage for technology adoption in education [89]. In many cases, video substituted in-person classes, and sometimes arguably been overused. As schools reopen and in-person classrooms are reinstated, the use of video will decline as instructors continue to determine and synthesise optimal methods of using video to teach. During this process, students have also been acclimatised to online video learning, as well as online invigilation, which might ease tensions about data collection and allow for better statistical models to be built to predict video viewing behaviour. Certainly, the push towards video learning due to the pandemic will have altered the attitudes of both instructors and students, and it would be interesting to study the effects of the pandemic on the perceptions of remote learning and

[6] https://www.ubyssey.ca/news/proctorio-chat-logs

[7] https://academic.ubc.ca/academic-community/news-announcements/news/senate-vote-remote-proctoring-software

the use of video in asynchronous learning.

## 5.3 Limitations

In each chapter, I described some limitations of each study and the mitigation strategies that were taken. The first limitation is the generalisability of our results to educators as a whole. Our demographic mainly targeted Canadian post-secondary institutes, specifically instructors, professors, and students from UBC and BCIT. Similarly, we focused primarily on classrooms that had both online and in-person components. In the Instructor study (Chapter 3), to broaden our demographic, we tried to recruit and interview instructors who taught a wide range of subjects including political science, philosophy, advertising, computer science, and natural sciences. Future studies could include instructors from different academic levels, such as elementary school, high school, or continuing education. For the Student study (Chapter 4), we performed a multi-cohort descriptive study and analysis of students' video viewing behaviour. Some behaviours and strategies that we observed in this study may have been characteristic to chemistry courses that use video due to the way the course was structured. Future studies could incorporate different courses that use video in some of the other ways that instructors described in the Instructor study (Chapter 3). Finally, the Video Highlighting study (Appendix A) only focused on post-secondary students; we used university e-mail lists and posted flyers around the university campus to recruit participants. Future work in this area could make use of crowd-sourced methods, such as Amazon Mechanical Turk[8] or other similar platforms.

The second limitation is the extensive use of ViDeX in the Student and Highlighting studies. The behaviours that the students exhibited may be a biased by the interface they were given. In the implementation of ViDeX, we tried to ensure that the features in traditional video players, like closed captioning, full screen, navigation and thumbnail previews, were also available for the students to use. Additionally, in the Student study, ViDeX was made available only to students who had Windows and Macintosh computers, with access provided via the school's computer lab for those who did not have a computer. ViDeX also needed to be down-

[8] https://www.mturk.com/

loaded and installed onto the computer, and could not be run in a web browser. This may have discouraged a set of students from using ViDeX, because of the extra effort involved to install a separate application. Future implementations of ViDeX could be platform-agnostic to lower the entry barrier. It could also be implemented for mobile, such as cell phones or tablets. A mobile implementation would bring enable testing scenarios, such as on-the-go viewing on public transportation, and the students' behaviours when using mobile devices.

The third limitation is related to the data collected in the Student study (Chapter 4). Due to ethical limitations, the students' identities remained anonymous and as a result, we were unable to link student interviews with any of the behaviours we observed. However, we were able to observe and confirm the strategies that students stated they utilised when watching videos. Through aggregate analysis, we were also able to identify the types of information presented in video that were most interesting and useful to the students, and the strategies that students would use to go back to those areas of interest. Future iterations of this kind of study could also incorporate assignment and test scores, which would allow us the linkage of specific behaviours to learning outcomes.

## 5.4 Future Directions

At the end of each chapter, some of the work that could be done for future research was discussed. In this section, we revisit those directions and provide broader areas of research for videos in teaching and learning, as well as designs for video interfaces for students and instructors.

### 5.4.1 Analytics for Instructors

In the Instructor study (Chapter 3), instructors described their desire to view their students' video watching behaviours in order to gauge their students' interest and understanding of the material. Currently, there are analytics systems for video, such as those on YouTube[9] or Kaltura[10], which provide instructors with data on impression rates, minutes viewed per viewer, and visitation heatmaps that show which

[9] https://support.google.com/youtube/answer/9002587
[10] https://knowledge.kaltura.com/help/user-analytics

parts of video viewers watched most. With the behavioural analysis we performed in the Student study (Chapter 4), we discovered analytics that can be extracted from individual student behaviours such as re-watching and searching behaviour across different viewing sessions. The visualised activity traces presented in the Student study could be developed into an analytics dashboard to help answer some of the questions that instructors had about their students, such as "Did the students watch the video?" and "Where did students watch the video the most?". Of course, the amount of detail about the students' viewing behaviour would have to be managed to ensure the students' privacy is not violated. Integration of artificial intelligence systems could also be implemented to detect specific patterns of viewing, notifying instructors of any relevant issues. Detection of these patterns might also be relevant for teaching in the context of MOOCs, taking into account course structure and content analysis. Similarly, another research direction would be to investigate the utility of such an analytics system from the instructor's perspective, for example, what kind of information and statistics would be useful, and how instructors would interpret the data.

### 5.4.2 Analytics for Students

Following a similar line of thought, analytics could also be utilised to help students with their studies. Future research could cover, for example, artificial intelligence systems could help students identify topics or concepts that they may not understand fully and may want to review, based on their viewing behaviour. Similarly, systems could identify which parts of a video a student should review based on the behaviours of previous viewers of the video.

### 5.4.3 Exploring Effects of Demographics

As we mentioned earlier, the demographics of the studies were limited to students and instructors from Canadian post-secondary institutes. Future research could investigate the strategies and behaviours exhibited by students in other areas of study, other stages of education, and other cultures. There may also be interesting differences amongst different genders for both teaching and learning, with the different social obligations which may limit the amount of time for study or teaching, similar to how prior work has shown differences in exercise time [76] and health [25].

### 5.4.4 Rich Annotations in Video

In the Video Highlighting study (Appendix A), we introduced and tested highlighting as an interaction for simple video annotation. In subsequent work, our research group also developed rich annotations that allowed students to apply textual notes as well as icons to further increase the fidelity of those annotations [100], and then introduced an annotation manager to help students organise and search for their notes [65]. These interfaces were tested in controlled studies with positive results from users, citing their usefulness for recall and ease of use. Further work to understand how such interfaces would be utilised in a real-world environment, and how such interfaces would affect traditional note-taking with pen and paper would extend the research for text-based annotations.

### 5.4.5 Mobile ViDeX Application

The ubiquity of smartphones allows students to always have access to the internet and in the majority of cases, allows students the flexibility of studying for their courses anywhere. Mobile interfaces (for example phones and tablets) offer different affordances due to their compact size, wireless mobility, and touch screen, which may elicit different strategies for watching video than on a desktop or laptop computer. For example, in terms of mobility, students could more easily watch videos while commuting, or while lining up to buy coffee. The touch screen would open up new methods for annotation like drawing and handwritten notes on top of videos. All of this information could then inform pedagogical video design, such as best formats for creating video that is suitable for watching “on-the-go”, or how to create video that can make effective use of touch screens for advanced forms of annotation.

## 5.5 Concluding Remarks

To conclude, this dissertation presented of instructors’ perceptions of video, students’ patterns of use of video in a flipped classroom setting, and a novel interface to enhance students’ interaction with video. Instructors who have adopted video in their teaching found it to be very useful engaging students in a higher-level understanding of the material. These findings can inform future video creation tools designed specifically for creating video from teaching materials, as well as facilitate easier migration from more traditional teaching mediums such as presentation slides, textbooks, and paper assignments. Similarly, the shortcomings we discovered from video lay the foundation for other technologies to improve the teaching and learning experience. The data analysis of video viewing behaviour can be used to provide feedback for instructors, which would allow them to continuously evaluate their students' progress in the course, and make adjustments to their teaching as necessary.

We are entering the digital age of education, where instructors have a wide range of tools at their disposal to better engage their students in learning. Despite the long history of video in teaching, there is still a long road ahead to make video easier to create and watch. Instructors are becoming increasingly familiar with technological advances as well as the pedagogy that will help them author interesting and engaging videos, and students are learning to develop strategies to incorporate watching video into their studying habits. It is an exciting time to see education evolve to take advantage of these technologies as they become available. Designing technologies to meet instructors' and students' needs should be a priority.

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# Appendix A

# Textbook-Style Highlighting for Video

In this appendix, we explore interfaces described by other researchers that aid in video navigation for general video and introduce a new interaction for highlighting in video, a concept that draws inspiration from how students use textbooks for studying[1]. While this study was carried out before the Instructor study and the Student study, the interfaces that were developed and tested in this study (the Video Highlighting study) are connected to findings in Chapter 4, where we found that video navigation is a common action students use in their study with video. In Chapter 3, instructors had indicated that one of the challenges of using large quantities of video to teach courses is providing students with effective video management tools. The features tested in this study are designed to support students' video management. As described in Chapter 2, traditional playback controls (play/-pause, search, preview) are the commonly seen video navigation tools, but do not support recall, history, or interval bookmarking. These traditional controls require the user to either note down timestamps for intervals or visually search within the video when they want to view it again. However, video is a complicated medium

[1]In this appendix, we describe the Video Highlighting study. G. Miller (GM), X. Zhang (XZ) and myself (MF) were the researchers involved in this study; G. Miller (GM) and X. Zhang (XZ) aided in feedback for interface development, generating interview questions for sub-study 1, ran the focus group in sub-study 2, and were involved in peer debriefing for the analysis in the main study. For the purpose of this study, I will use the term 'we' when others were involved in the project.

to navigate, so it is not clear which types of interactions would be helpful for learning. Therefore, a closer examination of functions that support recall, history, and interval bookmarking was conducted.

The first contribution in this study is a usability evaluation with university students to determine the type of video interfaces that would help them with their learning experiences. We created a prototype interface with various features from prior works, including filmstrip preview, view count visualisation, personal viewing history, interval bookmarking, and playlists. Students were individually interviewed while trying each feature and asked which they found to be useful or if they would modify or add aspects. Based on their feedback, we identified the most promising features and ran a focus group to obtain ideas on how to present their ideas in the context of education.

Our second contribution is an investigation into highlighting of video using a textbook metaphor. Based on the outcomes of the interviews and focus group, we designed a prototype interface supporting video playback, view count visualisation, transcript navigation, and a two-dimensional filmstrip. The transcript navigator and the filmstrip both allow "highlighting" of video intervals with various colours, like one might do with highlighting pens to mark relevant pages in a textbook. The goal of this prototype interface was to discover if the textbook metaphor of highlighting was effective and whether or not the use of highlights within instructional video is helpful for students.

Various aspects of the video highlighting problem were investigated with a qualitative evaluation, including:

- Does the textbook metaphor of highlighting work for educational video?
- If so, then what type of content would students highlight?
- When do students highlight video content? (i.e., while viewing, prior to viewing, or after viewing)
- What strategies are used to highlight, and what strategies are used to find sections that had been highlighted?

A series of interviews (sub-study 1) followed by a focus group (sub-study 2) were conducted before the usability study (sub-study 3). Prior to recruitment and data collection for all sub-studies, the research procedures were approved by the UBC Behavioural Research Ethics Board [Certificate #: H13-01589].

## A.1 Preliminary Investigation

In order to determine the usefulness of current video interfaces, we decided to perform interviews and focus group studies with students who would be able to provide informed feedback. We selected interfaces that we believed would support users in studying: the navigation history visualisations provided by Al Hajri et al. [5] (Figure A.1 and Figure A.2), the visitation heatmaps in a visualised by Al Hajri et al. [4] (Figure A.3), a regular filmstrip type visualisation, and a form of authoring functionality seen in [37]. We presented these components to students and collected feedback.

### A.1.1 Interviews Sub-study 1

I conducted structured interviews with 11 participants to identify how students watched videos for online learning, and in regular classes. Informed consent was obtained from all participants. All interviews were audio-recorded and transcribed verbatim by me. I employed a convenience sampling strategy by inviting students who were in a student lounge. The participants were compensated monetarily ($10) for their time. The participants were aged 19 to 33, three male, eight female, and all the participants had taken at least one course with video. Prior to each interview, I introduced to the participants the idea of the flipped classroom, where video lectures are watched before class, and "homework" is completed in class and used that as the context in which the participants should think about answering the questions that were posed to them. I demonstrated implementations of interfaces mentioned above to the participants and asked them about their thoughts on how they might use them while studying. The interview script can be found in Appendix E. We[2] performed a summative content analysis [82] using keywords.

[2]MF, GM, XZ

**Figure A.1:** The video timeline is a visualisation of intervals of video that users have watched previously. The timeline is generated dynamically from the user's searching behaviour; larger thumbnails represent intervals that have been visited more often. (Al Hajri et al. [5]) Video thumbnails © copyright 2008, Blender Foundation / www.bigbuckbunny.org. Used with permission.

#### A.1.1.1 Results

We[3] discovered that students wanted control over how they would be able to review the material. They expressed interest in the video heatmaps, which would allow them to go back to parts of video that they found important enough to watch, as well as a way to author review material, by selecting and stringing parts of video together. These results were communicated to the rest of the research group as a form of peer debriefing to ensure an accurate interpretation of the students senti-

[3] MF, GM, XZ

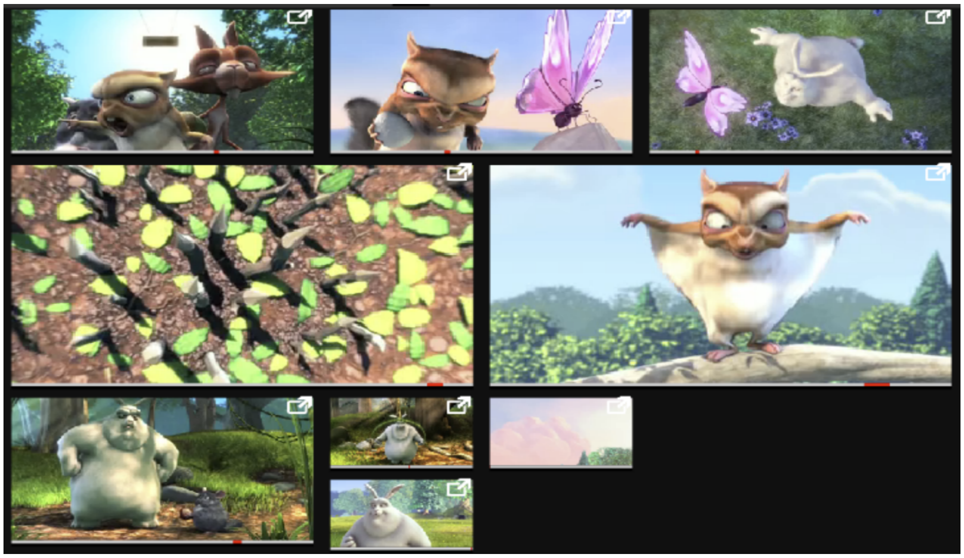


**Figure A.2:** Like the video timeline, video tiles is a visualisation of intervals that the user have watched previously. (Al Hajri et al. [5]) Video thumbnails © copyright 2008, Blender Foundation / www.bigbuckbunny.org. Used with permission.

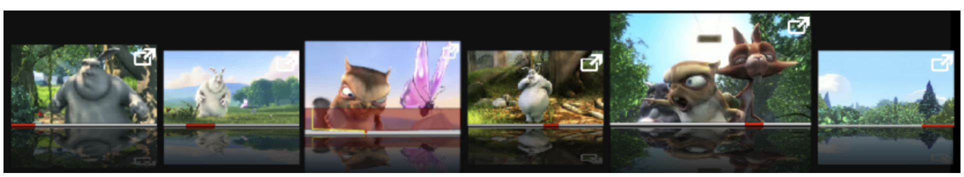


**Figure A.3:** This filmstrip visualisation combines the viewing heatmap seen in Mertens et al. [71] combines it with a filmstrip, which provides a visual representation of what parts of the video have been seen most. (Al Hajri et al. [4])

ments.

### A.1.2 Focus Group Sub-study 2

In order to better understand the results of the interviews, we[4] conducted a 45-minute focus group study. We employed a purposive sampling strategy, where we recruited seven students who had just completed a philosophy class that was taught partially with video using a standard video player (YouTube). This class was taught by an instructor we had been working with while developing ViDeX. We recruited the students by sending an email that was forwarded to the students by the instructor. We obtained informed consent from all participants and the focus group was audio-recorded and transcribed verbatim. The participants were monetarily compensated ($15) for their time. The seven participants in this focus group were aged 18 to 26, two male, and five female. During the focus group, we asked the participants to download a copy of the prototype interface to their laptops (the same interfaces used in the interviews above), and they were given a tutorial for each interface and given time to use and acclimatise to the interface. A script for the tutorial and demonstration phase can be found in Appendix F. The participants were asked to follow a speak-aloud protocol while they used the interface, so that they could voice any frustrations or ideas they had, to better inform us of a design of an interface that could support their studying needs. Similar to the interviews, we performed another summative content analysis [82] using keywords. Again, the results were communicated to the rest of the research group[5] as a form of peer debriefing to ensure an accurate interpretation of the students sentiments.

#### A.1.2.1 Results

We discovered that the participants wanted to be able to view a history of their own behaviour [5]. However, they expressed that the interface was difficult to use and the participants were frequently confused. They also thought being able to select intervals of video for manipulation ([37]) was useful in terms of organisation. The participants found the idea of being able to keep track of the parts of the video that have been seen more often, or parts of the video that have not been seen at all [56] intriguing and potentially useful. They wanted more control over the visualisation,

[4]MF, GM, XZ
[5]GM, XZ, SF

to be able to emphasise or de-emphasise certain parts of video without having to watch it repeatedly. Finally, they liked the idea of a playlist and being able to use it as an organisational structure mechanism.

Looking at the implications of user-adjustable emphasis and video organisation tools, we were led to the development of the proposed textbook metaphor for highlighting video and the prototype interface described in the following section.

## A.2 Usability Evaluation Sub-study 3

I ran a user study to investigate the usability and usefulness of the various methods for highlighting video presented in our system. The study provided insight into the patterns of highlighting material.

### A.2.1 Participants

I employed a convenience sampling strategy by placing flyers around a local university campus identifying the study's purpose, length, monetary compensation ($10 for 30 minutes), as well as a contact email. Participants would email me, and the participants and I would set a time to perform the study. In total, 11 volunteers participated in the experiment: six male and five female, ranging in age from 18 to 33. All the participants had taken at least one course online, and all but one had taken at least one course that used video as a teaching medium. I obtained informed consent from all participants. During the studies with each participant, I recorded both the audio and the screen. I did not record video of the participants.

### A.2.2 Apparatus

The participants were given a custom video player called ViDeX, which contained a filmstrip with video thumbnails that allowed users to navigate visually through the video, transcript viewer, and video display area. ViDeX is described in detail in Appendix B, and was developed following the input and feedback from the previous two sub-studies presented in Section A.1.1 and Section A.1.2.

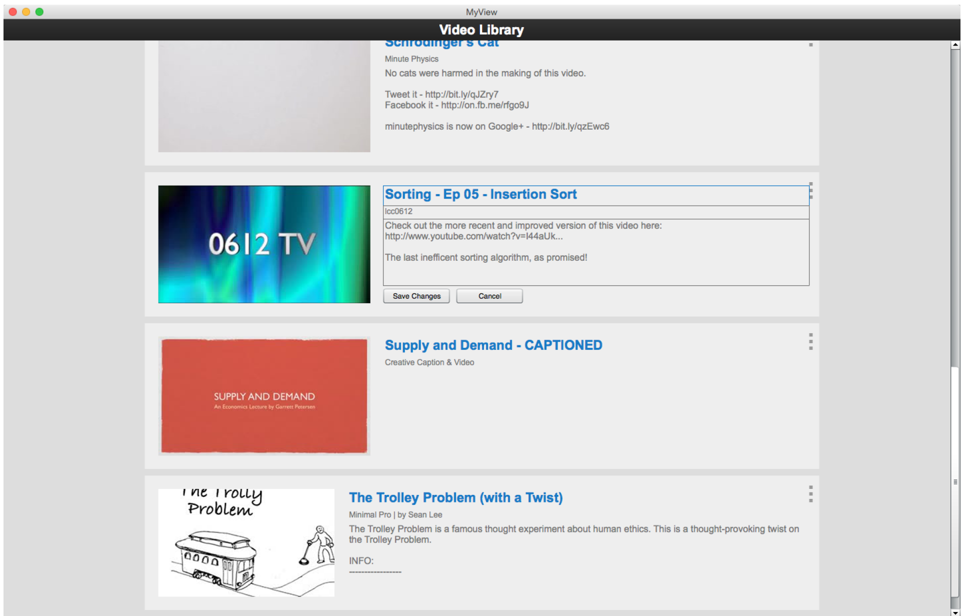



**Figure A.4:** The Video Library screen. Each video has a title, an author, and a description. The second video "Sorting Ep 05 Insertion Sort" currently being edited.

### A.2.3 Procedures, Data Collection, and Data Analysis

I exposed each participant to the two methods for highlighting described above, and gave the participants eight different educational videos to choose from, where each video was 2 to 3 minutes long. The videos were found on YouTube and included:

1. How chronic obstructive pulmonary disease (COPD) develops[6]
2. How to Balance Chemical Equations[7]
3. How To Read Music Two Minute Music Theory[8]
4. Learn Japanese Verb Groups[9]

[6]http://www.youtube.com/watch?v=iYjKZHmzWEA
[7]http://www.youtube.com/watch?v=8KH3laR2iR4
[8]http://www.youtube.com/watch?v=GiM2OKtACAQ
[9]http://www.youtube.com/watch?v=nOXuIYVzyL4

5. Schrödinger's Cat[10]
6. Sorting Ep 05 Insertion Sort[11]
7. Supply and Demand[12]
8. The Trolley Problem (with a Twist)[13]

By being able to select a video of their choice, I hoped they would choose a video that was interesting to them, thus encouraging them to pay attention to the video and use the interface in a way that would increase their enjoyment of the interface. I asked them to watch the video and pretend they were studying the video for a course and to highlight portions of video as needed. The experiment took approximately 30 minutes.

The evaluation began by introducing the participants to the idea of being able to mark up video as they would in a textbook, and a short description of the experiment. I first started by loading a demonstration video, and introduced the *transcript viewer* and the highlighting and search functionality. The video player filmstrip and the player widget were disabled during this section of the experiment. I then asked the participant to pick a video of their choice, watch it as if they were studying it, and highlight it as necessary with the transcript viewer. Once finished, I asked the participants three questions about the video, and they were asked to find answers in the video by searching for the answers. The questions were content-based and the answers to the questions were located at one-third, one-half, and two-thirds of each video. I noted the highlighting and search strategies that participants employed during each trial as well as the time taken for each search task. The participants repeated the process for the filmstrip, with the opposing interface element disabled. After introducing and using two elements, I asked the participant to watch one final video with the entire interface enabled. I then asked the participant to complete a questionnaire detailing their experience with the interface. The questionnaire contained 21 questions that were answered on a 5-point Likert

[10] http://www.youtube.com/watch?v=IOYyCHGWJq4
[11] http://www.youtube.com/watch?v=3orUYqcaEEQ
[12] http://www.youtube.com/watch?v=WdPI3hKUJYo
[13] http://www.youtube.com/watch?v=kKHOpw6tpd4

scale (Appendix G). I conducted a post-experiment interview asking about their experience with highlighting video, their preference for using highlighting via the filmstrip versus the transcript, as well as their highlighting experiences in e-books and physical textbooks.

I conducted t-tests on each question in the post-experiment questionnaire, and a chi-square test on participants' preference for highlighting interface.

### A.2.4 Results

In total, the 11 participants performed 99 search tasks (three times with filmstrip, three times with transcript viewer, three times with both), and in 44 of those search tasks, the participants searched for content that they had highlighted. A paired t-test revealed a significant difference in search time for content that had been highlighted compared to content that was not highlighted ($t(98) = 9.144$, $p < 0.0005$, $d = 0.919$).

Results derived from the questionnaire showed that the system was easy to use ($M = 4.18$), and learning to use each of the interface elements was easy (transcript viewer $M = 1.18$, filmstrip $M = 1.36$). General reactions to the video can be seen in Table A.1. Questions related to each particular interface element are shown in Table A.2. For "Learning was difficult", there was no significant difference between transcript viewer and filmstrip ($t = -0.767$, $p = 0.452$); for "Distracting", there was a significant difference ($t = -2.142$, $p = 0.045$), with filmstrip being more distracting than transcript viewer; and for "Utility of highlighting", there was no significant difference ($t = 1.596$ , $p = 0.126$). I also asked users to rank their preference of interface element to perform the highlighting and found a statistically significant difference with transcript viewer being preferred over filmstrip ($\chi^2(1) = 11.000$, $p = 0.001$).

The participants preferred the transcript viewer over the filmstrip for highlighting, and also found the transcript viewer less distracting than filmstrip while watching a video. Furthermore, while the participants found both features easy to use and both had useful highlighting functions, the filmstrip was significantly more distracting than the transcript viewer. The participants who thought the filmstrip was distracting cited the large playhead moving across as the video played as well

| Question | Score |
|---|---|
| Easy to use | 4.18 |
| Powerful | 4.27 |
| Flexible | 4.09 |
| Aesthetically pleasing | 3.82 |

**Table A.1:** General reactions to the system on a Likert scale from 1 to 5.

| Question | Transcript viewer | Filmstrip |
|---|---|---|
| Learning was difficult | 1.18 | 1.36 |
| Distracting | 1.27 | 2.18 |
| Utility of highlighting | 4.27 | 3.45 |

**Table A.2:** Reactions to specific interface elements on a Likert Scale from 1 to 5.

as the thumbnails being distracting. The participants who thought the transcript viewer was distracting cited the large amount of text on the screen. When we showed that it was possible to hide the panel, the participants were satisfied. In most cases however, participants would use the transcript viewer when asked to search for something in the video.

#### A.2.4.1 Highlighting Strategies

Participants utilised many different strategies of highlighting among the different interface elements. When given only the transcript viewer, the participants utilised the following techniques:

1. Pause the video and highlight the past video.
2. Watch entire video first, then go back and highlight.
3. While the video is still playing, highlight parts that have already been played.
4. Read ahead and highlight ahead of the still playing video.

Some participants in our preliminary interviews stated that when they watched online videos for studying, they oftentimes sped up the video 1.5 to 2 times faster. In fact, a couple of participants stated that they read ahead of the video, and one participant even skipped forward in the video, having evaluated for himself that a portion of video was not worth watching.

When given only the filmstrip, the participants only used retroactive highlighting, such as:

1. Pause the video and highlight the past video.
2. Watch the entire video first, expand the filmstrip, then go back and highlight.
3. While the video is still playing, highlight parts that have already been played.
4. Rewind and highlight the appropriate part while the video is playing.

While the participants remembered to highlight using the transcript viewer, they had to be prompted to highlight when they were given the filmstrip. When the participants were given both interfaces, only two participants decided to use the filmstrip at all to highlight, after having watched the entire video and going through again to highlight important points. Thus, the highlighting task is not only encouraged by the transcript viewer, but easier and more convenient to do as well. When asked about highlighting in the filmstrip, participants said that it was difficult to see what was being highlighted due to the lack of knowledge about what is being said during the highlighted interval (because the transcript was hidden for that part of the study).

#### A.2.4.2 Search Strategies

The search task required the participants to find portions of video using either interface element. Participants had more trouble with the search task using the filmstrip than the transcript viewer. As far as the search task itself, when the participants were restricted to the transcript viewer, they:

1. Watched through the video again.
2. Skimmed through text.
3. Used the text search.
4. Looked for the highlight when they thought it was highlighted.

When participants were restricted to only using the filmstrip, they:

1. Expanded the filmstrip and searched for visual information in the thumbnails.
2. Looked for highlights if they knew they highlighted the part.

Finally, when given both the filmstrip and the transcript viewer, participants did the following:

1. Searched to approximate point in the filmstrip and played the video.
2. If the portion was highlighted, used the highlight playback function.
3. Used the text search.
4. Looked for the highlights in the transcript viewer.

In terms of highlighting strategy, the participants stated that they would highlight what they didn't understand, what they thought were key points in the video, as well as review sections in the video. When the participants were asked about something that they had highlighted, the participants recognised it and were able to find the location of the video they were looking for, whether it was in the filmstrip or the transcript viewer. This indicates that the act of highlighting video acts as a memory aid for recall at a later time.

When the participants were asked about how they chose highlight colours, they had varied answers, but most commonly, they stated that choosing colours was random. Some participants stated they would highlight things in the order that they were given. For example, the first thing they would highlight would be red, the second highlight would be in yellow, the third highlight would be in green, which was the order that the colours were presented in the transcript viewer toolbox. It is worth noting that participants who utilised this method of highlighting were the quickest to find the answers to the experimenter's questions, immediately know which colour to look for and could very quickly find the appropriate time. One participant stated that they would use red for important points in the video and the rest of the colours would be random. Two participants stated that they would colour code their highlights based on the topic within the video, for example, definitions, or instructions sets. All participants except for one stated that the five colours included in the system were adequate for their needs. The participant who wanted more colours stated that the number of colours should be an even number, for example, four, six, or eight colours. The reasoning behind this was that she wanted contrasting colours so that she could highlight things positively or negatively. When asked if they highlight digital e-books or PDFs, nine participants said they did; the other two said that they did not. Following the experiment, some participants emphasised how much they liked the system with the following quotes: "*Is the app available now?*", "*I feel like the idea is really good, because you have highlight for e-book, for physical textbook, then why not for videos?*", and "*Are you guys planning on release this thing at all?*" These testimonials confirmed the need for intuitive methods for organising video for later recall.

## A.3 Discussion

Highlighting with the transcript viewer allowed students to highlight video in two ways: playing or watching the video first and returning to highlight, or reading ahead and highlighting at their own pace. For users, this meant that going through a video can be done much faster than real-time, which optimises their studying time. With the filmstrip, participants found it too difficult to differentiate the contents of the video from the thumbnails to highlight ahead of the playback. A design that provides users with a more detailed, full size preview would allow users to better visually determine the importance of the content.

Similarly, with search tasks, participants had more difficulty searching in the filmstrip over the transcript due to the smaller amount of distinguishable information displayed by the filmstrip. In the transcript viewer, the text is easily distinguishable, and it is easy to identify certain words, especially when aided by the search function. The filmstrip, while reported in other works to be useful for general video that contains many scene changes, was difficult to use due to the nature of educational videos. However, when a video contained screens of varying scenes, the filmstrip was more able to support searching. In the experiment, depending on how the filmstrip was expanded, the exact frame containing the answer to the search task appeared in the filmstrip and participants were able to quickly find the correct location.

When I restricted the participants to the transcript viewer, it was assumed that participants would use the automatic text search (often referred to colloquially as Ctrl+F). However, participants were more likely to scroll to the portion of the text they thought the answer was in and start skimming the text, searching for keywords manually. In these cases, participants stated that because they knew approximately where the answer was, it was easier to skim the text than perform a text search. This is because the text search required the participant to think of an appropriate keyword to search, and because the non-matching results were removed, breaking the linear flow of the text, and it was not clear where the search results resided in relation to the length of the entire video.

For videos where the narration plays a dominant role in conveying information, the transcript of a video is a useful tool. Should a video not utilise the spoken word as much, the concept of the timeline represented with the transcript viewer would have gaps. For example, if the video was focused on teaching music, large intervals in the video would be speechless, and no transcript would be present in those areas. Thus, the filmstrip or regular timeline could work as an alternate search mechanism.

## A.4 Limitations

In this study, most of our participants had prior experience learning with video, and this was beneficial for learning about how to improve the video learning experience. For students who have no experience learning with video, it might be possible that interfaces introducing more advanced features such as highlighting could be overwhelming. Similarly, the convenience sampling strategy I employed meant that the participants in the study consisted entirely of post-secondary students. In future studies, the sampling could be expanded to students of different age groups, such as elementary or secondary school students, or mature students in continuing education programs. The varying levels of exposure and familiarity to online video as well as familiarity to more traditional paper-based learning could pose an effect on their learning and applications a video highlighting interface. The nature of a controlled study, the small sample size, as well as the small variation in age and education level may limit the generalisability of the results pertaining to the perceptions of the interface. A larger and wider sample size (recruiting participants from a wider age range, academic background, and varying familiarity with video learning) would lead to more generalisable results, particularly in perceptions of difficulty in using the interface for their search tasks. However, it should be also noted that the participants exhibited a large variation of video search strategies.

The videos I used in the study were also short, ranging from two to three minutes. In other works on educational video, videos are recommended to be up to 6 minutes long [50] to maximise engagement. I selected relatively short videos for this study, but it would be interesting to see the highlighting and search strategies for longer videos. Finally, the actions of watching the video, highlighting the video, and then searching the video happened within five minutes of each other. In a more real setting, students would leave a video and return to it with a longer period of time between actions. Future research could explore these features in a more realistic context.

## A.5 Conclusions and Future Work

We presented a novel interface for highlighting video in both text and video representations. We performed two preliminary studies to inform us of what kind of interfaces work in a learning and education context, and developed an interface based on those findings. Then, I evaluated the interface and compared highlighting and search functions across both the filmstrip and the transcript viewer and found that the transcript viewer was more preferred. Furthermore, search tasks performed on content that was already highlighted was significantly faster. The interface as a whole was positively perceived, and we conclude that highlighting is a useful tool for educational video interfaces.

Future research could investigate collaborative video interfaces that can be used in and out of classrooms. This would allow students to share information and help each other, as well as allow the instructor more engagement with students. Many of the participants in the preliminary interviews stated that the face-to-face contact was invaluable, and we believe that adding more interaction between instructors and students in a video interface could aid in that respect.

# Appendix B

# ViDeX

ViDeX is an educational video viewing interface that allows users to manipulate emphasis on certain parts of video and be able to use that to organise the video in their own way. Thus, we designed the interface to allow users to highlight video, and then replay those highlights. In this way, the users are emphasising video (by highlighting it), and creating playlists (by being able to replay highlighted parts). We designed a ViDeX around this concept and took cues from physical highlighting tools as well as digital ones found in document readers. The interface consisted of two screens and three major elements. The first screen, shown in Figure A.4 allows the user to explore the videos offered by the interface. Clicking on one of the videos brings the user to the video player screen, shown in Figure B.2. This screen consists of three elements: the filmstrip (green), the player (red), and the transcript viewer (blue). In the next section, I will describe the design guidelines and each of the interface elements in detail.

## B.1 Video Library

The video library shows a list of videos offered by the interface. The user can see at a glance, the title, the author, the description, and a preview thumbnail. Upon putting the cursor over an item, a filmstrip, described in the next section, appears, allowing the user to quickly explore the visual contents of the video, see the highlighted parts of the video, as well as see which parts of the video have been

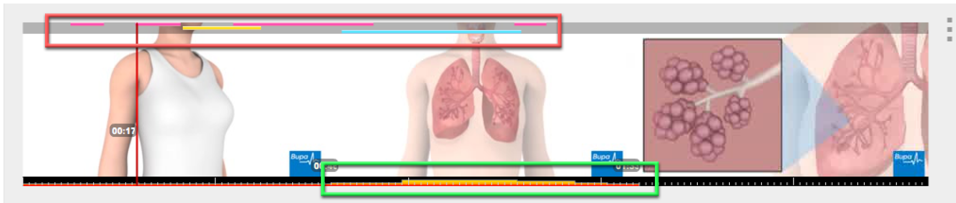



**Figure B.1:** The filmstrip as seen in the Video Library when the cursor is placed over a video. This at-a-glance view shows the user what parts of the video has been highlighted (top, red) and what parts they have seen (bottom, green). The user can also move the mouse across the filmstrip to preview the video.

viewed. This can be seen in Figure B.1. The details of each video can also be edited to the user's liking.

### B.1.1 Library Filmstrip

The filmstrip is a set of thumbnails from the video arranged side by side, each representing a portion of video. As the width of the filmstrip represents the entire length of the video, each $n$ thumbnail represents $1/n$ of the video. In the case of the video library, there are three thumbnails, and each thumbnail represents one-third of the video. Moving the cursor over top causes a floating timestamp (e.g. 1:30) to appear, and changes the corresponding thumbnail to show the frame represented by the horizontal location of the cursor. The initial preview in the thumbnail is the first frame the thumbnail represents in the interval of time in the video.

A bar indicating the highlights made in the video is located on the top side of the filmstrip. In pilot tests, users found that in slide-based videos the filmstrip resembled a set of slides instead of an actual timeline. In order to rectify this, we chose to insert time-ticks (the short vertical lines to represent intervals of time) at the bottom, distributing them evenly to a minimum of either one tick per second, or one tick every 10 pixels across the width of the filmstrip. Along the time-ticks, there are two timestamps placed at 1/3 and 2/3 of the width of the filmstrip to indicate time. Underneath the time-ticks, the filmstrip shows a heatmap of the user's visitation of the video. The height of the graph is logarithmic and the colour

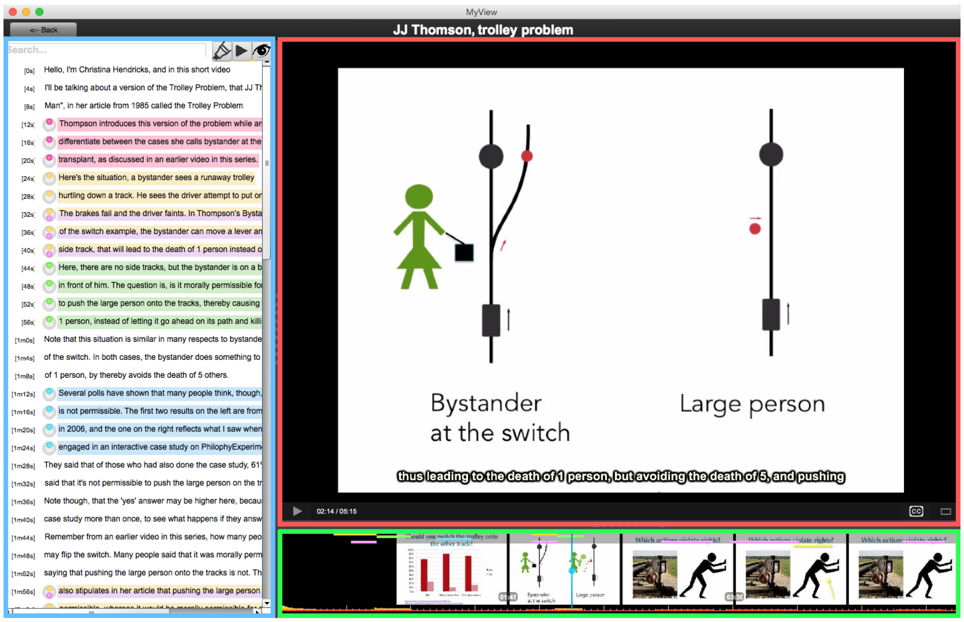



**Figure B.2:** The main video player view. The filmstrip (green), the player (red), and the transcript viewer (blue), reside here to help the user watch, and review the video.

ranges from red to orange to yellow, with red being least seen and yellow being most seen. This visualisation is similar to [56] and deals with scalability better, while less confusing than [4].

## B.2 Video Player

The video player, Figure B.2, allows the user to view the video. It consists of three major elements, the player, the filmstrip, and the transcript viewer.

### B.2.1 Player

The player, shown in red in Figure B.2 is the main focus of the interface and is typical of those found in other video players. On the bottom is a toolbar that houses video controls, allowing the user to play ( ) or pause ( ) the video, view the currently playing time, turn on and off closed captioning ( ), or make the video

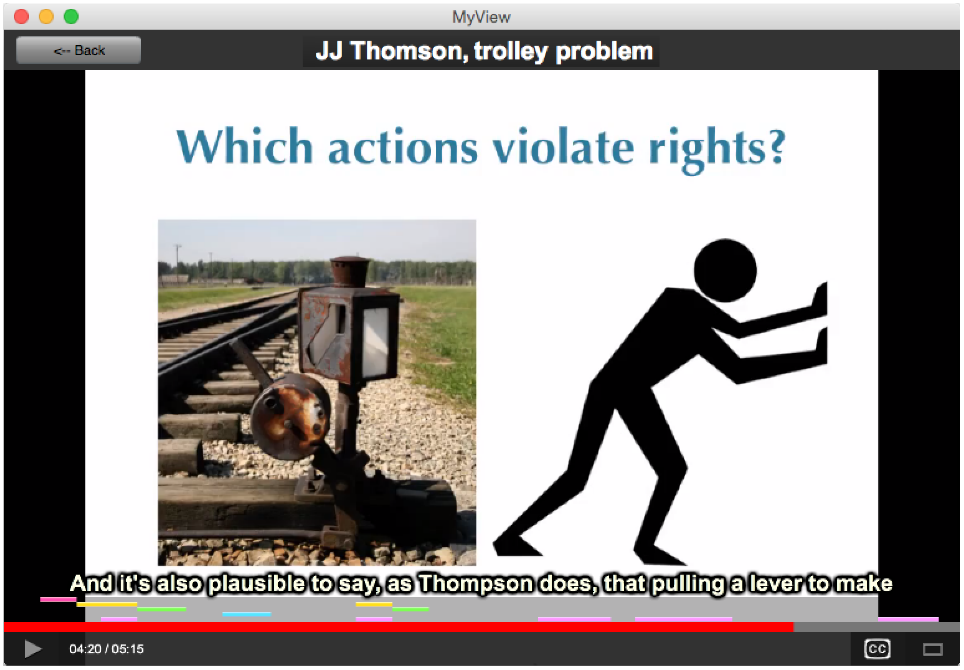



**Figure B.3:** The main player in full-screen view.

full-screen (). When the video is put into full-screen mode, a timeline appears on top of the toolbar, allowing the user to search without viewing the filmstrip. Furthermore, when the player is made full-screen, a bar of highlights appears on the top above the timeline. This can be seen in Figure B.3.

### B.2.2 Video Player Filmstrip

The filmstrip in the video player is very similar to the filmstrip found in the video library, with some extended functionality. When using the video player, the filmstrip provides the user with the ability to highlight intervals of time in the video. By clicking and dragging across the thumbnails, the user can select intervals, and then a set of buttons will pop up, allowing the user to select the colour they want to highlight (Figure B.4).

The filmstrip in the video player can also be expanded. By clicking dragging on the bar above it, the filmstrip can expand into multiple rows, and the scale of

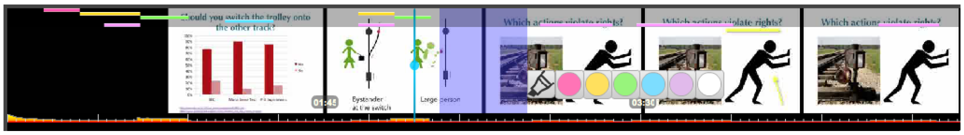



**Figure B.4:** The filmstrip with video selected (blue). A highlighting toolbar appears to allow the user to highlight the selected portion of video using the selected colour.


**Figure B.5:** The filmstrip, when resized, will split into multiple rows, each representing a portion of the video. Here, each row represents one-third of the video.

time is expanded across all the filmstrips. For example, in Figure B.5, there are three filmstrips and the width of each filmstrip represents one-third of the video. Some filmstrips ends and beginnings are jagged, indicating that they represent only parts of the video and not all of it.

### B.2.3 Transcript Viewer

The transcript viewer, shown on in Figure B.2 in blue or Figure B.6, is a transcript of everything said in the video. This provides the user with an overview of video in textual form, allowing them to quickly search through the spoken content of the video. As the video plays through, the text spoken at the time turns red. On the left of each caption is a timestamp, which the user can click, causing the player to move forward to the time indicated.

Like the filmstrip, the user can, in the transcript viewer, click and drag across text to select it, and using the button, the user can highlight the selected text in

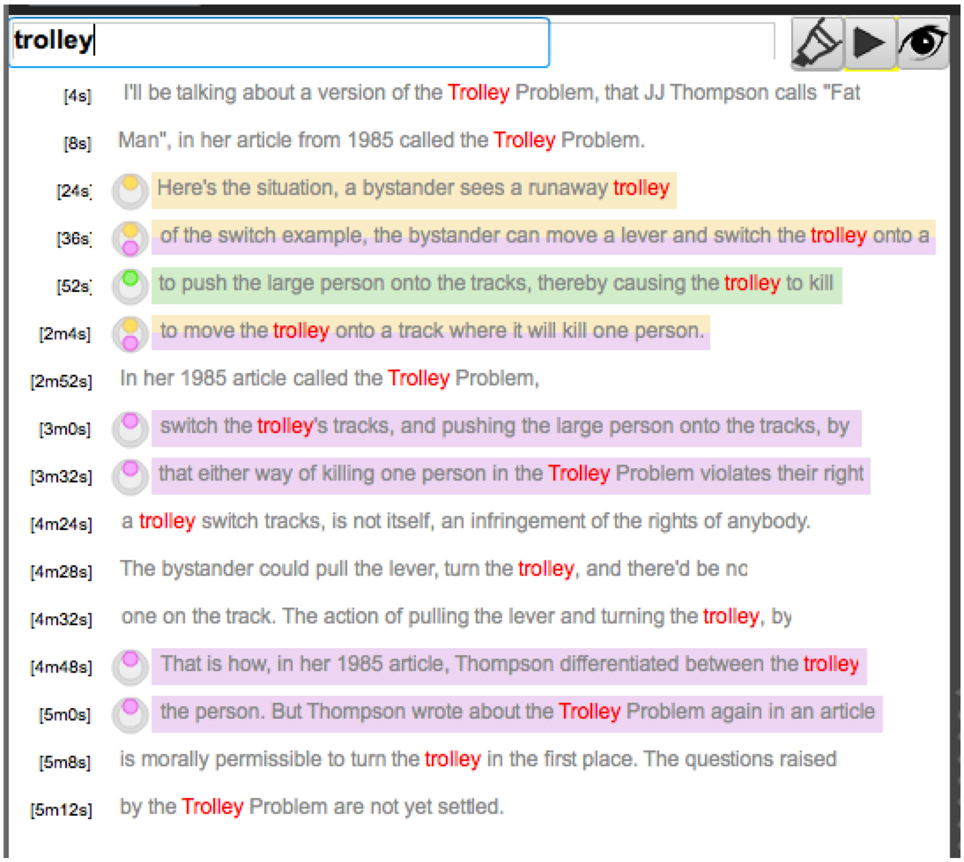



**Figure B.6:** All the text in the transcript is searchable.

the chosen colour. The text can also be highlighted in more than one colour, and each colour is stacked on top of each other underneath the text. Once a line of text has been highlighted, a small icon appears next to the text indicating to the user the colour that the text has been highlighted. This is designed for use when the text has been highlighted in multiple colours, because seeing which colour is underneath the text can be difficult.

The ► button allows the user to playback highlights and the 👁 hides the highlights within the text. A search functionality is also included, allowing the user to search for text within the transcript. When the user enters search terms, captions that do not contain any matches disappear and captions with a match remain on the

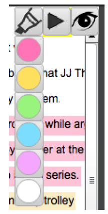


**Figure B.7:** Transcript viewer toolbox expanded to show the options of colours available to highlight.

screen. The text is greyed out except for the matching term within the text, which is marked in red.

# Appendix C

# Publication List

Some of the work presented in this dissertation have been previously presented in publications and oral presentations, which are listed here.

## C.1 Conference Publications

M. Fong, S. Dodson, N. Harandi, K. Seo, D. Yoon, I. Roll, S. Fels (2019). Instructors Desire Student Activity, Literacy, and Video Quality Analytics to Improve Video-based Blended Courses. *Proceedings of the Sixth (2019) ACM Conference on Learning@Scale*. 1–10.

M. Fong, G. Miller, X. Zhang, I. Roll, C. Hendricks, S. Fels (2016). An Investigation of Textbook-Style Highlighting for Video. *Graphics Interface*. 201–208.

## C.2 Oral Presentations

- May 2015 Poster Session at 2015 UBC TLEF Showcase, Vancouver, BC, Canada
- February 2017 Hackathon Demonstration at Microsoft Vancouver, Vancouver, BC, Canada

- May 2017 Poster Session at 2017 UBC TLEF Showcase, Vancouver, BC, Canada

## C.3 Other Publications

S. Dodson, I. Roll, M. Fong, D. Yoon, N. Harandi, S. Fels (2018). An active viewing framework for video-based learning. *Proceedings of the Fifth Annual ACM Conference on Learning at Scale*. 1–4.

S. Dodson, I. Roll, M. Fong, D. Yoon, N. Harandi, S. Fels (2018). Active viewing: A study of video highlighting in the classroom. *Proceedings of the 2018 Conference on Human Information Interaction & Retrieval*. 237–240.

S. Dodson, L. Freund, D. Yoon, M. Fong, R. Kopack, S. Fels (2018). Video-based consensus annotations for learning: A feasibility study. *Proceedings of the Association for Information Science, Technology*. 792–793.

N. Harandi, F. Agharebparast, L. Linares, S. Dodson, I. Roll, M. Fong, D. Yoon, S. Fels (2018). Student video-usage in introductory engineering courses. *Proceedings of the Canadian Engineering Education Association (CEEA)*. 1.

## C.4 Workshops

Seo, Kyoungwon, S. Fels, D. Yoon, I. Roll, S. Dodson, M. Fong (2020). Artificial Intelligence for Video-based Learning at Scale. *Proceedings of the Seventh ACM Conference on Learning@Scale*. 215–217.

# Appendix D

# Instructor Study Interview Script

1. Could you briefly tell me about what classes you have been teaching and how long you've been teaching for?
2. What kind of learning materials have you used in the past before video?
3. How do you know how your students are actually learning with the material?
4. Moving onto video, what content is in your videos? What is the format like?
5. How do you structure learning, in and outside the classroom using video?
6. How do you know how your students are actually learning with the videos?
7. How would you compare video with the other learning materials you teach with?
8. Are there any challenges that you came across when using video to teach? How did you overcome them?
9. Reflecting back, based on the stories today, what do you think about video as a learning material? What are its strengths and weaknesses?
10. What kinds of tools could help relieve the weaknesses and aid in overcoming the challenges you mentioned?

# Appendix E

# Video Highlighting Study Interview Script

Hi, we're investigating how students and professors leverage video as a platform for learning. Online learning, particularly those you see in EdX, Coursera, among others, have students watch videos online, and perform exercises based on these videos. In more traditional classrooms, there has been a move towards having students learn via watching video lectures online and performing lecture activities in class, forming the "flipped" classroom. Have you ever had something similar to this before?

- What software did you use to watch the videos in your course?
- (bring up the software if possible)
- Looking back, when you were watching the video for the first time, how did you watch it?
  - lead them a little bit about how they MAY have watched it, use behaviours from Al Hajri [2]
  - Did you take notes?
  - Did you ever skip around the video?
  - Did you ever re-watch parts of the video?

  - Did you ever review the material later?

- How did you look up information that you needed on an assignment?
- How did you study for an exam?
- Did you do anything special if you came across a part of the video that was very interesting or troubling?
- Can you suggest any improvements that could be made to this interface to aid in all the tasks mentioned above?

We have created an interface that aids users in finding sections of video quickly. We'll introduce the elements one at a time and you can tell us if these seem useful. (show interface w/ filmstrip) This filmstrip allows you to preview the entire video without having to watch through it. Each thumbnail represents a portion of the video and you can hover over it to preview.

- Given the filmstrip interface, do you think it would help you find video you're looking for faster?

Next, we have the playlist. In the playlist, you can save sections of video here for later viewing, by dragging across the filmstrip, you can select video intervals for placement in the playlist. Each playlist item can also be adjusted by dragging its edges. (show the interface w/ filmstrip, playlist)

- Given the playlist interface, how would you use it to aid in studying?
- Would you create proper clips?
- Would you use it as a bookmark? (and only get approximate locations)

Finally, this modified filmstrip allows you to see which part of the video has been seen most often. This is another representation of watching behaviour. (show the VCR, demo VCR changing) As you can see, as we watch the video, the size of the thumbnails changes, as well as the time duration of each of the thumbnails.

- Can you see this as being useful during studying?

(show the modeless history interface) The history then, is an automatic collection of portions of video based on your watching behaviour. Every time you go to another part in the video, a new item is created, represented as a thumbnail. As you watch the video, the thumbnail's duration gets longer. (demo history creation)

- Given the history interface, do you think it would help with studying?
- How do you foresee using it?
- How do you see it compared to the playlist?

(show moded history) Here is another way to visualize the history, and this provides a more detailed view about how we watched the videos. For example, items here are grouped together, summarizing the viewing more succinctly.

- What do you think of this collapsed history?

(overall interface questions)

- If we were to combine all these interface elements together, which would you see as being useful for studying?
- Can you think of a workflow that would be appropriate?

# Appendix F

# Video Highlighting Study Focus Group Script

Hi, we're investigating how students watch video in their learning. Online learning, particularly those you see in EdX, Coursera, among others, have students watch videos online, and perform exercises based on these videos. In more traditional classrooms, there has been a move towards having students learn via watching video lectures online and performing lecture activities in class, forming the ”flipped” classroom.

General:

(Bring up YouTube)

Imagine you're doing this course, and the instructor has told you to watch this video before the lecture. How would you go about it?

(watch 30 seconds or 1 minute of the video)

Coming back to that question, is there anything you would do differently while watching this video?

- Generally, when you are watching the video for the first time, how would you watch it?
  - Did you take notes?
    - Tablet, phone, pencil and paper?

- Did you ever skip around the video?
- Did you ever re-watch parts of the video?
- Did you ever review the material later?

- Suppose you came across a part that you found interesting or hard to understand, would you do anything in particular?
- Can you suggest any improvements that could be made to this interface to aid in all the tasks we mentioned? (Have some questions based on their answers from before.)

Filmstrip:

- What did you do when you wanted to search for a specific portion of the video? If I were to give you YouTube, could you show me?
- When does this work for you?
- When does this not work for you?
- For the times that this doesn't work, how can it be fixed, or how did you work around it?
- Here is an example design of a concept called the filmstrip. The filmstrip lets you preview more of the video without having to watch it. (demo)
- Can you see any advantages or disadvantages to this approach, compared to YouTube's seekbar?

VCR:

- If you could see which parts of the video you watched most or least, how would you use it?
- What if you could see what parts of the video other people watched most?
- Here is an example design of a modified filmstrip that shows just that.
- (demo)

- As you watch the video, it changes to reflect how you watched it.
- What are some situations in which you might want to switch to this view?
- Can you see any advantages or disadvantages to this approach?

Playlist:

- Did you ever use the videos to review for exams or assignments?
- How did you do it?
  - Did you take notes? Write down timestamps?
- What if you were be able to create your own video(s) from the lecture videos?
- This is an example design of the playlist, which allows you to make videos from lecture videos.
- (demo)
- How would you use the playlist?
  - Would you use it to create summaries?
  - Would this be useful for combining multiple videos together?
- Can you see any advantages or disadvantages to this approach?

History:

- Did you ever have to look for a specific portion of video that you knew you saw before?
  - How did you do it?
- Here is an example design of a history for video (similar to a web browser).
- (show modeless history)
- Did you ever have to look for a specific video that you've seen many times?

- How did you do it?

- (show moded history)
- How should the video shown here be ordered?
  - By time? By most watched? Allowed to customize?

Re-watching/Chaptering:

- With both the history and the playlist, you can see what you watched and create chapters for all your videos.
- (demo)
- What do you think about this process?
- If we were to combine all these interface elements together, which would you see as being useful for studying?
- Can you think of a workflow that would be appropriate?
- Was there anything that you thought was particularly good that I showed you today?
- If you had to pick one ”feature” that you’d like to see for UBC instructional video, which would it be?

# Appendix G

# Video Highlighting Study Post Experiment Questionnaire

# Questionnaire

1. Age: ___________
2. Gender: ____ Male ____ Female
3. Area of Expertise:

   ____ Architecture/Design ____Arts/Humanities ____ Business/Management

   ____ Computer Science ____ Education ____ Engineering

   ____ Mathematics/Quantitative ____ Natural Sciences/Medicine

   ____ Social/Behavioural Sciences

   ____ Other (specify): ________________________
4. Which online services have you taken courses from?

   ____Coursera ____edX ____Khan Academy ____MIT OpenCourseWare

   ____Udacity ____ Other (specify): ________________________
5. How many online courses have you taken that taught with video?

   ____ 0 ____ 1 – 2 ____ 3 – 5 ____ 7+

---

Overall reactions to the system

| | | | | | | |
|---|---|---|---|---|---|---|
| difficult | 1 | 2 | 3 | 4 | 5 | easy |
| inadequate power | 1 | 2 | 3 | 4 | 5 | adequate power |
| rigid | 1 | 2 | 3 | 4 | 5 | flexible |
| aesthetically displeasing | 1 | 2 | 3 | 4 | 5 | aesthetically pleasing |

Screen

characters on the screen

| | | | | | | |
|---|---|---|---|---|---|---|
| hard to read | 1 | 2 | 3 | 4 | 5 | easy to read |

screen layouts were helpful

| | | | | | | |
|---|---|---|---|---|---|---|
| never | 1 | 2 | 3 | 4 | 5 | always |

amount of information that can be displayed on the screen

| | | | | | | |
|---|---|---|---|---|---|---|
| inadequate | 1 | 2 | 3 | 4 | 5 | adequate |

arrangement of information on the screen

| | | | | | | |
|---|---|---|---|---|---|---|
| illogical | 1 | 2 | 3 | 4 | 5 | logical |

computer keeps you informed about what it is doing

| | | | | | | |
|---|---|---|---|---|---|---|
| never | 1 | 2 | 3 | 4 | 5 | always |

performing an operation leads to a predictable result

| | | | | | | |
|---|---|---|---|---|---|---|
| never | 1 | 2 | 3 | 4 | 5 | always |

length of delay between operation

| | | | | | | |
|---|---|---|---|---|---|---|
| unacceptable | 1 | 2 | 3 | 4 | 5 | acceptable |

Subtitles

learning to use it was difficult

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

distracting

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

utility of the highlighting function

| | | | | | | |
|---|---|---|---|---|---|---|
| not useful | 1 | 2 | 3 | 4 | 5 | useful |

Filmstrip

learning to use it was difficult

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

distracting

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

utility of the highlighting function

| | | | | | | |
|---|---|---|---|---|---|---|
| not useful | 1 | 2 | 3 | 4 | 5 | useful |

Player

learning to use it was difficult

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

round balls are distracting

| | | | | | | |
|---|---|---|---|---|---|---|
| disagree | 1 | 2 | 3 | 4 | 5 | agree |

utility of the highlighting function

| | | | | | | |
|---|---|---|---|---|---|---|
| not useful | 1 | 2 | 3 | 4 | 5 | useful |

utility of highlight playback

| | | | | | | |
|---|---|---|---|---|---|---|
| not useful | 1 | 2 | 3 | 4 | 5 | useful |

AUDIO QUESTIONS

1. Which method of highlighting do you prefer?
   ____ Subtitles ____ Filmstrip ____ Player
   a. Why?
   ________________________________________________________________________
   ________________________________________________________________________
2. Does showing text alongside the video help or hinder your learning? Would you use it for watching video first time or reviewing it?
   ________________________________________________________________________
   ________________________________________________________________________
3. When do you highlight? (Before/during/after first viewing?)
   ________________________________________________________________________
   ________________________________________________________________________

4. What do you highlight?

_______________________________________________________________________________

_______________________________________________________________________________

5. How do you utilize highlight colours?

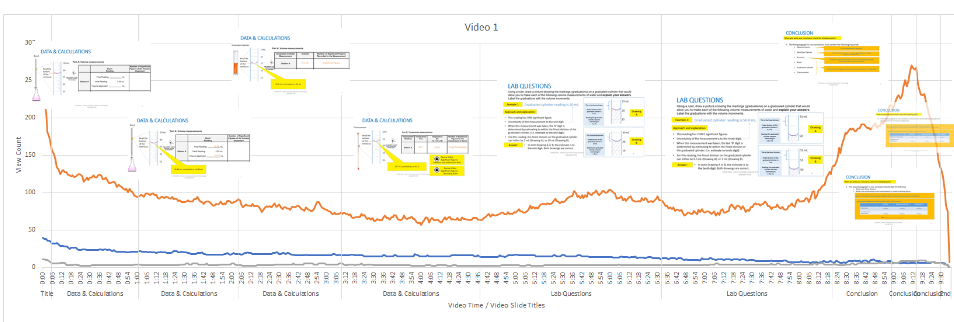
_______________________________________________________________________________

_______________________________________________________________________________

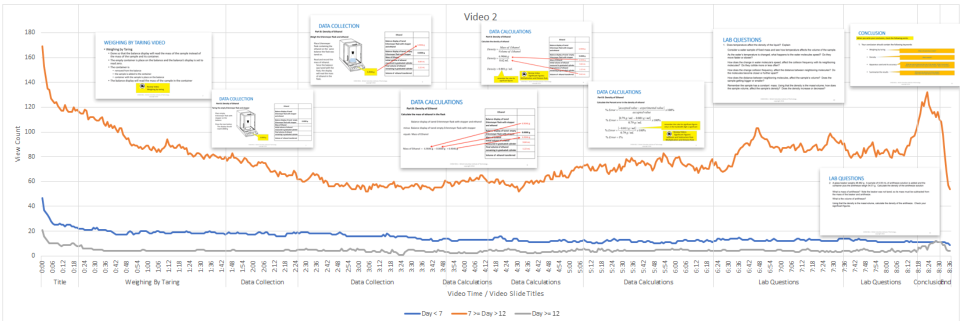
6. Do you highlight in PDF/textbooks?

# Appendix H

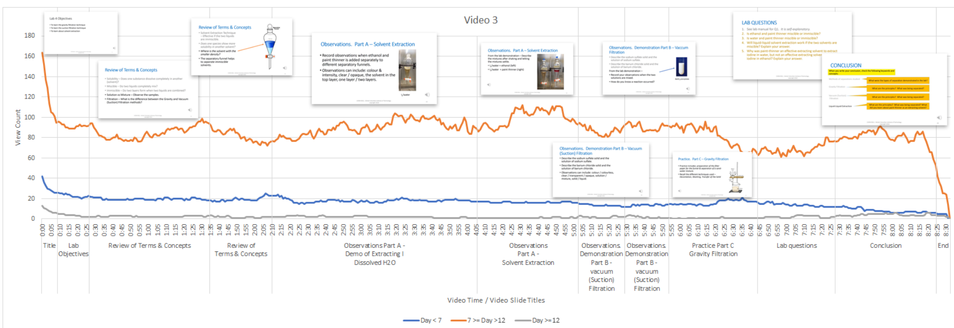
# View Count Records for Videos 1 to 9



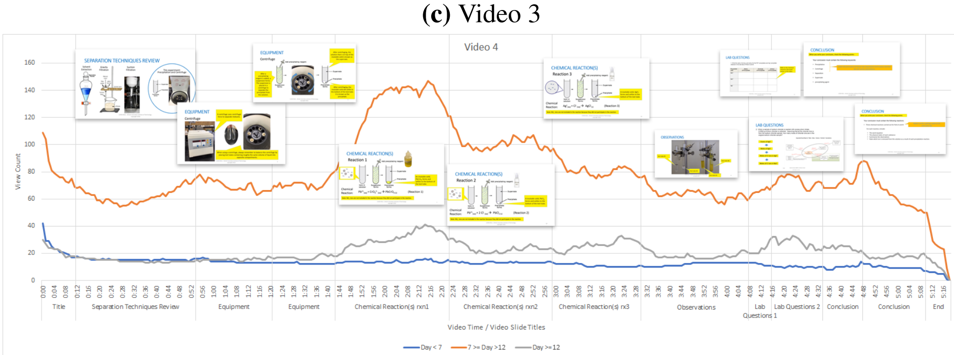

(**a**) Video 1



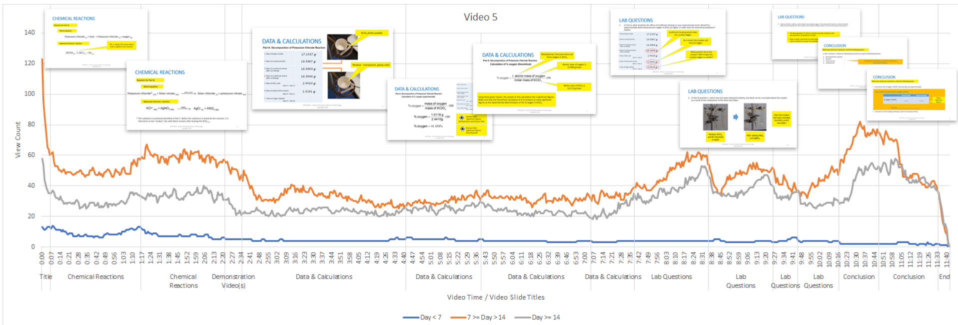

(**b**) Video 2



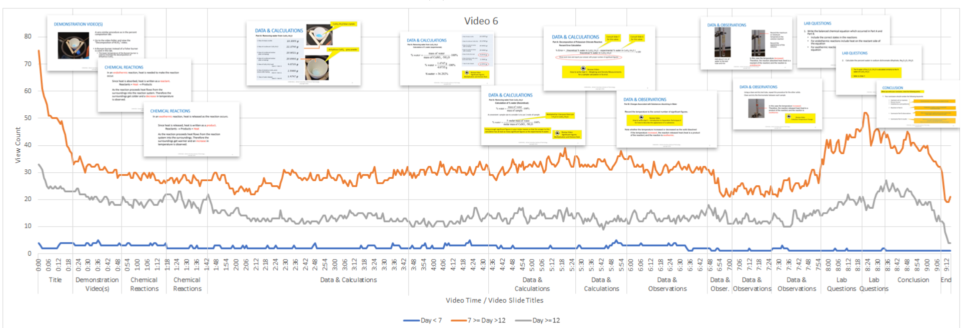

(**c**) Video 3



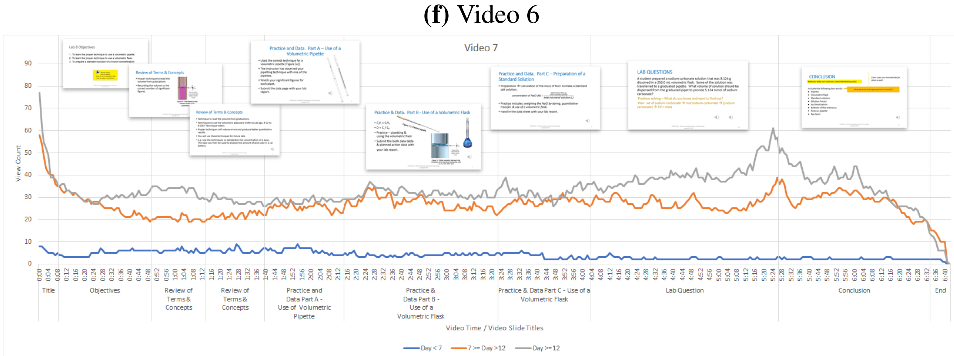

(**d**) Video 4



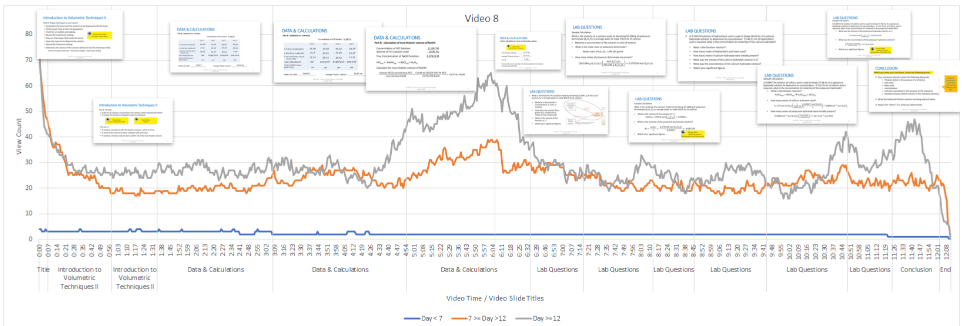

(**e**) Video 5



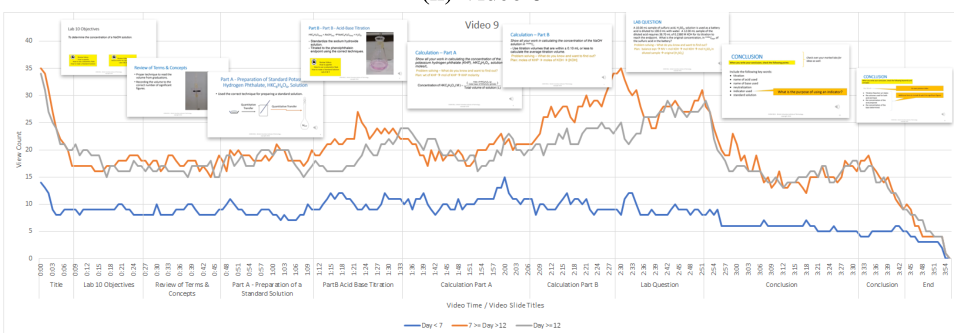

(**f**) Video 6




(**g**) Video 7




(**h**) Video 8




(**i**) Video 9

**Figure H.1:** Students' view counts of the videos. There is generally minimal viewing activity leading up to the experiment, and most of the activity happens after the experiment and before the assignment is due. Students most often find themselves watching and re-watching lab questions and conclusion slides. Video thumbnails used with permission.