Effects of In-Video Quizzes on MOOC Lecture Viewing

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ABSTRACT

Online courses on sites such as Coursera use quizzes embedded inside lecture videos (*in-video quizzes*) to help learners test their understanding of the video. This paper analyzes how users interact with in-video quizzes, and how in-video quizzes influence users' lecture viewing behavior. We analyze the viewing logs of users who took the Machine Learning course on Coursera. Users engage heavily with in-video quizzes – 74% of viewers who start watching a video will attempt its corresponding in-video quiz. We observe spikes in seek activity surrounding in-video quizzes, particularly seeks from the in-video quiz to the preceding section. We show that this is likely due to users reviewing the preceding section to help them answer the quiz, as the majority of users who seek backwards from in-video quizzes have not yet submitted a correct answer, but will later attempt the quiz. Some users appear to use quiz-oriented navigation strategies, such as seeking directly from the start of the video to in-video quizzes, or skipping from one quiz to the next. We discuss implications of our findings on the design of lecture-viewing platforms.

Author Keywords

in-video quizzes; lecture viewing; lecture navigation; seeking behaviors; MOOCs

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION

In-video quizzes are short, automatically-graded questions shown to users upon reaching a certain point in a lecture video, as shown in Figure 1. They are commonly found in MOOCs on Coursera.

In-video quizzes are beneficial because they provide learners with a way to test themselves on the material, which helps long-term retention (a finding known as the *testing effect*) [10]. They are particularly valuable in the context of MOOCs, because many learners interact primarily with videos and do not engage with assignments or exams [8] [2].

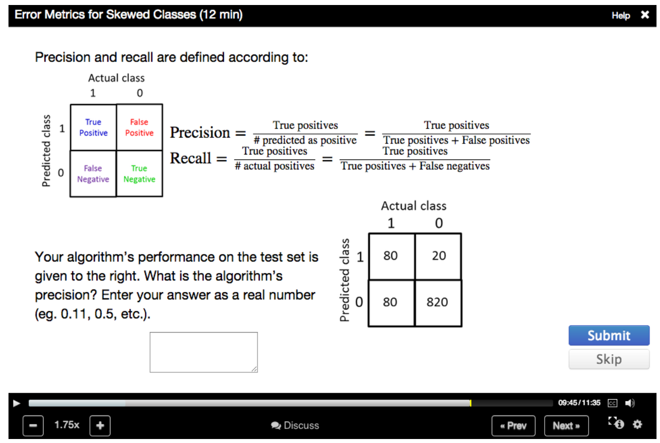

Figure 1. An in-video quiz on Coursera. In-video quizzes are short questions that are shown upon reaching certain points in the video.

In-video quizzes differ from other assessments in that they are displayed directly in the video viewer, so users can easily seek elsewhere upon encountering the quiz – seeking backward to review material related to the quiz, seeking forward to skip the quiz, etc. The presence of in-video quizzes inside videos can thus influence users' video viewing behaviors, potentially causing nonlinear navigation patterns such as seeking.

In this paper, we aim to learn more about how learners engage with in-video quizzes, and how video interaction patterns differ in the portions surrounding in-video quizzes. We do this by analyzing the video-viewing logs of the Machine Learning course on Coursera (ML4). We discovered the following interaction patterns associated with in-video quizzes:

- Users engage with in-video quizzes – among lectures with in-video quizzes, 74% of viewers will attempt a quiz.
- Users commonly seek forward to in-video quizzes, and seek backwards from in-video quizzes.
- Most backwards seeks from in-video quizzes occur after the user has seen the question, but before they answer it. This suggests that users are reviewing the preceding section to help them answer the quiz.
- Users do not tend to skip over in-video quizzes, either in the forward or backward direction.
- Users sometimes jump directly from the start of the video to in-video quizzes, or jump from one quiz to the next.
- Most users answer in-video quizzes correctly, with 76% answering correctly on their first try.
- In-video dropout is lower on lectures that have in-video quizzes, compared to lectures that lack in-video quizzes.

RELATED WORK

Kim et al performed an analysis of reasons for peaks in viewing and seeking while viewing lectures [7]. They found that users steadily leave videos over time, a phenomenon known as *in-video dropout*, and that visual transitions (such as slide transitions) tend to result in *interaction peaks*, with peaks in events such as users seeking back to the previous slide. They also presented a video viewer that encourages video navigation to interaction peaks [6]. However, the courses that they perform their video log analysis on do not have in-video quizzes, hence they are unable to report on interaction peaks that result from in-video quizzes. We similarly found in our own analysis that while there are many peaks in seeking behavior that can be accounted for by slide transitions, in-video quizzes tend to also be a major factor for determining where interaction peaks occur.

Guo and Kim analyzed the effects of video properties such as video length on viewer engagement [3]. They found that users become less engaged as videos grow longer, which is related to the problem of in-video dropout. However, they did not analyze the effects of in-video quizzes on viewer engagement, because the courses they analyzed do not have in-video quizzes. Our findings suggest that in-video quizzes may encourage viewer engagement, as indicated by the increase in rewatching and seeking behavior in the regions of the video surrounding the in-video quiz.

Guo and Reinicke investigated factors that contribute to nonlinear navigation through MOOCs [4]. They discuss examples of nonlinear navigation such as jumping back to previous lectures, rewatching videos, and going back from assessments to refer to lectures. Our present work focuses on navigation within videos as opposed to within MOOCs. However, we find that in-video quizzes, which are effectively assessments that are embedded into lecture videos, trigger similar backjumps and reviews within a video that Guo and Reinicke discuss at the course-level in their paper.

Anderson et al found that learners differ in the ways they engage with online courses: some only watch videos ("viewers"), some only complete assignments ("solvers"), and some engage in both ("all-rounders") [2]. Kizilcec et al discover similar engagement patterns [8], and discuss how these engagement patterns may be a result of learners' motivations for taking the course [9]. These differences between learners' engagement patterns are relevant to our work analyzing in-video quizzes, as they help explain why we find that some users' viewing behaviors seem to be aimed towards solving in-video quizzes. Additionally, the large population of users who engage primarily with videos underscores the importance of in-video quizzes as a means to test users' knowledge, which helps them retain the material [10].

In-video quizzes are not new; there are many past systems that embed quizzes into multimedia [1]. In-video quizzes are believed to have positive effects on learning [5], as testing helps in long-term retention of material [10]. However, to our knowledge, our paper is the first analysis of the effects of in-video quizzes on learners' rewatching and seeking behavior in the context of MOOCs.

Type of event or data within the ML4 course on Coursera	Value
Users who registered for the course	96,195
Users who visited the course page at least once	81,189
Users who started viewing at least 1 lecture	61,453
Users who reached the end of at least 1 lecture	41,643
Users who answered at least 1 in-video quiz	42,437
Users who visited the forums at least once	32,378
Users who downloaded at least one video	28,369
Users who had a nonzero grade (did an assignment or review exercise)	26,035
Users who earned at least 80% of total points (threshold for certificate)	8,615
Number of lecture videos	113
Length of average video (in seconds)	621
Number of in-video quizzes	109
Number of slide transitions	339
Number of external multiple-choice assessments ("review exercises")	18
Number of distinct lectures started viewing, across all users	1,495,954
Number of distinct lectures watched until end, across all users	976,933
Number of distinct lectures downloaded, across all users	1,223,237
Number of distinct in-video quizzes answered, across all users	1,031,061
Number of distinct review exercises answered, across all users	229,556
Total number of seek events	6,442,590
Total number of seek chains *(see Methodology section)*	2,103,336
Average length of video skipped over by a seek event (in seconds)	31
Average length of video skipped over by a seek chain (in seconds)	96

Figure 2. Summary statistics for the ML4 course.

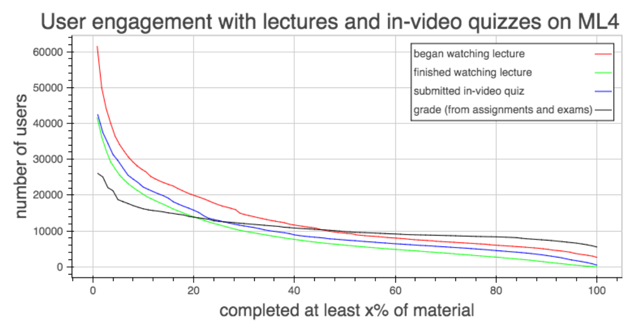

Figure 3. Response rates to the 109 in-video quizzes were similar to the viewing rates of the 113 lecture videos.

DATASET AND ENGAGEMENT LEVELS

The course we are analyzing in this work is the fourth iteration of the Machine Learning course on Coursera (ML4), which operated from October 2013 to January 2014. Our dataset contains data from 96,195 users, of whom 61,453 viewed at least one video. There are 113 lecture videos in the course, totaling 19.5 hours of video content, with an average length of 10 minutes per video. With 109 in-video quizzes over 19.5 hours of video, this averages out to one in-video quiz for every 11 minutes of video.

Of the 113 videos, 92 videos (81%) have 1 in-video quiz, 14 videos (12%) have no in-video quizzes, 6 videos (5%) have 2 in-video quizzes, and 1 video (1%) has 3 in-video quizzes. Videos with no in-video quizzes tend to be optional lectures covering interesting applications of machine learning, or are introductory videos that explain what will be covered next in the course.

Engagement with in-video quizzes is high: as shown in Figure 3, the answering rate of in-video quizzes closely mirrors the viewing rates for videos. In fact, the number of users who answer the in-video quiz is higher than the number who finish watching the video – if we look at the 92 videos that have one in-video quiz, 74% of users who begin watching a video sub-

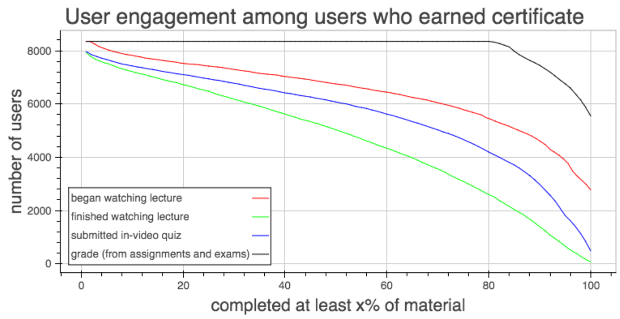

Figure 4. Users who earned certificates answered most of the in-video quizzes, even though in-video quizzes and lecture viewing do not count towards their scores.

mit an answer to its in-video quiz, whereas only 66% watch it to completion. This is likely because users often leave the video after completing the quiz, instead of watching it to the end (50% of in-video quizzes occur in the last 1/10 of the video, so the part following the quiz is often just a recap or preview). These high engagement rates with in-video quizzes contrast with the lower engagement rates typically observed for traditional assessments placed outside of the video [8] [2].

Certificate-earners (users who earned 80% of the points – note that in-video quizzes and lecture viewing do not count towards grades) also engage heavily with in-video quizzes, as shown in Figure 4. If we look at the 92 videos that have one in-video quiz, 79% of certificate-earning learners who begin watching a video submit an answer to its in-video quiz, whereas only 72% watch it to completion. That said, even certificate earners skip a few videos and in-video quizzes; the ones they tend to skip are optional lectures, early material reviewing prerequisite math such as matrices, and tutorial videos about Octave (a software package used by the course).

Other summary statistics are shown in Figure 2. Coursera provides users the ability to download videos and view them offline – meaning they will not see in-video quizzes, and their viewing activity will not appear in the logs. However, as we see in Figure 2, the number of users who download videos is less than half of those that view videos online.

METHODOLOGY

Determining Portions of Video Seen

The Coursera logs we used for our analysis are labelled with an action (such as play, pause, or seek) associated with a point in the video, and a timestamp. We use these logs to reconstruct the portions of the video that the user has seen, with a technique similar to the one described in [7]. If we observe a play event associated with video position p, followed by another event at video position p+i, we can assume that the user watched that segment of the video.

Reconstructing Seek Source Positions

The seek events in Coursera's logs only specify the destination of the seek and the timestamp at which it occurred, but not the origin (the logs tell us where in the video the user seeked to, but not where the user seeked from). However, we were able to reconstruct the seek source positions based on

Event type	Seek chains going forward		Seek chains going backward	
	% of all seek chains	# seek chains, normalized by the length of the seek target (seconds). Ratio to baseline in parentheses	% of all seek chains	# seek chains, normalized by the length of the seek target (seconds). Ratio to baseline in parentheses
All seek chains	56%	16.40 (baseline)	44%	12.86 (baseline)
Seek chains going to in-video quizzes (and their surroundings)				
Seeks to quiz (+/- 0.5 sec)	0.35%	**67.43 (4.1x)**	0.20%	38.21 (3.0x)
Seeks to 10 seconds preceding quiz	3.35%	**62.17 (3.8x)**	1.82%	34.58 (2.7x)
Seeks to 10 seconds following quiz	1.15%	21.89 (1.3x)	0.70%	13.33 (1.0x)
Seek chains going to slide transitions (and their surroundings)				
Seeks to slide transition (+/- 0.5 sec)	0.22%	13.60 (0.8x)	0.35%	20.89 (1.6x)
Seeks to 10 seconds preceding slide transition	2.49%	15.04 (0.9x)	3.41%	20.63 (1.6x)
Seeks to 10 seconds following slide transition	3.54%	21.42 (1.3x)	2.33%	14.11 (1.1x)
Seek chains coming from in-video quizzes (and their surroundings)				
Seeks from quiz (+/- 0.5 sec)	0.36%	**67.17 (4.1x)**	3.79%	**713.4 (55x)**
Seeks from 10 seconds preceding quiz	0.65%	12.30 (0.8x)	0.96%	17.99 (1.4x)
Seeks from 10 seconds following quiz	1.89%	35.95 (2.2x)	1.63%	30.76 (2.4x)
Seek chains coming from slide transitions (and their surroundings)				
Seeks from slide transition (+/- 0.5 sec)	0.30%	18.22 (1.1x)	0.27%	16.22 (1.3x)
Seeks from 10 seconds preceding slide transition	6.72%	40.68 (2.5x)	2.27%	13.73 (1.1x)
Seeks from 10 seconds following slide transition	2.78%	16.81 (1.0x)	3.98%	24.10 (1.9x)

Figure 5. Sources and destinations of seek chains. Users tend to seek backward from in-video quizzes (55x higher than baseline back-seek rate), and forward to in-video quizzes and the 10 seconds immediately preceding them (4x higher than baseline forward-seek rate)

the previous event – for example, if the user started playing from video position p at timestamp t, and we observe a seek event at timestamp t+i, then we assume the seek originated from video position p+i (or p+2i if the user is playing back the video at 2x speed, etc).

Grouping Seek Events into Seek Chains

Additionally, we observed that many seek events tend to occur in rapid succession as the user narrows down on the actual target. For example, when users seek via the keyboard, if they are at the beginning of the video and their seek target is 3 minutes into the video, they will press the right-arrow repeatedly until they reach the destination, resulting in a large number of small, noisy seek events, rather than a single seek from 0 to 3 minutes that we are interested in analyzing. Because we are primarily interested in where the user ends up seeking to, rather than the individual seek operations that got them to that point, if there are seek events that occur within 5 seconds of each other, we group them together into a single unit which we will call a *seek chain*. Using this approach, we reduced the 6,442,590 total seek events in our dataset into 2,103,336 seek chains. When we analyze seeking in this paper, as well as seek sources and destinations, we will be analyzing seek chains rather than raw seek events, to reduce noise from repeated seeks. That said, our main findings about peaks in seeking around in-video quizzes also hold if we analyze raw seek events instead of seek chains.

Limitations of Coursera's Dataset

Since Coursera's logs do not record when a user closes their browser window or the network disconnects, the full duration of what users finished watching may be underestimated. For example, if a user starts playing a video at time t, and this play event is the last logged event, we know that the user must have closed their browser prior to the next in-video quiz or the end of the video (otherwise a pause event would have been logged), however we do not know exactly when the browser was closed. We address this ambiguity by treating it as though

Event type	value
Forward seek chains	
Total # of forward seek chains	1169873 (55.6% of seeks)
Average length of a forward seek chain, in seconds	129 seconds
Average # of times each second of video was seeked forward over	2153 (baseline forward seek rate)
# forward seek chains crossing slide transitions (339 slide transitions total)	909675 (43.2% of seeks)
# forward seek chains crossing each slide transition	2683 (1.25x baseline)
# forward seek chains crossing quizzes (109 quizzes total)	98613 (4.69% of seeks)
# forward seek chains crossing each quiz	905 **(0.42x baseline)**
Backward seek chains	
Total # of backward seek chains	933463 (44.4% of seeks)
Average length of a backward seek chain, in seconds	54 seconds
Average # of times each second of video was seeked backward over	719 (baseline backward seek rate)
# backward seek chains crossing slide transitions (339 slide transitions total)	301129 (14.3% of seeks)
# backward seek chains crossing each slide transition	888 (1.24x baseline)
# backward seek chains crossing quizzes (109 quizzes total)	47184 (2.24% of seeks)
# backward seek chains crossing each quiz	432 **(0.60x baseline)**

Figure 6. Lengths of seek chains, and portions of the video that they skip over. Users typically do not seek forward or backward across in-video quizzes.

the user had immediately stopped watching after that last play event, so we do not include the last (unknown) segment that was watched after their final interaction with the video.

AGGREGATE SEEK CHAIN STATISTICS

Sources and Destinations of Seek Chains

The sources and destinations of seek chains are shown in Figure 5. We see that in-video quizzes are a popular destination of seeks, particularly in the forward direction – users seek forward to the in-video quiz at 4x the baseline rate of all seek chain destinations. Given the high answering rate for in-video quizzes we showed in Figure 3, this suggests that these seeks originate from users who want to answer the in-video quiz at that point. Note that Coursera's interface does not have any UI features for seeking to in-video quizzes apart from the progress bar, so the only way to reach the in-video quiz is to seek to a segment of video right before it. Hence, we consider seek chains which terminate at most 10 seconds before the in-video quiz to represent users intending to jump to the in-video quiz.

Users also seek backward from in-video quizzes at 55x the baseline rate. As we will show, these represent users reviewing the preceding section, likely trying to find material that will help them answer the in-video quiz.

Lengths and Directions of Seek Chains

As shown in Figure 6, on average forward seek chains tend to be over longer distances, while backward seek chains tend to be of shorter duration. A potential explanation is that forward seeks aim to go to some salient part of the video – for example, an in-video quiz – whereas backward seeks aim to review a part of the video that was just missed. We also observe that users seek forwards more than backwards overall, including across slide boundaries; however, they tend not to seek forward over in-video quizzes. As we will see, this is because they are seeking to right before the in-video quizzes, either to view the quizzes, or to search for answers to quizzes.

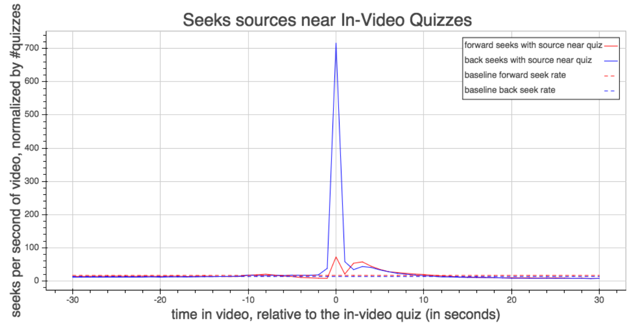

Figure 7. Seek chains with sources near in-video quizzes, averaged across all 109 in-video quizzes in the ML class. There are many backward seeks originating at the in-video quiz, reflecting users wanting to review the preceding material.

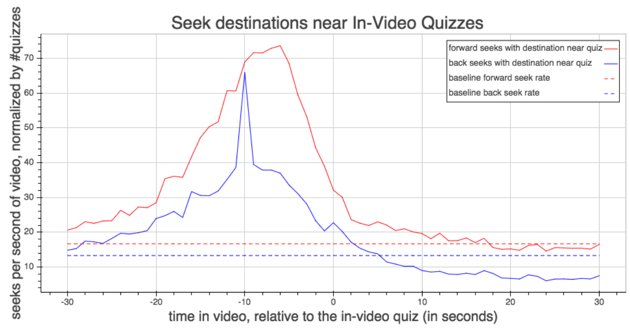

Figure 8. Seek chains with destinations near in-video quizzes, averaged across all 109 in-video quizzes in the ML class. The portion immediately preceding the in-video quiz is a common destination of both forward and backward seeks. The peak in forward seeks reflects users seeking forward to the in-video quiz, while peak in back seeks at 10 seconds before the video is likely due to users seeking back with their keyboard.

Seek Sources and Destinations near In-Video Quizzes

As we saw in Figure 5, there are many seeks originating from and terminating near in-video quizzes. In this section we will analyze seek chains near in-video quizzes in more depth.

Seek Sources near In-Video Quizzes

Figure 7 illustrates the sources of seek chains near in-video quizzes, averaged across all 109 quizzes. As we can see, there are a large number of backward seeks originating from in-video quizzes. These reflect users who, having seen the in-video quiz, are reviewing the preceding section to find information to help them answer the question. However, there are also many forward seeks originating from the in-video quiz as well as the portion that immediately follows it. These likely reflect users who, having looked at or completed the in-video quiz, are seeking forward to preview the next section.

Seek Destinations near In-Video Quizzes

Figure 8 illustrates where users seek to near in-video quizzes, averaged across all 109 quizzes. As we can see, the 10 seconds immediately preceding the in-video quiz are a popular destination of seeks, both in the forward and backward directions. Seek chains in the forward direction arriving just before the in-video quizzes may reflect users who intend to go to the in-video quiz – Coursera's interface does not provide a means of going directly to an in-video quiz, other than seeking to the immediately preceding portion and playing the video. Seek chains in the back direction arriving just before the in-video quizzes may reflect users who are reviewing the video to help them answer the in-video quiz. We observe a spike in back-seek destinations at exactly 10 seconds before the in-video quiz. This is likely users who are seeking backwards from the in-video quiz using the back arrow key on their keyboards, which causes a backward seek of exactly 10 seconds.

VIEWING BEHAVIOR IN AN INDIVIDUAL LECTURE

Visualization of Seeks and Watching

In order to explain why users are seeking to and from in-video quizzes, let us first visualize a representative video before moving on to all videos in aggregate. This is Lecture 13 from ML4, titled "Matrices and Vectors". We chose it because it has 2 in-video quizzes, and neither is located at the very end of the video, so results should not be overly influenced by the position of the in-video quizzes.

Figure 9 presents the seek chain sources and destinations in this video as a scatter plot. It illustrates users seeking forward to in-video quizzes and going back to the preceding section to look for answers. It also show how seek chains do not tend to cross forward or backward across in-video quizzes. Thus, the in-video quizzes subdivide the video into smaller sections that users do not tend to skip between.

As shown in Figure 10, in-video quizzes are a popular destination of seeks. Many of these seeks originate from the preceding section, confirming the statistics we saw in Figure 5. This suggests that users may have found the answer to the quiz, and are seeking forward to answer the in-video quiz. However, there are also many seeks to the in-video quiz from the start of the video and from the previous in-video quiz. This suggests some users might be following a quiz-centric navigation strategy of seeking directly to the quiz to preview it before they watch the video.

Increased Rewatching near In-Video Quizzes

We hypothesized that if users search for relevant material in the preceding segment upon encountering an in-video quiz, this should be reflected in the viewing logs. Namely, we would expect to see increased re-watching of the portion prior to the in-video quiz. We would also expect to see seeks that originate from the in-video quiz and go backwards to the preceding section, which contains material related to the quiz. We show examples of these phenomenon in this section.

We see in Figure 10 E that the portion of the video surrounding the in-video quiz tends to receive more views. We also observe a trend of fewer views for portions of the video that occur later, which can be explained by in-video dropout [7].

We believe the increase in the number of views surrounding the in-video quiz is due to users rewatching the portion preceding the in-video quiz, perhaps searching for material that will help them answer the quiz. Indeed, if we exclude each user's first-time watch, and look only at what users are rewatching in aggregate, we still observe this peak in number of rewatches around the first in-video quiz, as shown in Figure 10 F.

Because Coursera does not require users to take in-video quizzes, we wondered whether users explicitly skip across in-video quizzes to avoid taking them. As illustrated in Figure 10 B, we found that this does not seem to be the case. On the contrary, there is actually a dip in the number of forward seeks that cross over the in-video quiz, so users are explicitly trying not to skip the in-video quizzes. This low number of forward seeks crossing over the last in-video quiz in this example might be attributed to the fact that it is located towards the end of the video, so the user may be aware that there is no new content to find towards the end. However, if we look at the first in-video quiz in the example, we also observe a dip in the number of forward-seeks over the in-video quiz, even though there is important content in the video after it.

Thus, we observed that users rewatch the regions surrounding in-video quizzes, tend to backseek to review the materials preceding the quiz, and do not forward-seek over quizzes.

VIEWING BEHAVIOR IN ALL LECTURE VIDEOS

In this section, we analyze seek chains in all videos to learn how in-video quizzes influence users' viewing behavior.

Forward Seeking to In-Video Quizzes

Figure 11 shows the destinations of forward seeks for each of the 113 videos in the course. Each horizontal line represents a video, where darker shades indicate more seek chains going to a particular segment of the video. We label the locations of in-video quizzes (red) and slide transitions (green).

In-video quizzes are a popular destination of seeks, as indicated by the black streaks immediately preceding the in-video circles (recall that Coursera does not let users seek directly to in-video quizzes, but requires them to seek to the segment right before the quiz if they want to take it). As we showed in Figure 5, forward seek rates to the in-video quizzes are 4 times higher than the baseline rate.

If we look at lectures 25-30 in Figure 11, they do not visually match the pattern we see in the other lectures. This is because they're optional videos discussing applications of Machine Learning, which don't have in-video quizzes.

In-Video Quizzes are a Major Source of Backward Seeks

As we can see in Figure 12, there are many seeks in the backward direction that start from the in-video quizzes (red circles). Specifically, as shown in Figure 5, the rate of backward seek chains from in-video quizzes is 55 times higher than the baseline rate. We also see peaks in backward seeks after slide boundaries (green diamonds), which confirms prior findings of interaction peaks at slide boundaries in EdX videos which lack in-video quizzes [7].

Video Parts Skipped Back Over

As we can see in Figure 13 and Figure 5, in-video quizzes are a major source of backward seek chains. As we can see in Figure 13, if we look at all portions of the video that are skipped backwards over by seek chains, it is primarily the

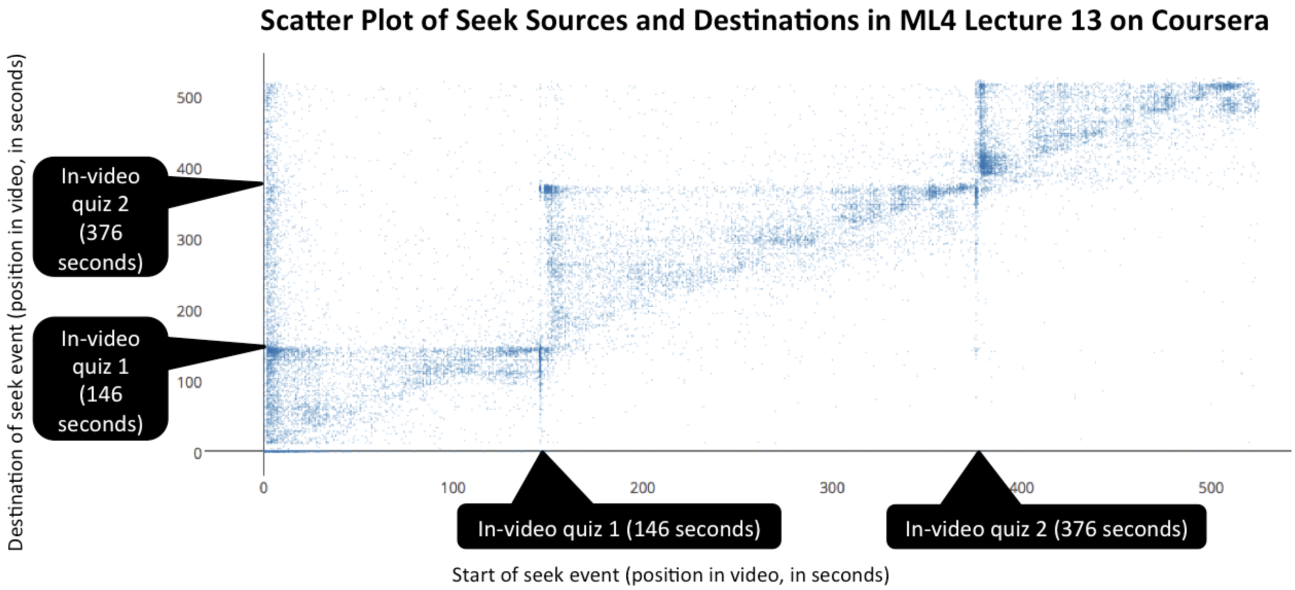

Figure 9. Seek sources and destinations in a lecture with 2 in-video quizzes. Each point at (x,y) represents a seek from time x to y. There are many seeks to in-video quizzes from the start of the video, the previous section, and between quizzes.

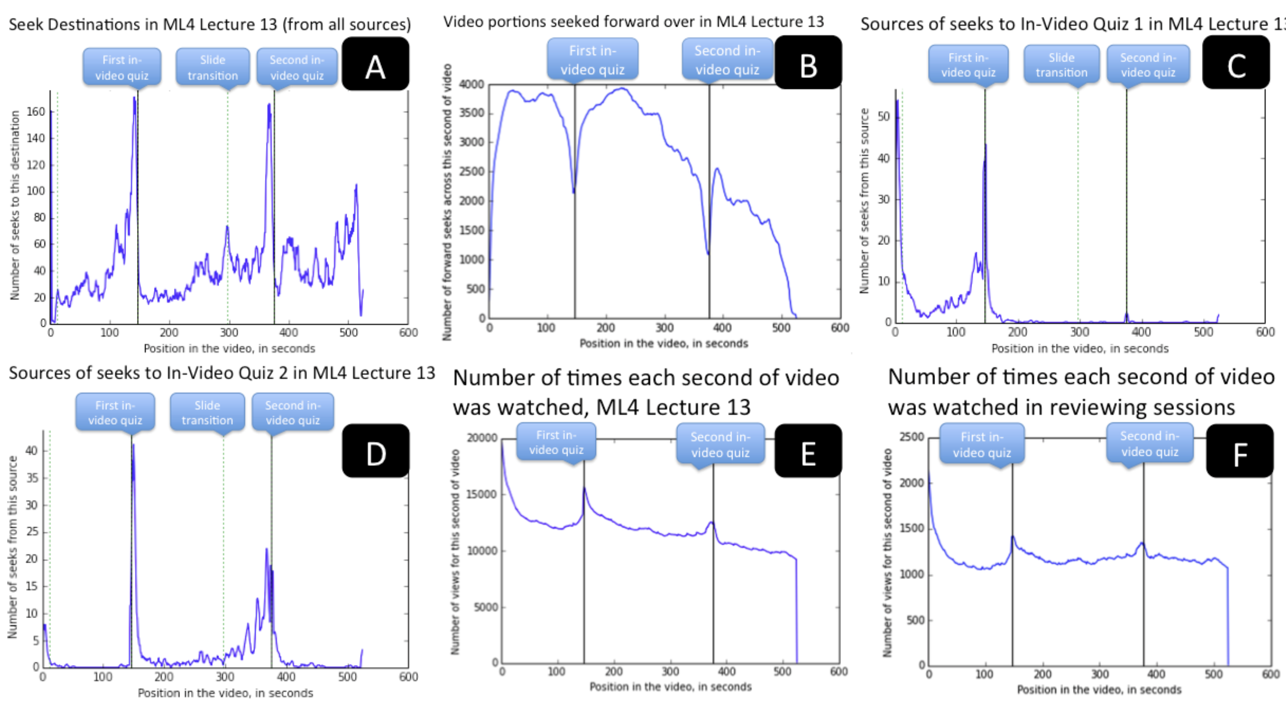

Figure 10. A) in-video quizzes are a popular destination of seeks. B) users do not tend to skip forward over in-video quizzes. C) seeks to in-video quizzes tend to be from the preceding section. D) some users are seeking directly from one in-video quiz to the next. E+F) local peaks in viewing occur around in-video quizzes.

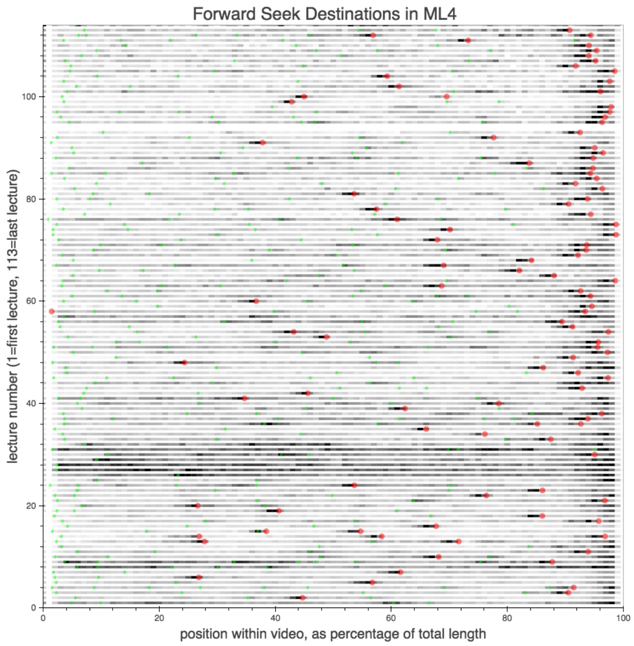

Figure 11. Destinations of forward seek chains in all videos. Each horizontal line represents a video; darkness of a segment indicates the number of seek chains going to that part of the video. Red dots indicate in-video quizzes, and green diamonds indicate slide transitions. Users tend to seek forward to in-video quizzes.

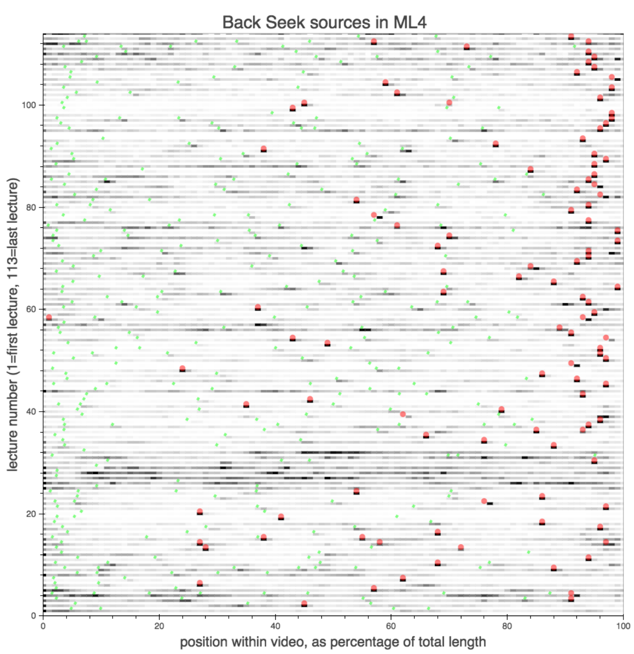

Figure 12. Sources of backward seeks. Red dots indicate in-video quizzes. In-video quizzes are a major source of backward seeks, due to users going back to the previous section to review the video.

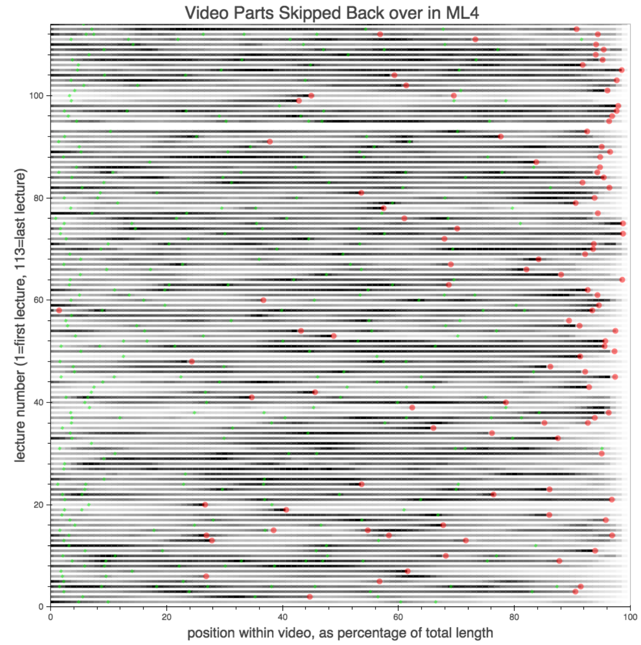

Figure 13. Parts of the video skipped over by backwards seek chains. They tend to be the portions preceding the in-video quizzes, reflecting that users are reviewing the video in response to seeing the in-video quiz

segments preceding the in-video quizzes. This can be explained by users searching in the preceding segment for the answer to the in-video quiz.

Interestingly, we observe that when the last in-video quiz occurs at the midpoint of a video, as is the case with Lecture 19 in Figure 13, there is little back-seeking which occurs after the quiz. This suggests that the back-seeking phenomenon which occurs directly before a quiz is indeed a result of the in-video quiz causing users to seek backwards more, as opposed to being a side-effect of in-video quizzes tending to occur near the end of the video.

Seek Destinations from In-Video Quizzes

As we can see in Figure 14, the seek destinations from in-video quizzes are primarily backwards, towards the immediately preceding portion. This is confirmed in Figure 5, which shows that there are over 10x more seeks in the backward direction from in-video quizzes than in the forward direction. This can be interpreted as users deciding to go back and review the preceding segment in response to having seen the in-video quiz.

Seek Destinations from the Start of the video

As we can see in Figure 15, many users jump directly from the start of the video to in-video quizzes. This suggests that these users might be previewing the quizzes before they watch the video, or they are using the quizzes as a navigational tool to help them decide which parts of the video they need to see and review.

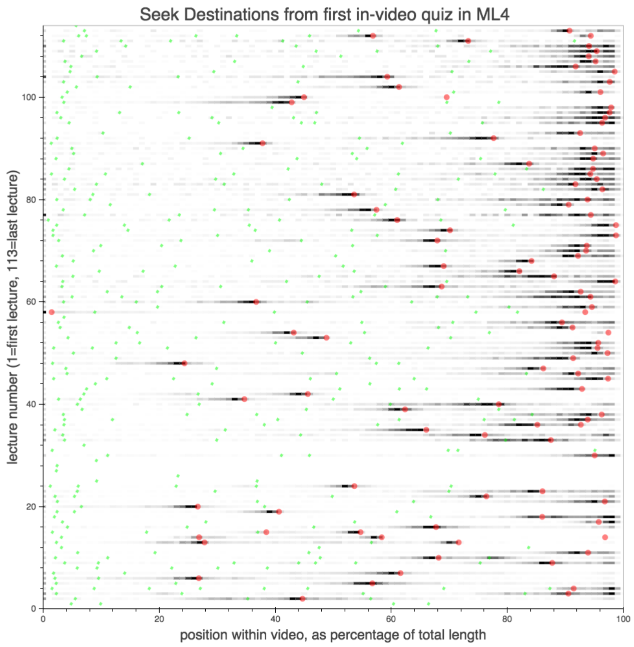

Figure 14. Seek destinations from the first in-video quiz in each lecture. The portion preceding the in-video quiz is a major seek destination, which is often where the answer to the quiz can be found.

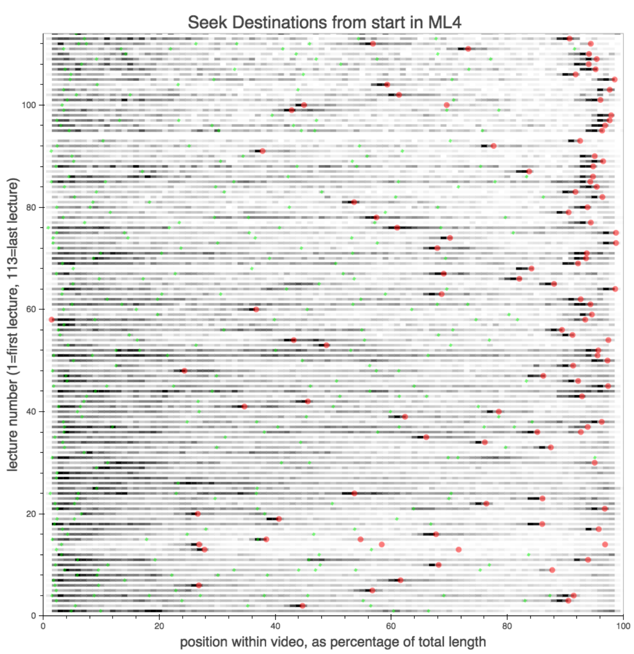

Figure 15. Seek destinations from the start of the video. Many users seek directly from the start of the video to the in-video quizzes.

Type of data	Lectures with no in-video quizzes	Lectures with 1 in-video quiz	Lectures with 2 in-video quizzes
Number of lecture videos	13	92	7
Average lecture video length (in seconds)	534.8	628.7	704.9
Average number of seconds of video watched per viewing session	333.8	492.4	528.7
Average percent of video watched per viewing session	59.3%	79.1%	75.6%
Percentage of viewers who start watching the video that reach the end	61.9%	67.5%	62.8%
Average number of seek chains per viewing session	1.16	1.43	1.78
Percentage of viewers who seeked at least once while viewing the video	36.2%	42.7%	47.5%

Figure 16. Users tend to watch a larger portion of lecture videos that contain in-video quizzes during viewing sessions, and have more seeking activity.

ARE LECTURES WITH IN-VIDEO QUIZZES MORE ENGAGING THAN THOSE WITHOUT?

We saw in the previous sections that there are bursts in activities such as seeking and reviewing in areas near in-video quizzes. This leads us to wonder whether lectures featuring in-video quizzes have higher viewer engagement.

In Figure 16, we compare engagement metrics in videos with in-video quizzes to videos without in-video quizzes. On average, videos with in-video quizzes have more seek chains per viewing session. However, the increased seeking may also be attributable to video length – lectures with in-video quizzes tend to be slightly longer. Users who start watching a video with in-video quizzes will also view a larger percentage of that video before leaving the video. This increased viewing is in spite of video length – previous studies have found that users tend to stop viewing longer videos, especially videos longer than 6 minutes (this is known as *in-video dropout*) [7].

That said, although this data suggests that in-video dropout is lower in lectures with in-video quizzes, it does not prove a causal relationship. It may simply be the case that the videos with quizzes happen to have more engaging content.

HOW MUCH EFFORT DO USERS INVEST IN ANSWERING IN-VIDEO QUIZZES?

In this section, we will look at how many attempts users make to answer in-video quizzes, and how much time they spend between attempts. As shown in Figure 17, 76.0% of users will answer the in-video quiz correctly on their first try.

Among the users who answered an in-video quiz incorrectly on their first try, 76.5% will submit a correct answer within the next 30 minutes. Users who submit an incorrect answer first but later submit a correct answer submit an average of 1.28 incorrect times before they finally submit a correct answer (72.5% submit one incorrect answer before getting a correct answer, and 27.5% submit two incorrect answers before submitting a correct answer). Users who submit an incorrect answer first but later submit a correct answer spend a median of 13 seconds (mean=32, σ=85) from when they submit their first incorrect answer until when they submit a correct answer.

Users who submit an incorrect answer and never submit a correct answer submit an average of 2.68 incorrect answers

Type of interaction with in-video quiz			Percentage of users	Median time spent between initial and final answer (seconds)	Mean number of incorrect attempts
Answers in-video quiz correctly on first try			76.0%		
Answers in-video quiz incorrectly on first try			24.0%	13 (mean=31, σ=83)	1.54
	Will not submit a correct answer within the next 30 minutes		23.5% (4.3% of total)	13 (mean=29, σ=71)	2.68
	Will submit a correct answer within the next 30 minutes		76.5% (18.4% of total)	13 (mean=32, σ=85)	1.28
		Does not seek before submitting answer	90.9% (16.7% of total)	11 (mean=23, σ=53)	1.28
		Makes a seek before submitting answer	9.1% (1.7% of total)	115 (mean=218, σ=278)	1.51
		Backward seek	97.0% (1.6% of total)	116 (mean=217, σ=275)	1.51
		Forward seek	3.0% (0.1% of total)	56 (mean=229, σ=367)	1.48

Figure 17. Most users answer in-video quizzes correctly on the first try. Among users who seek back to review the preceding section after answering a question incorrectly, they spend almost 2 minutes before they submit the correct answer.

Context in which backwards seek chain from in-video quiz occurred		Percentage of backwards seek chains from quiz
Seeked back to review preceding section before first attempt to answer the quiz		60.5%
	User's first attempt to answer the quiz will be correct	62.4% (37.8% of total)
	User's first attempt to answer the quiz will be incorrect	37.6% (22.8% of total)
User never attempts to answer the in-video quiz		19.4%
Seeked back to review preceding section after submitting an incorrect response		14.4%
	Will eventually submit a correct response after reviewing	81.8% (11.8% of total)
	Will submit at least one more incorrect response (but will never submit a correct response)	9.4% (1.3% of total)
	Will never attempt to answer the quiz again (will submit neither incorrect nor correct responses)	8.8% (1.3% of total)
Seeked back to review preceding section after submitting a correct response		3.0%

Figure 18. Most backwards seek chains from in-video quizzes occur after the user has seen the question, but before they have submitted an answer to it.

(13.8% submit one incorrect answer and give up, 4.4% submit two incorrect answers and give up, and 81.8% submit 3 times, at which point Coursera will show them the correct answer). They spend a median of 13 seconds (mean=29, σ=71) from when they submit their first incorrect answer until when they submit their final (incorrect) answer.

Let us now return to the users who first submit an incorrect answer but later (within the next 30 minutes) submit a correct answer. Between the period when a user submits the incorrect answer and when they submit the correct answer, 9.1% of these users will make a seek. Among those, 97% seek backward, while 3% seek forward. Users who perform a seek will spend a median of 115 seconds (mean=218, σ=278) before they submit a correct answer. As indicated by the backwards seek chain, the user is presumably using this time to review the preceding section. In contrast, the users who do not perform a seek spend a median of 11 seconds (mean=23, σ=53) before submitting a correct answer.

Thus, most users who attempt an in-video quiz (94.4%) will submit a correct answer within 30 minutes, with the majority answering correctly on their first try. However, most users who answer incorrectly simply answer again within the next 13 seconds, without referring to the rest of the video.

WHEN AND WHY DO USERS SEEK BACKWARDS FROM IN-VIDEO QUIZZES?

There are several possibilities for when backwards seek chains could occur in the context of in-video quizzes. Users might see the in-video quiz, realize they don't know the answer, and then seek back to review the preceding section. Or, users might try answering the in-video quiz, get the answer wrong, and then seek back to the review the preceding section. We sought to see which of these reviewing strategies was the most popular, as shown in Figure 18.

It turns out that the former strategy – of seeing the in-video quiz, and seeking back to review before attempting to answer the quiz – is the most widely used. Of all backwards-seeking that occurs starting from an in-video quiz, a total of 60.5% actually occurs before the user attempts to answer the in-video quiz (but after they have seen the question). Of these, after the user returns to the in-video quiz, they will answer it correctly 62.4% of the time. It is rather peculiar that this is lower than the overall rate at which users correctly answer quizzes on their first attempt (76.0%); one possible explanation is that the learners who needed to review the preceding section did not understand the material as well as those who felt they could answer the quiz as soon as they saw it.

14.4% of backwards seeking from the in-video quiz occurs after the user submitted an incorrect response. Of these, 81.8% will eventually submit a correct response after reviewing, 9.4% will submit at least one more incorrect response but will never submit the correct response, and 8.8% will never attempt the problem again.

3.0% of backwards seeking from the in-video quiz occurs after the user submitted a correct response. These users are presumably just reviewing the video for purposes other than to answer the in-video quiz. In the remaining 19.4% of backwards seek chains starting from in-video quizzes, the user saw the question, but will never submit any answer to it.

Thus, most (75%) backwards seek chains from in-video quizzes occur before the user answers the quiz correctly and are followed by an answer attempt within the next 30 minutes, while only 3% occur after the user submits a correct answer. This suggests that the reason why users seek backward from in-video quizzes is to review the preceding section to help them answer the in-video quiz.

DISCUSSION AND CONCLUSION

In this paper we sought to characterize the ways in which users engage with in-video quizzes, and how they affect users' video viewing behavior. We did so by analyzing the video viewing logs in Coursera's Machine Learning course.

We found that users engage heavily with in-video quizzes, with a similar fraction of learners answering in-video quizzes as those who finish watching videos, as shown in Figure 3. We also found certain video viewing patterns emerge in regions surrounding in-video quizzes, specifically:

- There are peaks in rewatching behavior in the regions surrounding the in-video quiz. In particular, we see a large amount of back-seeking from in-video quizzes to the immediately preceding video section. This is likely due to users seeking answers to in-video quizzes.
- Users do not tend to skip forwards or backwards over in-video quizzes. They thus segment the video into isolated subsections that users rarely seek between.
- In-video quizzes are a common source of seek chains within videos. Users most frequently seek backward from the in-video quiz to the preceding section. Most backwards seek chains from in-video quizzes occur after the user has seen the question, but before they answer it. This suggests that users are reviewing the preceding section to help them answer the quiz.
- In-video quizzes are a common destination of seek chains. Users most commonly seek from the preceding video segment, which contains material relevant to the quiz.
- Some users follow quiz-oriented navigation strategies, jumping straight to the quiz from the beginning of the video, or jumping from one in-video quiz to the next.
- In-video dropout is lower on lectures that have in-video quizzes, compared to lectures that lack in-video quizzes.
- Most users answer in-video quizzes correctly on the first try. Among those who answer incorrectly, the median time until they answer correctly is just 13 seconds.

Our results suggest future work investigating the effects of in-video quizzes on in-video engagement rates. Previous work (on videos lacking in-video quizzes) has shown that there is a steady drop-off in users watching lectures, particularly in longer lecture videos [7]. We saw in Figure 16 that in-video dropout is lower in lecture videos that have in-video quizzes, compared to videos that don't have in-video quizzes. However, this may be caused by differences in the lecture content, rather than the presence of in-video quizzes. Additionally, as we also saw in Figure 10 E, the drop-off in number of views appears to temporarily decline in the area surrounding the in-video quizzes. Thus, because we found that users tend to answer in-video quizzes and not skip over them, and we found peaks in seeking activity around in-video quizzes, this leads us to wonder whether in-video quizzes could help counteract the disengagement patterns that occur in longer lecture videos. However, A/B tests would be required to actually verify the effects of in-video quizzes on engagement rates.

The peaks in seeking towards in-video quizzes suggest a number of possible interface modifications that could be explored. Coursera currently does not allow users to easily skip directly to in-video quizzes, instead requiring them to go to the preceding few seconds of videos. Since in-video quizzes were one of the most common destinations for seek chains, particularly in the forward direction, one might investigate the effects of modifying the interface to make it easier to seek to in-video quizzes. We also observed that users often seek back from in-video quizzes to the preceding section, upon seeing the in-video quiz. Hence, another interface modification that may be worth exploring is to let users preview the in-video quizzes, and see whether this allows them to navigate the lecture more effectively.

In-video quizzes have many appeals, such as the potential for improving engagement by making lectures more interactive and enabling users to test their understanding of the material. We have examined users' interaction patterns with lecture videos in the context of Coursera's in-video quizzes, and hope that our findings can inform future improvements to the design of interactive lecture-viewing systems.

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