QuizCram: A Quiz-Driven Lecture Viewing Interface

1st Author Name
Affiliation
City, Country
e-mail address

2nd Author Name
Affiliation
City, Country
e-mail address

3rd Author Name
Affiliation
City, Country
e-mail address

ABSTRACT

QuizCram is an interface for navigating lecture videos that uses quizzes to help users determine what they should view. We developed it in response to observing peaks in video seeking behaviors centered around Coursera's in-video quizzes. QuizCram shows users a question to answer, with an associated video segment. Users can use these questions to navigate through video segments, and find video segments they need to review. We also allow users to review using a timeline of previously answered questions and videos. To encourage users to review the material, QuizCram keeps track of their question-answering and video-watching history and schedules sections they likely have not mastered for review. QuizCram-format materials can be generated from existing lectures with in-video quizzes. Our user study comparing QuizCram to in-video quizzes found that users practice answering and reviewing questions more when using QuizCram, and are better able to remember answers to questions they encountered.

Author Keywords

video flashcards; lecture viewing; in-video quizzes

ACM Classification Keywords

H.5.2. User Interfaces: Graphical user interfaces (GUI)

INTRODUCTION

Lectures on platforms such as Coursera use *in-video quizzes* to test learners on material while they watch videos. Although online courses also have problem sets and exams, many learners only watch lectures [1] [5]. For these students, in-video quizzes are an important opportunity to test themselves on the material, which is critical for long-term retention [11].

While analyzing viewing logs of the Machine Learning course on Coursera, we observed that in-video quizzes play an important role in video navigation. Specifically, we observed that users often seek backward from in-video quizzes to review the preceding section, and forwards to in-video quizzes to look at the upcoming question. We also observed that users rarely review lecture videos. Based on these observations, we wished to develop a video viewer that would better support quiz-centric navigation strategies and encourage reviewing.

A demo is available at **http://quizcram.herokuapp.com/**
The demo is anonymized for review. Please view it in Chrome.

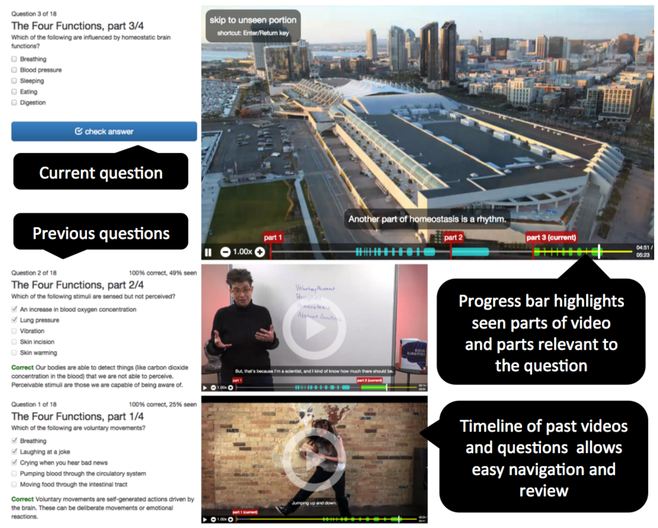

Figure 1. The Quizcram interface shows questions on the left, and corresponding video segments on the right. The scrollable timeline displays the past videos and associated questions, to help users review parts they had trouble with.

Our system, Quiz-driven Video Cramming (QuizCram), uses quizzes to help users navigate the course and guide their review process. It includes the following features:

- QuizCram shows questions while users watch the video, to serve as a preview of the video content, and to guide their focus towards key concepts.
- QuizCram keeps track of which video portions users have already seen, as well as questions they need to review, in order to suggest which videos and questions the user should review.
- QuizCram facilitates adding questions to videos by allowing questions to depend on multiple video segments rather than just the immediately preceding one. This enables a greater density of questions to be presented in QuizCram.

We used a user study with a within-subjects design to compare QuizCram to the in-video quiz format. We found that:

- Users remember answers to in-video questions significantly better when studying using QuizCram.
- Users practice answering and reviewing questions more often when studying using QuizCram
- We can improve the recall of particular facts from the video by adding extra questions in QuizCram.

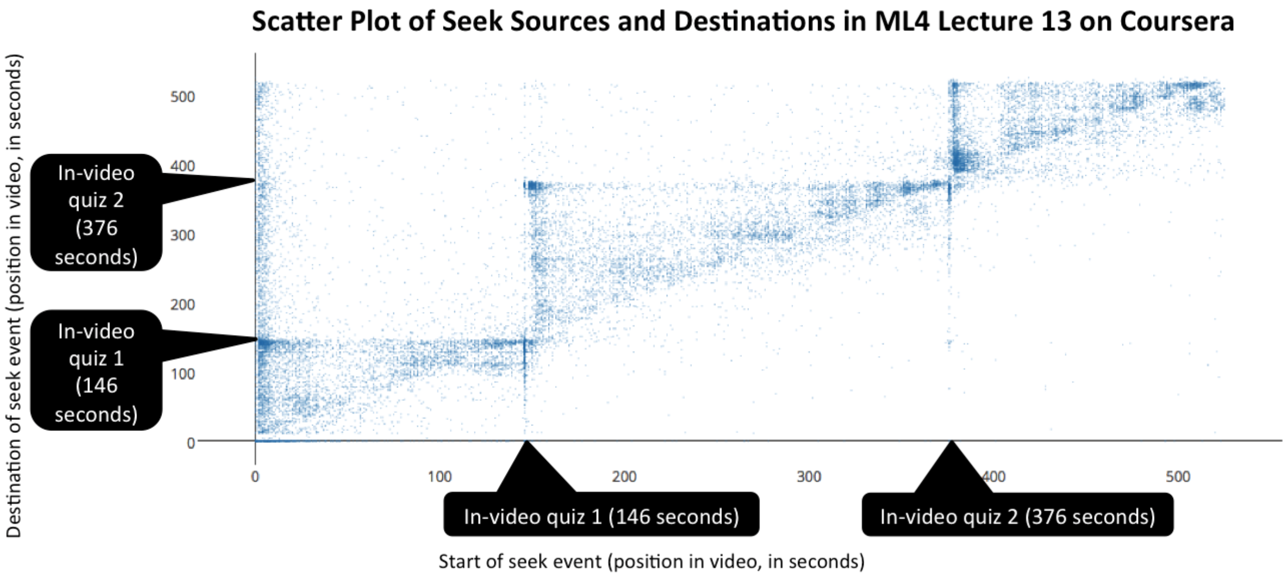

Figure 2. Seek sources and destinations in a lecture with 2 in-video quizzes. Each point at (x,y) represents a seek from time x to y. There are many seeks to in-video quizzes from the start of the video, the previous section, and between quizzes.

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 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)

Figure 3. Sources and destinations of seek chains in the Machine Learning course on Coursera, which uses in-video quizzes. 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)

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 forwards over	2153 (baseline forward seek rate)
# 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 back seek chains	933463 (44.4% of seeks)
Average length of a back seek chain, in seconds	54 seconds
Average # of times each second of video was seeked back over	719 (baseline back seek rate)
# back seek chains crossing quizzes (109 quizzes total)	47184 (2.24% of seeks)
# back seek chains crossing each quiz	432 **(0.6x baseline)**

Figure 4. Portions of the video that are skipped over by seek chains in the Machine Learning course on Coursera. Users do not tend to seek forward across in-video quizzes.

MOTIVATION: COURSERA'S IN-VIDEO QUIZZES

This work was motivated by interesting patterns of seeking activity around in-video quizzes which we uncovered while analyzing viewing logs of the Coursera Machine Learning course. We observed that there are large peaks in seeking activity around in-video quizzes, which is likely due to users previewing the questions and trying to find answers to them.

Since users may seek several times while trying to reach their target, our analysis groups together seek events that occur within 5 seconds of each other into a *seek chain*, so we can better observe users' intended seek targets. Details on this methodology can be found in the supplement.

There are many backwards seeks starting from in-video quizzes. As shown in Figure 3, 8.6% of all backwards seek chains (or 3.8% of total seek chains) start from in-video quizzes – which is 55x more seeking per in-video quiz than we'd expect from a second of video in the course. This peak in backwards-seeking from in-video quizzes is likely due to users searching for answers in the preceding section.

We also observe that there are forward seeks that end up at or immediately preceding the quiz. As shown in Figure 3, 6.6% of all forwards seek chains (or 3.7% of total seek chains) end up either at the in-video quiz or within 10 seconds preceding it. These forward seeks are likely generated by users attempting to view the in-video quiz – as Coursera's interface does not provide an option to jump directly to in-video quizzes, users must seek to directly before the in-video quiz in order to view it.

Most seek chains (93%) do not cross in-video quiz boundaries. As shown in Figure 4, users are 0.4x less likely to skip forward across an in-video quiz, than across a second of video. Figure 2 visualizes seek sources and destinations in a single lecture video with 2 in-video quizzes: there are many forward seeks to quizzes, and backward seeks from quizzes.

Users also rarely rewatch lecture videos: only 11% of users who finished watching a lecture will ever open it again.

Based on these observations, we aimed to develop a video viewer that would better support quiz-centric navigation strategies and encourage reviewing.

RELATED WORK

Testing and Pre-Testing Effects

The *testing effect* shows that repeated testing combined with fast, informative feedback helps students remember material [11]. QuizCram's emphasis on answering and reviewing questions is designed to exploit this effect.

The *pre-testing effect* shows that having users try answering a question before they actually study the material enhances long-term retention [10]. QuizCram exploits the pre-testing effect by allowing users to preview the question before watching the associated video.

Spaced repetition

Spaced repetition is a technique designed to help learners retain information by having them review items at regular intervals [3]. A class of applications that exploit this are flashcards, which split information into independent chunks that are scheduled for review based on factors such as mastery and recency of review. There have been a number of algorithms and models designed for optimizing learners' retention of the material via spaced repetition [9] [2]. However, they tend to be designed for flashcard-like content, such as isolated facts or vocabulary, rather than lecture videos.

A key difference between flashcard-like content and lecture videos is that lecture videos are typically presented in sequence, and a given video may build upon concepts introduced in a previous video. Additionally, there is a difference in the costs of testing and reviewing – with flashcards, both testing and reviewing can be done in seconds. In contrast, the cost of reviewing a video is much greater than the cost of testing – we can test a user's knowledge of a video segment with a question that takes seconds to answer, but viewing a video may require several minutes. These additional constraints are reflected in QuizCram's modified scheduling algorithm that takes into account the order of videos, as well as its increased emphasis on testing via questions.

Advance Organizers

Advance organizers are information presented prior to learning, that help the learner process the material that is about to be presented [12]. QuizCram's questions can be thought of as an advance organizer for the video segment – the question provides a preview of the content that is to be covered in the video.

Interfaces for Navigating Lecture Videos

Video Digests is a system that uses textual summaries of video clips to help users navigate through the video [8]. LectureScape uses other users' aggregated viewing logs to help identify points of interest in the video [4]. Panopticon uses a visual display of all video segments to help users find segments of interest [7]. Similar to these systems, QuizCram aims to help users navigate through lecture videos. However, rather than relying on external annotations, QuizCram instead uses questions extracted from existing in-video quizzes as a navigational aid.

SYSTEM DESIGN PROCESS

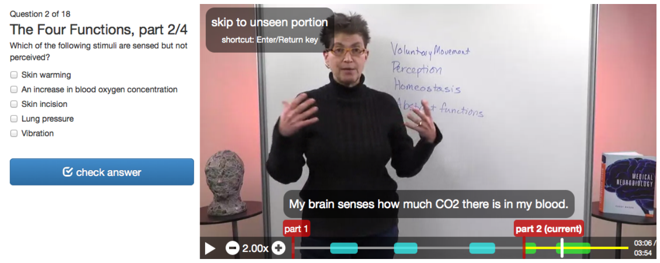

Figure 5. The QuizCram interface, showing the focus question on the left, and the associated video on the right. The progress bar highlights the relevant portion of the video in yellow. Segments that have already been watched are highlighted in blue (segments from previous parts) and green (segments from current part).

Based on our observations that users tend to engage with in-video quizzes but rarely ever revisit MOOC lecture content (see supplement), as well as the importance of testing and review for retention, our goal was to build a system that would test users' knowledge of lecture materials and encourage them to review materials using spaced repetition.

Our initial design was to treat video segments as flashcards, and schedule them using a spaced repetition algorithm. By associating each video segment with a question, we could easily test users's knowledge of each segment. However, scheduling videos with a standard spaced-repetition algorithm would often result in the user being asked to review older material before they completed all of the video segments, which we found that users were unaccustomed to. Hence, we also enabled users to freely review videos on their own, and only started scheduling older videos for review once they had attempted an initial pass through the videos.

QUIZCRAM INTERFACE FEATURES

QuizCram's interface displays a question and associated video segment, as shown in Figure 5. It also shows a timeline of previous questions below the current question, as shown in Figure 1. Once the user has made an initial pass through the questions, we suggest questions that they should review, based on past performance. We use the video progress bar to indicate the section of the video that is relevant to the current question, and portions that the user has previously seen. Existing courses with in-video quizzes can easily be transformed into the QuizCram format.

Question-Directed Video Viewing

Each video section is associated with a question. We can extract these question-video pairs automatically from existing videos with in-video quizzes, by associating the in-video quiz section with the immediately preceding video segment. For video segments that did not have an associated in-video quiz, we can either automatically insert a generic "How well did you understand this video" question, or manually write a new question.

The question is designed to help users decide whether they should watch the video. If the user knows the answer, they can answer the question and move to the next section. For users who do not know the answer, reading the question summarizes the key points they will see in the video.

Timeline of Previous Questions and Videos

The *timeline* feature is designed to encourage review by making it easy to refer back to previously answered questions and video segments. Whenever a question is correctly answered, we insert the next question and associated video segment at the top of the interface, and push the existing questions down. This results in a scrollable visual history of the previously answered questions, as shown in Figure 1. The timeline displays the question, its answer, and a miniaturized version of the video which can be clicked to enlarge it to full size and play it. The miniaturized video displays the frame the user left off at, so it serves both as a visual summary, and also allows users to easily resume watching previous videos.

The timeline gives users the option to use a more self-directed reviewing strategy, in contrast to the flashcard-style reviewing that our question scheduling algorithm encourages. By organizing the list of previous video segments according to the associated question that users answered, this allows users to scan video segments with a more salient summary than just the title. Question-based video navigation also allows users to search at a higher granularity, as questions refer to a specific subsection of the video, while the title refers only to the entire video contents.

Scheduling Questions and Video Sections for Review

We want users to spend their study time focusing on material that they have not yet mastered. Hence, we assign each question a *mastery score*, which represents how well the user currently knows the material, and show users the questions for which they have low mastery score. The question's mastery score is based on the following 3 factors:

- *Past performance on question*: This element of the score encourages users to review questions they answered incorrectly. Each time a user tries answering the question, we give them a score equal to the fraction of checkboxes they correctly checked (the questions used in our study were all multiple-check questions). We then take a weighted-mean of historic scores, weighing recent answers more heavily.

- *Fraction of associated video segment watched*: This element of the score encourages users to view video segments they have not seen. For each second of video, we keep track of whether the user has ever seen it. This score is the fraction of the video segment that has been seen.

- *Recency of review*: This element of the score ensures that users review old questions, but are not shown same questions repeatedly. For simplicity, we use a score that is inversely proportional to how recently the question was last answered. Ideally, one would instead use a more advanced spaced-repetition algorithm like MemReflex [2].

Once the user has seen all the questions in the unit, QuizCram encourages them to review questions and sections for which they have low mastery scores, by showing them at the top of the video timeline.

Directing Attention to Unseen Parts of Videos

To help users review videos and resume where they left off, QuizCram keeps track of which parts have been watched. It highlights on the progress bar the portions that have already been seen. If the user is viewing a section they have already watched, they can skip to the unseen portion by clicking a button, as shown in Figure 5. This technique for visualizing the viewing history has previously been shown in the literature [6] [4], though our system adds the novel feature of allowing users to skip to the next unseen portion.

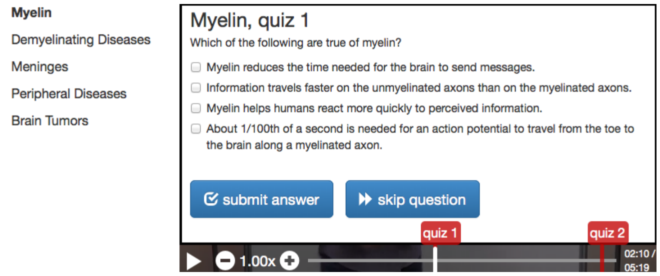

Figure 6. The in-video quiz format that served as our baseline. Locations of quizzes are indicated in red on the progress bar.

EVALUATION

Our study used a within-subjects design to compare users' studying behavior with QuizCram against an in-video quiz interface that mimcs the format used on Coursera, as shown in Figure 6. We used the videos, in-video quizzes, and unit exam from the Neurobiology course on Coursera. We wished to answer the questions:

- Does QuizCram help users better remember answers to the original in-video questions?
- Does QuizCram help users score higher on exams?
- Can we improve recall of particular facts from the video by adding extra questions with QuizCram?
- Do users find QuizCram helpful for studying videos?

Participants

We recruited 18 students by posting on university mailing lists. 12 were female, 6 male. Their average age was 21.7 (σ=4.91, min=18, max=37). All had native-level English proficiency. None had prior exposure to neuroscience. They received $60 for participating.

Materials

The videos, in-video quizzes, and unit exams were from Unit 1 of the Neurobiology course on Coursera. There were 9 questions and 5 videos in each 25-minute section. We generated the initial QuizCram materials directly from the course.

Not all of the segments of the lecture videos had in-video quizzes immediately following them. For such segments, QuizCram would normally show a generic "How well did you understand this video" question as the focus question. However, in pilot studies, users indicated that they found these self-assessment questions less helpful than regular questions, as they did not provide a preview of what the section would be about. Furthermore, we believe that the QuizCram format is best-suited towards a more question-heavy viewing experience than in-video quizzes currently provide. Hence, to simulate what content that was designed for the QuizCram format would look like, we added our own extra questions

Exam	QuizCram	In-Video	Statistically significant?
Original in-video questions	**85.4%**	**81.3%**	**Yes (t=2.24, p=0.039)**
Original unit exam	65.1%	63.4%	No (t=0.44, p=0.669)
Extra multiple-checkbox questions	**85.5%**	**76.0%**	**Yes (t=2.44, p=0.026)**
Extra free-response questions	**67.6%**	**49.0%**	**Yes (t=3.95, p=0.001)**

Figure 7. Average exam scores for each condition

for video segments which lacked associated in-video quizzes. This doubled the total number of questions per section in the QuizCram condition. The extra questions were in the same multiple-checkbox format as the original questions. We made sure that the extra questions did not cover the same material as the unit exam or original in-video quizzes, to ensure that they would not help users learn the other material by giving them an extra testing opportunity.

We also wrote a set of free-response questions, with one corresponding to each of the extra questions. We used these free-response questions to test whether users had learned the material tested by in-video questions well enough to recall it (rather than recognizing it).

Procedure

The study was conducted online over 2 days. Before users started the study, we informed them that they would be given 2 sets of videos, they would study them for 40 minutes apiece, and they would be given an exam the next day. We did not tell them about the content of the exam in advance.

On day 1, users studied the first section with one tool for 40 minutes, and answered a survey about the tool. Then, they studied the second section with the other tool for 40 minutes, and answered a survey about the tool. The order of tools was randomized.

On day 2, users took the following exams:

1. Extra free-response questions
2. Original in-video questions from Coursera
3. Original unit exam from Coursera
4. Extra multiple-checkbox questions

Parts 2-4 were automatically graded. Free-response questions were graded blindly according to the formula:

$$\frac{\#correct\ examples\ given}{Maximum(\#examples\ requested,\ \#examples\ given)}$$

RESULTS

Exam Results

Exam results are shown in Figure 7. QuizCram users performed significantly better on the original in-video questions, which had been shown in both conditions. They also performed better at both types of extra questions. Thus, QuizCram improves retention of the original in-video questions, and we can use added questions to improve retention of particular facts from the video. However, there was no significant improvement in scores on the original unit exam.

Survey Results

When users were asked to rate satisfaction with the tool on a scale of 1 to 7, the average rating was 5.28 for QuizCram, and 5.17 for in-video quizzes. 61% said would prefer QuizCram if they wanted to remember material long-term or were preparing for an exam. These improvements were not significant.

Event	QuizCram	In-Video	Statistically significant?
Original in-video questions answered	**22.3**	**13.5**	**Yes (t=3.22, p=0.008)**
Original in-video questions answered correctly	**13.8 (62%)**	**5.3 (40%)**	**Yes (t=4.62, p=0.0007)**
Original in-video questions re-answered (after at least 1 minute)	**9**	**0.17**	**Yes (t=5.00, p=0.0004)**
Extra questions answered	18.3		
Extra questions answered correctly	14.4 (79%)		
Extra questions re-answered (after at least 1 minute)	8		
Number of seek events	7.2	11.9	No (t=-0.82, p=0.43)

Figure 8. Average number of events per user in each condition

Survey feedback showed that users liked QuizCram's question-based timeline of videos, and thought it was helpful for reviewing.

I liked that it picked out the key information I should retain by asking me questions. It helped me decide what to focus on as I watched the video. The chunks were very manageable as well. I liked how it was broken up.

However, some users thought that the prominent display of questions distracted them from watching the video.

I did not like the fact that you could answer questions while the video was playing. It made me more focused on answering the questions rather than watching and learning the material.

Analysis of Users' Video Interaction Logs

To compare how users interacted with the two tools, we logged the users' interactions as they studied the lectures, as shown in Figure 8.

We found that users practiced answering each question more times when using QuizCram. They also tended to answer questions correctly a higher percentage of the time, perhaps because they had been able to preview the question before watching the video. Users also reviewed previously-answered questions more often when using QuizCram. This increase in practice and reviewing helps explain the increased exam scores on the original in-video questions.

Users seeked less on average when using QuizCram, which may partly be because they did not have to seek to and from in-video quizzes. However, this difference was not statistically significant.

CONCLUSION

We have presented QuizCram, a system that guides users' video viewing using questions. QuizCram aims to:

- Encourage users to answer and review questions while they watch videos
- Enable users to easily follow question-driven video navigation strategies (which we currently observe some users already using on Coursera)

QuizCram breaks the video into segments associated with questions, and always shows a focus question alongside the video. The focus question serves as an advance organizer that guides the user's attention towards the key points in the video. QuizCram also encourages reviewing based on questions: it displays a timeline of questions previously answered and their associated videos. It keeps track of users' progress through questions and videos, and suggests questions for users to review. Courses in the QuizCram format can be generated from existing videos with in-video quizzes.

Our user study found that QuizCram increases focus on questions – when the in-video questions were tested again a day later, users using QuizCram remembered them better than if they were presented as in-video quizzes. Users practiced answering and reviewing questions more often when using QuizCram.

Our user study has focused on a cramming scenario – where the user is trying to memorize a small amount of material to prepare for an imminent exam. However, another potential use case for QuizCram-like systems is for long-term retention – where the user is attempting to remember the content of multiple courses over multiple months. Given the success of spaced repetition systems in helping users' long-term retention of flashcards and vocabulary, we expect that having a system schedule quizzes that review course contents should similarly be helpful for helping users' long-term retention of course materials. Studying how question-driven lecture-reviewing systems can scale to entire courses and longer study periods is potential future work.

We designed QuizCram to address the needs of users who wish to complete the MOOC and master the entire material. Hence, the system tests users' knowledge of video segments, and schedules reviews to ensure that users remember the material. That said, learning the complete course material is not the objective of many learners – many users are only interested in a subset of the material, and do not complete the rest of the course [5] [1]. Although addressing the needs of users interested in only a subset of the material was not an objective of QuizCram, it is potential future work.

Current online courses rely on external problem sets and exams to test understanding of content in more depth than the in-video quizzes. However, many MOOC participants interact primarily with videos and do not take exams or do problem sets [5] [1]. Thus, moving more of the course content out of problem sets and making the video more interactive and question-oriented provides a way to benefit these viewers without removing them from the scaffolding of videos. We believe that QuizCram is a logical step from in-video quizzes towards more interactive, question-driven study experiences.

REFERENCES

1. Anderson, A., Huttenlocher, D., Kleinberg, J., and Leskovec, J. Engaging with massive online courses. In *Proceedings of the 23rd international conference on World wide web*, International World Wide Web Conferences Steering Committee (2014), 687–698.
2. Edge, D., Fitchett, S., Whitney, M., and Landay, J. Memreflex: adaptive flashcards for mobile microlearning. In *Proceedings of the 14th international conference on Human-computer interaction with mobile devices and services*, ACM (2012), 431–440.
3. Karpicke, J. D., and Bauernschmidt, A. Spaced retrieval: absolute spacing enhances learning regardless of relative spacing. *Journal of Experimental Psychology: Learning, Memory, and Cognition 37*, 5 (2011), 1250.
4. Kim, J., Guo, P. J., Cai, C. J., Li, S.-W. D., Gajos, K. Z., and Miller, R. C. Data-driven interaction techniques for improving navigation of educational videos. In *Proceedings of the 27th annual ACM symposium on User interface software and technology*, ACM (2014), 563–572.
5. Kizilcec, R. F., Piech, C., and Schneider, E. Deconstructing disengagement: analyzing learner subpopulations in massive open online courses. In *Proceedings of the third international conference on learning analytics and knowledge*, ACM (2013), 170–179.
6. Mertens, R., Farzan, R., and Brusilovsky, P. Social navigation in web lectures. In *Proceedings of the seventeenth conference on Hypertext and hypermedia*, ACM (2006), 41–44.
7. Nicholson, J., Huber, M., Jackson, D., and Olivier, P. Panopticon as an elearning support search tool. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, ACM (2014), 1221–1224.
8. Pavel, A., Reed, C., Hartmann, B., and Agrawala, M. Video digests: A browsable, skimmable format for informational lecture videos. In *Proceedings of the 27th annual ACM symposium on User interface software and technology*, ACM (2014).
9. Pavlik, P. I., and Anderson, J. R. Using a model to compute the optimal schedule of practice. *Journal of Experimental Psychology: Applied 14*, 2 (2008), 101.
10. Richland, L. E., Kornell, N., and Kao, L. S. The pretesting effect: Do unsuccessful retrieval attempts enhance learning? *Journal of Experimental Psychology: Applied 15*, 3 (2009), 243.
11. Roediger III, H. L., and Butler, A. C. The critical role of retrieval practice in long-term retention. *Trends in cognitive sciences 15*, 1 (2011), 20–27.
12. Stone, C. L. A meta-analysis of advance organizer studies. *The Journal of Experimental Educational* (1983), 194–199.