VideoScape: Augmenting Video Learning Experience with Concept Map

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ABSTRACT

Videos have become privileged materials for on-line learning. However, the usability problems of video lectures still limit learners to retrieve information based on their needs. For example, learners can't decide whether to watch a video by previewing at a glance, find video section based on demanded concepts, or personalize their learning environment for next time review. Furthermore, it is hard for learners without enough metacognitive skills to understand the lecture and reflect on their understanding without instructors' support. This paper aims to improve video learning experience through the augmentation of interactive concept maps. We introduce VideoScape, a video learning system that extend a web-based video player with a time-anchoring and editable concept map to facilitate video browsing and provide metacognitive support. By conducting a qualitative evaluation study with online learners, we find that VideoScape can effectively help participants organize their knowledge, preview and review the lecture, track their progress, reflect on their understanding and navigate the video.

INTRODUCTION

Videos have become widely adopted materials for online learning, but it is hard for learners to retrieve information based on their needs [4, 2]. Linear representation of video is one of the biggest problems that limits learners from controlling on learning materials effectively. For example, learners can't easily navigate the video based on concepts of interest to them or personalize their learning paths in video watching, not to mention saving their mental modal for navigation when revisiting and the video in the future,

It is also hard for learners without external metacognition support to reflect and organize knowledge, perceived from a knowledge-intensive and fast-paced video lecture. Constructivist learning theory suggests that learning consists of individuals' constructed meanings and involves social activities, language, and motivation. It takes time to learn. We need to organize our new knowledge, revisit ideas, and play with them [5]. However, online learners are

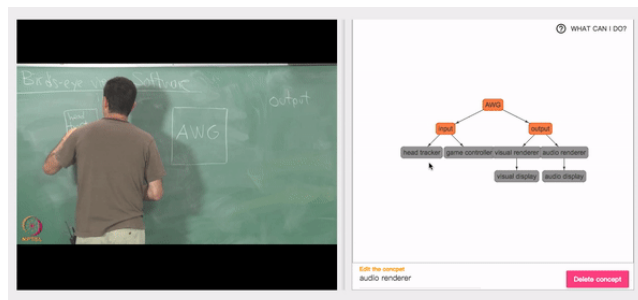

Figure 1. Our prototype that integrates an interactive concept map with a video. Every concept contains has a time anchor linking to a specific playback time point in the video, which captures the encounters of the concept in the video. When the video is playing, the concept that covered by current lecture would change it's color from gray to orange. User can also double click the concept to navigate the video.

likely to become passive knowledge receiver, without actively engaging in knowledge construction or even revising misconceptions, as the instructors cannot directly give personalized help to thousands of learners [1]. The problems in video lecture (e.g., content omission, misconception) can mislead the learners.

Previous research have introduced certain strategies of engaging learners with videos in video-based learning, such as using interactive exercises to promote engagement [10]. However, existing video lectures rarely support learners with such supplementary materials or activities as producing these materials and designing these activities can be costly. Peer learning (e.g., discussion forum [6]) are common alternatives to support online learning. For example, peer assessment promotes students' reflection and exposes them to diverse ideas [9]; peer-generated explanations help learners make sense of the answers of embedded questions [15]. While peer learning techniques such as discussion forum or peer assessment may be easier to implement and deploy in online video learning, these techniques may be restricted in offering learners support for navigating the knowledge space associated with a video, and to learn from videos in a structural and systematic manner.

The aim of this work is to improve video learning experience by (1) affording non-linear concept-based video navigation and (2) providing external metacognition support. In this paper, we explore using concept map as a tool to support video learning. Concept map is a graphical tool to organize and visualize knowledge. In education, it is widely applied as a learning activity, which can let students self-organize their ideas and further promote meaningful learning [11]. On the other hand, concept map can also serve as a useful tool for navigation of informational spaces [13]. As concept map is a good visualization tool to represent, organize, and communicate knowledge, there's a potential to apply it to solve problems in video learning.

To explore how concept map can help video learning, we first design a video learning system, VideoScape (shown in Figure 1), which embeds interactive concept maps to videos. Next, we conducted a qualitative study to assess the effect of VideoScape in video learning and obtain insights regarding learners' concept mapping strategies for practices and designs.

RELATED WORK

Research in video learning

As a widespread of video learning platforms emerged learners can easily obtain a large variety of videos for different purposes. Those platforms can be divided into two types: companies managed platforms (e.g., Coursera, Udacity) where learners can get feedback and homework assessment from instructors, and non-profit platforms (e.g., YouTube, MOOCs) that simply offer video courses. While many learners can not receive personalized help from instructors, it is hard for learners without enough metacognition to construct their knowledge through meaningful learning [3, 12]. On the other hand, usability problems in video learning environment hinder learners to control their materials [2]. Current research in this area follow two trends. First, research tried to improve learner-video interaction, which can be within one video (e.g., [8, 7]) or across videos (e.g., [13]). Other research focus on scaffolding learners' metacognitive knowledge, such as [16]. Follow the trends of previous research, we focus on within-video environment and extend the design space by considering how to integrate metacognitive support with concept-oriented learner-video interaction.

Applying concept maps in online learning environment

Many research have discovered the value of knowledge representation (e.g., concept map, mind map knowledge graph) in online education. Wang et al. investigated a knowledge visualization approach to support resource-abundant and self-regulated text-based online learning [14]. Teo et al. proposed a knowledge-driven model to personalize e-learning. Schwab et al. explored hierarchical concept maps to support dynamic non-linear learning planning for modularized short videos [13]. These research mainly utilize the non-linear benefit of knowledge representation to support organize and indexing learning materials across different resources, which is critical for self-regulated learning [17]. In this research, we expect the same strength of concept map can be applied to support organizing and indexing concepts within a video.

SYSTEM DESIGN

VideoScape augments an ordinary Youtube video player with an interactive concept map. Each concept in the concept map has a time anchor linking to a specific playback time point in the video, which captures the encounters of the concept in the video. While playing the video, the concepts covered in the previous section would change their colors from gray to orange. By distinguishing learned and unlearned concepts, we hope to lead learners to focus on learned concepts and their relationships. Learners can also use the time data to navigate the video in a concept level by double clicking the concept.

To support learners organizing their understanding and personalizing their learning environment, we allow learners to edit on the concept map. They can add, update, and delete concepts, links, or link phrases. Notice that newly added concepts also have time information collecting from the video time where user add concepts. Usability improvements are carefully considered to support learners manipulating on the. concept map and watch the video simultaneously, such as providing zoom in/out and concept map level dragging function and shortcuts to support concept map editing.

VideoScape is a web-application implemented by HTML, Javascript and CSS using React framework. We deployed VideoScape online for further evaluation.

EVALUATION

To assess the value of a concept map for learners, we ran an online study. We hypothesized that the interactive concept map can support video learning. Specifically:

H1: Concept map can help learners understand the video lecture with our prototype

H2: Concept map can facilitate learners navigating the video with our prototype

H3: Learners utilize the concept map differently in different phases of video learning (before/during/after video watching).

Participants

We recruited 20 participants {P1 - P20} through online social media posting. Participants were composed of 10 male and 10 female, with diverse background knowledge about the lecture (see Table 1). They received $3.3 for up to 30 minutes participation.

Task and procedure

Participants were required to visit our website and watch a video lecture with a concept map. Once participants visited our website, they were randomly assigned into one of two groups: first group watched a video about virtual reality with a less complex concept map, and the second group watched a video about the science of persuasion with a more complex concept map. The concept maps were generated by one of the authors. To make sure the concept map can simulate the result from real learner, the author create the concept map while watching the video and stop the process 3 minutes after the video was finished. Participants were asked to improve the concept map according to what they learned, but there was no constraint on the improvement task. So we could make sure every participant at least see the concept map in some degree and they can still have freedom on how much did they use the concept map. After they finish the lecture, they have to finish a questionnaire.

The questionnaire includes questions to understand their self-evaluated background knowledge to the lecture, the difficulty of the video, their understanding about the lecture and engagement in the process. Next, they need to evaluate in what degree (1: totally not helpful, 7: very helpful) concept map is helpful before, during and after video learning and a reason is needed for each evaluation. Finally, we listed some possible usages of the concept map and asked them to check whether those usages happened in participants' learning process; such usages are:

Video	**Introduction of software in virtual reality (G1)**	**The science of persuasion (G2)**
Attribution of the concept map	9 concepts 8 links 0 link phrase	24 concepts 20 links 12 link phrases
Number of participants	10 {P1-P10}	10 {P11-P20}
Participants self-evaluated background knowledge about the lecture (1-10)	AVG=4.9 SD=3.1	AVG=3 SD=2.7
Participants evaluated difficulty of the video lecture (1-10)	AVG=4.3 SD=2.5	AVG=5.3 SD=1.6
Participants self-evaluated understanding about the lecture after finish the task (1-10)	AVG=6.8 SD=2.4	AVG=6.5 SD=1.8
Participants self-evaluated engagement while performing the task (1-10)	AVG=8.6 SD=0.8	AVG=8 SD=1.8

Table 1. General report of experiment settings and participants' background knowledge, evaluated difficulty on the video, self-evaluated understanding and engagement.

- Preview what content will the lecture cover before you watch the video
- Find certain moment in the video
- Recall the content in previous section of the video while you were listening to the lecture
- Jump through not interesting part in the video lecture
- Organize your knowledge
- Check whether you understand the content after finishing the video lecture
- Recall the video content after finish the video lecture

Results

H1 (Concept map can help understanding the video lecture with our prototype) and **H3** (Learners utilize the concept map differently in different sections of video learning) are supported.

Statistical result from the questionnaire (Table 2) shows that most of the participants used concept map to organize their knowledge, while some people use concept map to preview (before watching the video) and review (after finish the video) the lecture. We found more feedback on how participants utilize concept map from our qualitative result:

Before watching the video lecture: Several participants {P1,P2, P15, P16, P17} said the concept map gave them a summary of the lecture before they watched the video and the preliminary overview help them know what concepts may covered in the lecture. While other participants found the concept map not useful before watching the video when some concepts contain technical words {P3,P4,P6} or when the concept map is too complicated {P9}.

While watching the video lecture: Most participants found the concept map is helpful while watching the video. They use concept map as an overview and outline while tracking the coloring concepts to help them concentrate on the current lecture. "I can easily understand where the lecturer is talking about, and the relationships of the concepts are clear." {P7} "The concept map shows the big picture of the topic of the videos so that I can understand the lecture more clearly, and it makes me concentrated." {P10} "It helps me understand the relationship of the concept, which the lecture is focusing on, with other concepts. I can also know which level the current concept is in the hierarchical concept map." {P17} While some participants {P2, P6, P10} said concept map helps them organize their notes.

After finished the video lecture: Most participants found the concept map helpful in recalling and understanding the lecture, integrating the concepts and reflecting their knowledge. "Although I didn't know how to design VR, it is helpful to clarify my knowledge." {P1} "Concept map is really helpful. For me, I can review the concept map after finishing the lecture, and if I found something I didn't understand well, I can quickly jump to that part and watch the video again. For others, collaborators can focus on certain section, quickly revisiting and learning the content." {P2} "It helps me recall and understand the lecture." {P5}

"I can recall and rethink the content of the previous section. I may have different thoughts on the previous section while listening to the current section, which is helpful." {P10} "After I review the concept map, I finally understand what the lecture is about…" {P19}

In summary, we found concept map can help learners understand the video lecture in two ways:

(1) Giving participants metacognitive support [12] including an expected overview on what they will learn, a cognitive road map on where they are learning, and a visualized summary to help them reflect on what they learned

(2) Providing a template to help learners organize their knowledge

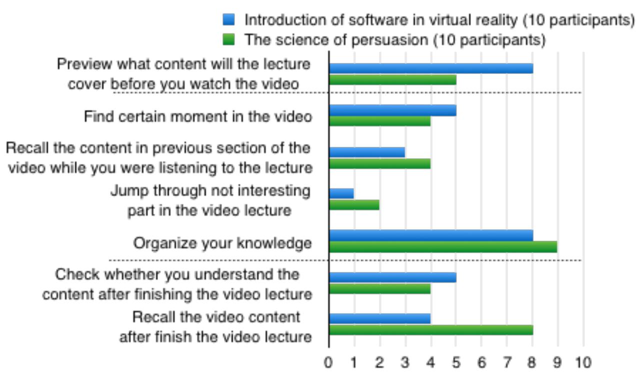

Table 2. Statistic results of concept map usages from user study questionnaire.

H2 (Concept map can facilitate learners navigating the video with our prototype) is supported.

Half of the participants use concept map to find certain moment in the video or skip uninteresting part. While concept map can serve as an overview and summary of the lecture as well as learner's perceived knowledge, the navigation function can help learners quickly revisit demanded section after they found it not clear. Unlike traditional video tagging, which aligned to sequential video time, using concept map as a video navigation tool can connect different part of the video in a meaningful way, which can scaffold learners in organizing their learning resources.

Lessons from learner-generated concept map

Overall 20 improved concept maps were collected from our participants.

We conclude our observations from collected improved concept maps that:

1. The result concept map doesn't necessary to be a single connected graph, but a separated graph may implicate a gap between two concepts in the lecture.

In G1 3 out of 10 participants create separated part of concept map and all of those parts represent the same knowledge (e.g., self-motion). Based on our knowledge from reviewing the video several times after this observation, we found that the instructor doesn't explain how does self-motion relate to the main concept. Observing a common pattern of separation in learner-generated concept maps, indeed helped us identify a knowledge gap in the lecture. This insight implies a possibility to leverage learner generated/improved concept maps as a *feedback to instructors*.

2. Different concept mapping strategies were developed by learners given a visual aid (e.g., video).

7 out of 10 participants from G1 share a common strategy to improve the concept map by changing the link direction between two concepts (e.g., input and AWG), shown in figure 2. We find that their concept maps imitate the instructor handwriting which contains flow chart to demonstrate the idea. While researcher suggested that a link represents the semantic relationship between two concepts, our participants use links to represent a data flow (e.g., input→AWG→output).

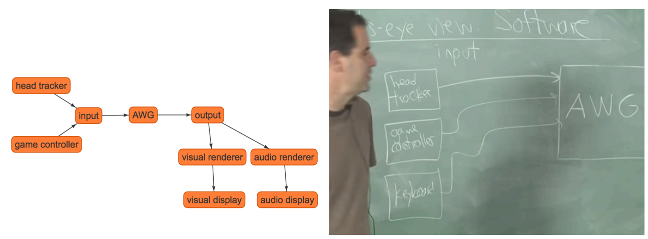

Figure 2. An example from over half of our participants who improve concept map from Figure 1 to the left one that imitate the handwriting of instructor.

3. Learner-improved concept maps share a similar structure of main topics while diverge in detail concepts.

In G1, 7 learners used the same structure and same topics while 3 of them created a new common topic. In G2, 4 learners created a topic with a set of new concepts and connected it to their main concept map. Others made micro modifications on the original concept. Overall, we find a similar structure of the main topics, but individual learners may have different idea on detail concepts. Although this finding may due to the influence of common original concept maps, the action that learner followed the main structure to add new concepts may indicate a possibility that the concept map can serve as a *common understanding* from learners.

4. Aggregated learner-generated concept maps can help learners identify what are important concepts and what are sub-concepts.

Investigating the improved concept maps from our participants, we find that some concepts were added by multiple learners, which were missing key concepts from the original concept map. On the other hand, some new added concepts only appear in single concept map, inferring to minor concepts. While single learner may neglect some points in the lecture or fail to filter out non-important concepts, an aggregated concept map can help learners identify what are important concepts and what are sub-concepts.

CONCLUSION AND FUTURE WORK

This paper presents VideoScape, a system integrates an interactive concept map with a video to afford concept-based video navigation and provide metacognitive support for video learning. Our online user study result shows the value of interacting and learning with a concept map in VideoScape. VideoScape provides external metacognitive supports, including an expected overview on what they will learn, a cognitive road map on where they are learning, and a visualized summary to help them reflect on what they have learned. Learners also effectively leveraged VideoScape to retrieve video content based on their need.

Results from learner-generated concept maps also imply future applications for aggregating learner-generated concept maps to give feedback to instructors, present common understanding for learners, and help learners find key concepts while filtering out non-important concepts. Our future work will explore methods of aggregating learner-generated concept maps to support instructors and learners in video learning environment.

Another direction for research is managing online video learners into asynchronous cooperative concept mapping. While aggregating individual concept maps requires large data set and intensive commutation, learners' cooperation can potentially create more persuasive result to represent a common understanding. Furthermore, we expect concept map can serve as an artifact to mediate collaborative online learning.

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