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Developing a Video-based e-Learning System Incorporating a Fill-in-the-blank Question-type Concept Map

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Abstract: E-learning, which can be used anywhere and at any time, is very convenient and has been introduced to improve learning efficiency. However, securing a completion rate has been a major challenge. Recently, the learning forms of e-learning require learners to be introspective, deliberate, and logical and have proven to be incompatible with many learners with low completion rates. In this study, we propose an e-learning system that incorporates a fill-in-the-blank question-type concept map to deepen learners' understanding of learning contents while watching learning videos. The proposed system promotes active learning reflectively and logically by allowing learners to answer blank question labels on concept maps from video content and labels associated with the question labels. We conducted an experiment with 14 subjects to evaluate our proposed system by comparing it with a conventional video-based e-learning system and confirmed that the proposed system promotes active learning while watching lecture videos and is effective in improving the comprehension of learning content for learners who are unfamiliar with video-based learning.

Keywords: e-Learning Support, Visual Thinking Tool, Video-based Learning

1. Introduction

In online video-based learning, a learner typically does not have to be in direct contact with the class at the same time, which has significant advantages. It supports learning anywhere and anytime via a mobile phone or a computer and enables access to learning that has never been available before. Recently, although online learning courses have been increasingly marketed to adults and students, the high dropout rate from such courses remains a concern to educational institutions. Much research has shown a high dropout percentage rate of learners participating in online courses compared with learners in a face-to-face classroom; e.g. more than 95% of learners dropped out from MOOC (Alraimi, Zo, & Ciganek (2015)) and approximately 78% of learners dropped out from Open University (Simpson (2013).

According to a survey report (Tominaga & Koga (2014)), the reasons for learners dropping out of online learning courses are classified into two major problem categories: learners' procrastination and incompatible learning style to e-learning. The first problem category entails that some learners cannot effectively manage the time and learning progress of e-learning by themselves, which makes it difficult to complete e-learning courses. To solve the first problem category, some e-learning institutions have introduced online tutoring and mentoring to provide individual support to such learners (Huang, Lin, & Huang (2012)). Others have identified learners who are likely to drop out by analyzing their learning activities from system logs (Mduma, Kalegele, & Machuve (2019)). These approaches are effective ways to maintain the retention rate of e-learning courses (Grau, & Minguillon (2013)). Meanwhile, the second problem category is that multimedia content provided by e-learning systems generates cognitive load effects on learners compared with typical face-to-face learning in the classroom (DeLeeuw & Mayer (2008)). The cognitive load effects in e-learning reduce the learning performance of learners, increasing the tendency of learners to drop out. To solve the second problem category, some researchers have designed e-learning systems with functions to match the learning style of e-learning (Kizilcec, Papadopulolos, & Sritanyaratana (2014);

Mayer(2005); Guo, Philip, Kim, & Rubin (2014)). Despite creating a better approach than the normal e-learning style, many recent e-learning systems still adopt a simple form with a video in the center of the interface. Moreover, some researchers have investigated the learning style of e-learning and demonstrated that both reflective and active learning styles are relevant to enhance the e-learning progress and that sensory learners are probably adaptive to the learning style of e-learning(Huang, Lin, & Huang(2012); Dalmolin, Mackeivicz, Pochapski, Pilatti, & Santos (2018)). Therefore, it is required for a learner to perform learning with metacognitive skills and a step-by-step thinking method during e-learning. However, it is difficult for many learners to use their skills because current video-based learning affords passive learning, and it is challenging for learners to leave the concepts of learning content while watching the video. Furthermore, learners who have dropout tendencies cannot effectively understand the learning content from the beginning of an e-learning course (Simpson (2013)). If the e-learning system has support to match a learner's thinking method in e-learning and learning style, which e-learning requires, the dropout rates in each e-learning course will be reduced.

Therefore, in this study, we propose an online video learning interface that provides a fill-in-the-blank question-type concept map. A concept map is an effective way to provide complex concepts with graph representations and frequently used in educational institutions (Novak (1990)). However, it is almost impossible for them to create an appropriate concept map while watching a lecture video(Hayama & Sato(2020)). Thus, we employed a fill-in-the-blank question-type concept map in which some labels that are important for understanding learning contents are punched out from a completed concept map, encouraging learners to think about them while watching the video. To achieve this, we also developed a method for extracting labels for fill-in-the-blank questions from the concept map. We conducted an experiment with 14 subjects to evaluate our proposed system by comparing it with a conventional system with a concept map and confirmed that the proposed system promotes active learning while watching a lecture video and is effective in improving the comprehension of learning contents for learners who are unfamiliar with video-based learning.

2. Related Studies

A concept map is a useful tool for supporting learners' deep understanding, evaluating their understanding, and so on (Novak (1990); Schmid & Telaro (2015)) as it can visually represent the relationships between various concepts. Some researchers have used concept maps to support learning by reflecting on the learning content of a class, complementing or deepening the understanding of the learning content after the class. For example, Cimolino & Kay (2002) confirmed the effectiveness of concept maps for teachers to assess students' understanding of concepts in a subdivided learning area by having students create and analyze concept maps to recognize conceptual understandings and misunderstandings of the learning content. As it is difficult for all learners to create proper concept maps, some researchers have developed a method using Kit-Build concept maps, where experts prepare components with labels and links in advance, and learners assemble them. For example, Hirashima, Yamasaki, Fukuda, & Funaoi (2011) demonstrated that Kit-Built concept maps can be used to diagnose a learner's comprehension of learning content and to compare the concept maps of learners with those of experts, respectively, for learning assessment. Hayashi (2019) presented more examples in which a Kit-Built concept map was highly useful in actual classroom teaching and cooperative learning. Conversely, some researchers have developed systems incorporating fill-in-the-blank concept maps, where some labels are masked from a concept map created by an expert. Chang, Sung, & Chen (2001) developed a system using fill-in-the-blank concept maps. They confirmed that the system was more effective than conventional concept maps in terms of students' understanding of learning content through the task of creating a concept map of learning content after the class.

Nevertheless, with the recent spread of online learning, technologies using concept maps while watching lecture videos have been developed. For example, Liu, Kim, & Wang (2018) developed a system incorporating concept maps as navigation while watching lecture videos. In their study, they proposed a concept map creation method by aggregating multiple concept maps created by general users and confirmed that the concept maps created by their method contained contents similar to those created by experts. However, their method only allows learners to pore over concept maps while watching a lecture video. To promote a more active learning style, learners need to interact when creating concept maps while watching lecture videos. In this study, we propose a learning support system incorporating a concept map with fill-in-the-blank questions, which makes a learner answer questions about important points of the learning contents while watching a lecture video. To achieve this, we develop a method for identifying the fill-in-blank labels on the concept map to understand the learning contents. To the best of our knowledge, this is the first study on the above approach.

3. Developed System

We developed a video-based e-learning system using a concept map with fill-in-the-blank questions. As depicted in Figure 1, the developed system consists of a lecture video-watching area, a concept map display area, and an answer input area for fill-in-the-blank questions.

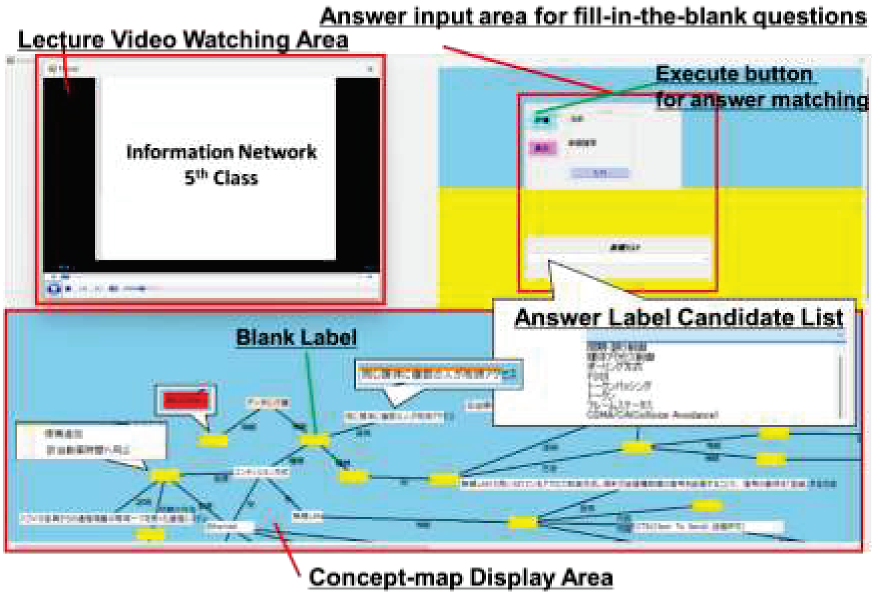

Figure 1. Interface of the Developed System.

In the video-watching area, lecture videos, including lecture slides and lecture speeches, are provided. These lecture videos can be played and stopped using buttons, and the playback position can be specified using the playback bar. In the concept map display area, the locations of multiple labels on the concept map created by the lecturer or other experts are automatically punched out and displayed. As shown in the concept map display area, the yellow blank labels have been automatically punched out of the concept map. Each label is automatically associated with the playback position of the lecture video that may contain the content of the label. To make the user notice the label(s) associated with the playback position of the lecture video, the label(s) is/are colored orange, and a link to the corresponding video playback position is also set.

In the answer input area for the fill-in-the-blank questions, a label candidate list is provided, as well as an execute button for matching the answers. In the label candidate list, a list of punched-out labels is displayed. In the concept map display area, for each label selected with the mouse, the item selected in the candidate list is inserted into the blank label. When a user presses the execute button to match the answers, the system checks whether the item inserted into the blank label in the concept map is correct or not, and if the wrong item is inserted into the blank label, the label turns red to notify the user that it is a misunderstanding.

While watching a lecture video, the user checks the part of the concept map related to the learning contents being watched, considers the learning contents corresponding to the blank label, and inserts the item into the label by selecting it from the candidate label list. The user then confirms whether his/her answers are correct, and if there is/are wrong answer(s), the user reconfirms the corresponding learning contents in the video. Thus, the system enables the user to always be aware of important points of lecture contents to pay attention to and to watch the lecture video while confirming information related to the important points.

Label extraction for fill-in-the-blank questions on concept maps:

We created heuristic rules to automatically extract labels for fill-in-the-blank questions from a concept map. To extract fill-in-the-blank question labels, labels related to important parts of learning content are identified on the basis of the number of links to each label and the kinds of link labels, and blank labels should be recognized from the surrounding labels. As link labels for concept maps, simplified by trial and error, the labels of "Method," "Description," "Function," "Example," "Contents," "Advantage/Disadvantage," and other user's definition phrases were used. The label extraction rules for fill-in-the-blank questions are listed below.

(a) If a label outputs a link with a ``Description'' label, the label is left blank because the answer to the label can be inferred from the output link label that describes it.
(b) If a label outputs a link with a label that appears only once in the concept map, the linked label is left blank because the content of the linked label is inferred from contents associated with the unique user's defined link label.
(c) If a label outputs multiple labels linked with a link label of ``Method,'' ``Description,'' ``Function,'' or ``Contents,'' the odd-numbered label(s) from the left side of the linked labels is/are left blank because the characteristics of the contents of the linking label are inferred from the linked labels. However, if a blank label has no output link, the blank to the label is canceled.
(d) If a label outputs link(s) with a ``Function'' label, the linked label(s), which have more than one output link(s), is/are left blank because the content of each label can be inferred from the contents of labels linking/linked to the label.
(e) If a label does not output a link and is linked from multiple labels, the label is left blank because the content of the label is inferred from the contents of multiple labels linked to the label.
(f) If a label outputs links with ``Advantage'' and ``Disadvantage'' labels, the labels to which each link of their labels is output are left blank because the contents of the label can be inferred from the link labels with its advantage and disadvantage.
(g) If a label outputs only a link(s) with an ``Example'' label(s), the label is left blank because the content of the label is inferred from the contents of the example(s) of the label.

4. Evaluation

4.1 Settings

We conducted an experiment to investigate the effectiveness of our proposed system in terms of comprehension of the learning content and interaction with the system. In this regard, the developed system and a video-based system that incorporates a concept map as it is were compared based on the comprehension test results and the operation history of the system.

Two lecture videos (approximately 50 min each) on the subject "Information Networks" were selected for the experiment. Fourteen undergraduate and graduate students majoring in information engineering, but who had never taken the subject, were recruited as subjects. For cross-validation, the subjects were divided into two groups (8 and 6 subjects, due to the absence of two subjects). The time limit for each lecture was set to 1 h, and each subject completed the lectures to his or her satisfaction. A comprehension test was then conducted for each lecture, consisting of 29 and 26 correct/incorrect questions on the learning contents of each lecture. Given the difference in the number of questions and the difficulty level of the lectures, the subjects' deviation scores for each lecture were compared between the two systems for learning comprehension. The system operation history for each subject during the experiment was recorded with timestamps in a file, including the playback positions of the learning videos and the answers to the fill-in-blank questions on the concept maps. The concept maps for Lectures 1 and 2 used in this experiment were similarly composed of 77 and 67 labels, 35 and 29 blanked labels, and 83 and 76 links, respectively. The concept maps and comprehension tests were created by the lecturer.

4.2 Results

The results of the comprehension test are shown in Figures 2 and 3, respectively.

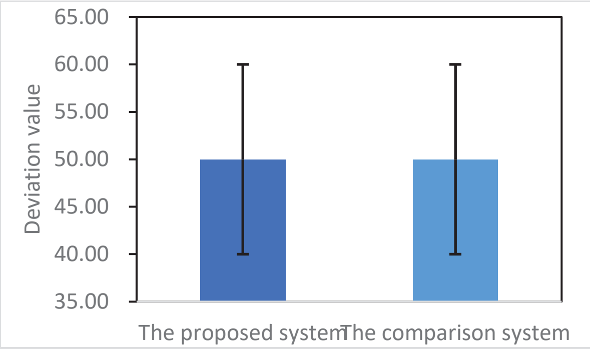

Figure 2. Average deviation values of learners' comprehension scores using the developed system/comparison system.

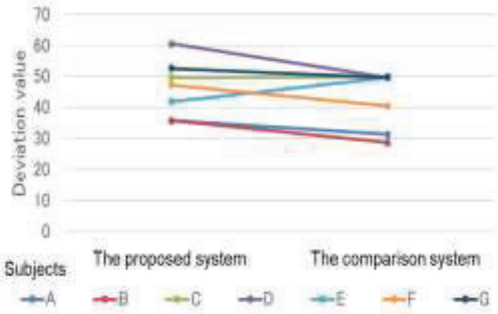

Figure 3. Deviation values of comprehension scores for each subject with lower performance when using the comparison system.

We calculated the deviation values of the subjects' comprehension scores for each lecture and compared them separately for the proposed and comparison systems. As shown in Figure 2, there was little difference between the proposed and comparison systems. Conversely, the deviation values of the comprehension scores were examined for the seven subjects with lower performance when using the comparison system, which requires a conventional learning style for a learner. As shown in Figure 3, the results showed that the five subjects improved their performance when using the proposed system, with subject (C) exhibiting a significant difference in performance when using both systems and subject (E) exhibiting lower performance; thus, this indicates that subjects with low performance in the conventional system improved their understanding of the learning contents in video-based learning by using the proposed system.

Next, we confirmed that all of the system functions were used while watching the learning videos. All subjects provided correct answers to the fill-in-blank questions on the labels for each lecture. The number of trials for matching the correct answers to the fill-in-the-blank questions was 4.3 and 4.8 for the 77 and 67 questions in Lectures 1 and 2, respectively, indicating that the subjects answered some of the questions before jointly checking their correctness. The number of times the subjects intentionally moved the playback position of the lecture videos during learning was 29.4 and 12.4 for the proposed and comparison systems, respectively, indicating that the subjects moved the playback position of the lecture videos more frequently with the proposed system than with the comparison system, with a statistically significant difference.

The post-questionnaire on the proposed system showed good results, with all items being rated at 3.4 or higher out of 5. For the learning environment of the proposed system, "Satisfaction with his/her learning," "Level of understanding of the learning contents," "Sufficiency of the learning time," and "Usability of the proposed system" were highly rated, indicating that the proposed system is a favorable learning environment to introduce. For the functions of the proposed system, "Effectiveness of the system function 'concept maps with fill-in-the-blank questions' in understanding the learning contents" was rated very high at 4.36 of 5. From the free description items, it can be inferred that the proposed system made it easier for the learners to watch and learn lecture videos by making them aware of what they need to pay attention to while watching the videos. In addition, we confirmed that the function of "the label extraction for the fill-in-the-blank questions on the concept map" was properly applied to the concept maps of Lectures 1 and 2 because the labels for the fill-in-the-blank questions were related to the questions of the comprehension tests.

Overall, the proposed system promotes active learning by having learners answer fill-in-the-blank questions on a concept map while watching a lecture video and can provide learning effects to improve the understanding of learning contents for learners who do not fit the learning style of conventional video-based learning.

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