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Practical Application of an e-Learning Support System Incorporating a Fill-in-the-Blank Question-Type Concept Map

Takumi HASEGAWA[†], ***Nonmember and*** **Tessai HAYAMA**[†a)], ***Member***

SUMMARY 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. Thus, we developed 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 developed 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 blank question labels. We confirmed in the laboratory experiment by comparing with a conventional video-based learning system that the developed system encouraged a learner to do more system operations for rechecking the learning content and to better understand the learning contents while watching the learning video. As the next step, a field experiment is needed to investigate the usefulness and effectiveness of the developed system in actual environments in order to boost the practicality of the developed system. In this study, we introduced the developed system into the two class of the uviversity course and investigated the level of understanding to the learning contents, the system operations, and the usefulness of the developed system by comparing with those in the laboratory experiment. The results showed that the developed system provided to support the understanding to learning content and the usefulness of each function in the field experiment, as in the laboratory experiment. On the other hand, the students in the field experiment gave lower usefulness of the developed system than those in the lab experiment, suggesting that the students who attempted to thoroughly understand the learning contents in the field experiment were fewer than those in the lab experiment from their system operations during the learning.
key words: *e-learning support, visual thinking tool, field experiment, video-based learning*

1. Introduction

Generally, providing learners with step-by-step understanding of learning content in online video courses prevents many learners who don't fit a learning style required for e-learning in online video courses from dropping out. As the first step to achieve it technically, this study proposes an e-learning system that provides video-based learning content with visual thinking tool for promoting learners' understanding of learning content in real time, and investigates its effectiveness on learning comprehension and learning style in actual learning courses.

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 and organizations. Much research has shown a high dropout percentage rate of learners participating in online courses compared with learners in a face-to-face classroom. For example, it has been reported that more than 95% of learners dropped out from MOOC [1], [14] and approximately 78% of learners dropped out from Open University [22], [23].

According to a survey report [24], 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 [13]. Others have identified learners who are likely to drop out by analyzing their learning activities from system logs [18]. These approaches are effective ways to maintain the retention rate of e-learning courses [7]. 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 [6]. 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; e.g., designing a web-based course with consideration of content and learning style [4] and effective multimedia presentations [8], [15], [17]. 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 [5], [13]. Therefore, it is required for a learner to perform learning with metacognitive skills and a step-by-step thinking method during e-

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[†]The authors are with Nagaoka University of Technology, Nagaoka-shi, 940–2188 Japan.
a) E-mail: t-hayama@kjs.nagaokaut.ac.jp
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learning. However, it is difficult for many learners to use their metacognitive 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 [23]. 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, we developed an online video learning interface that provides a fill-in-the-blank question-type concept map [9]. A concept map is an effective way to provide complex concepts with graph representations; hence, it is frequently used in educational institutions to provide learners with an enhanced understanding of the learning content [19]. However, as discussed in detail in Sect. 2, it is typically difficult for a certain number of learners to create concept maps from scratch, and it is almost impossible for them to create an appropriate concept map while watching a lecture video [11]. 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. In the laboratory experiment, we confirmed that the developed system encouraged a learner to better understand the learning contents and promoted the learners active learning style while watching the learning video. As the next step, a field experiment is needed to investigate the usefulness and effectiveness of the developed system in actual environments in order to boost the practicality of the developed system.

In this study, we introduced the developed system into the two class of the actual uviversity course and investigated the level of understanding to the learning contents, the system operations, and the usefulness of the developed system by comparing with those in the laboratory experiment. The results showed that the developed system provided to support the understanding to learning content and the usefulness of each function in the field experiment, as in the laboratory experiment. On the other hand, the students in the field experiment gave lower usefulness of the developed system than those in the lab experiment, suggesting that the students who attempted to thoroughly understand the learning contents in the field experiment were fewer than those in the lab experiment from their system operations during the learning.

2. Related Studies

A concept map is a useful tool for supporting learners' deep understanding, evaluating their understanding, and so on [19]–[21] 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 et al. [3] 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, Yamasaki et al. [26] and Hirashima et al. [12] 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 [10] 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 et al. [2] 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 et al. [16] 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.

Above all, we developed 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. In our laboratory experiment, we confirmed that the developed system promoted the learners a more active learning style. As a next step, we conduct a field experiment on the developed system, since investigations into the practicality of the developed system are required. To the best of our knowledge, there is no case study of a video-based learning of using concept maps in a practical setting.

3. Developed System

3.1 Overview

We developed a video-based e-learning system using a concept map with fill-in-the-blank questions. As depicted in Fig. 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.

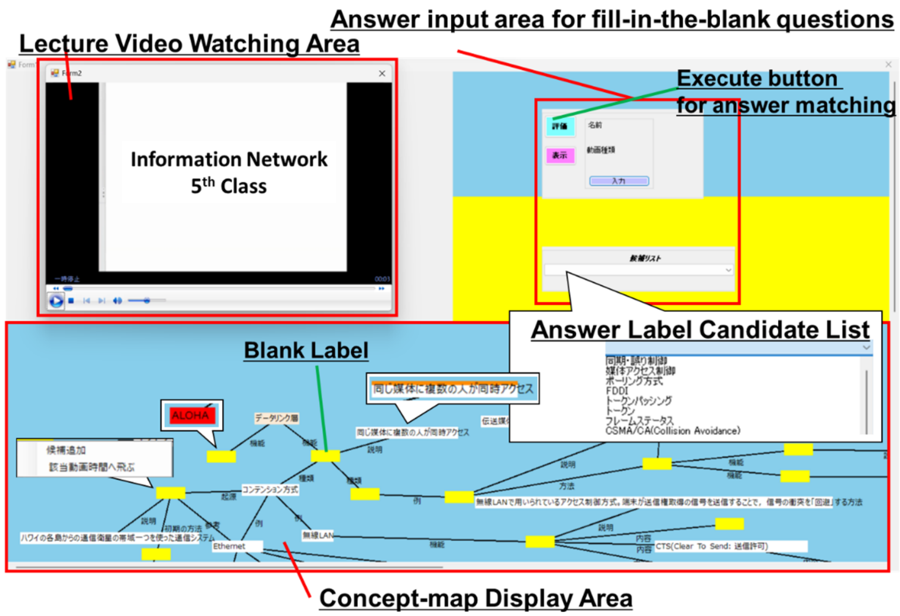

Fig. 1 Interface of the developed system.

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. The playback time of lecture videos is set to 0.8 times slower than usual to make it easier for users to work while watching the video. 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 in Fig. 1, the yellow blank labels have been automatically punched out of the concept map consisting of links and labels. 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. The label extraction process for the fill-in-the-blank question from the concept map and the correspondence between labels and video playback positions are explained in detail in Sects. 3.2.1 and 3.2.2, respectively.

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 provided in the video-watching area, 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.

3.2 Functional Modules

3.2.1 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. In this study, 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 rules for extracting labels for fill-in-the-blank questions are shown in Fig. 2 and 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

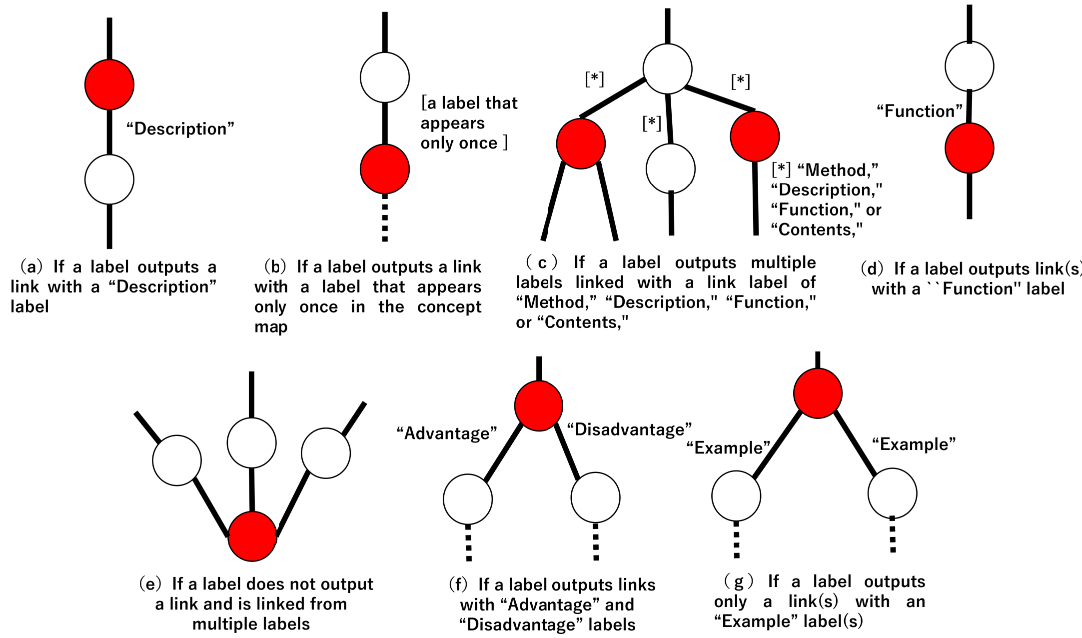

Fig. 2 Extraction rules for fill-in-the-blank question labels on concept maps. (The nodes above and below indicate the parent–child relationship, and the colored node indicates a blank label.)

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.

The extraction rules are applied to all labels in order from (a) to (g), with top priority and left priority on a concept map, and the extraction process is completed if there are no labels to be applied by the rules.

3.2.2 Correspondence between Concept Map Labels and Lecture Video Playback Positions

To correspond each label in a concept map to the playback position of the lecture video, the term(s) contained in each label and the term(s) contained in each slide displayed in the lecture video were matched. If each label includes multiple video playback positions in the corresponding result, the first playback position in which the term(s) for the label appears is likely to contain a more detailed explanation; thus, the lecture video is played in order from the first appearing playback position when the label is selected by a user.

In the procedure of the correspondence process, the term(s) contained in each label of a concept map and the term(s) contained in the slides are morphologically analyzed to extract only the content words (noun, verb, adjective, adverb, and numeral). Each label is then assigned the start position of the video playback describing the slide that contains all content words contained in the label. If no slide contains all content words in the label, the label is assigned to the slide that contains the most content words in the label.

3.3 Effects

The developed system draws the attention of a learner, who is learning while watching a lecture video, to the important terms that he/she should understand in the learning content and the terms related to them. The learner reviews the learning videos and performs trial and error operations until he/she obtains the correct answers to the fill-in-the-blank questions of the concept map.

In the other study [9], we conducted a laboratory experiment with 16 subjects to evaluate our developed system by comparing it with a conventional system with a concept map and confirmed that the developed system promotes active learning while watching a lecture video and is effective in improving the comprehension of learning contents for learners who are not familiar with video-based learning.

4. Settings of Experiments

To investigate the learning effects and how the developed system is used in an actual course, we conducted a field experiment and compared it with a laboratory experiment based on the level of understanding of the learning content, system interaction, and a post-questionnaire survey. An overview of the field and laboratory experiments is described in Sects. 4.1 and 4.2, respectively.

4.1 Field Experiment

The field experiment was conducted in two of the 15 sessions of the “Information Networks” course for university undergraduates, in which students watched videos using the developed system. In all other classes of the course, the lecturer gave a face-to-face lecture using slides. The course was held in a university computer room with a large screen in front of the room and a PC for each student. There were 14 participants for each of the two lectures, Lecture 1 and 2, 13 of whom attended both classes and the different one attended one class each.

In the first 10 minutes of the first class, the students were given a hand-out of the instructional material as shown in Fig. 3 and were given an oral explanation of how to use the developed system and the learning procedure. Then, the students learned by watching the lecture video using the developed system on their own PCs in the classroom. They could also use the normal learning method, such as simply watching the video without asking to use the developed system. After each lecture, tests of 32 and 29 true/false questions was administered to confirm the students’ understanding of the lecture contents, respectively. A post-questionnaire about learning using the developed system was also conducted after each lecture. The history of the students’ system operations during the classes using the developed system was recorded in a file.

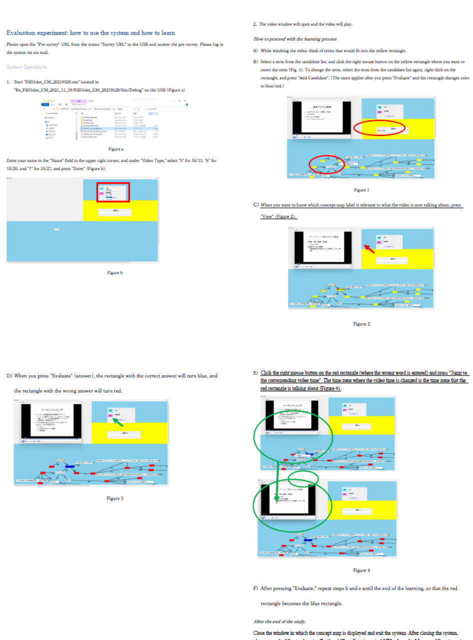

Fig. 3 Images of the handout used to explain the system operation and how to learn in the experiment to the subjects.

In the videos of Lecture 1 and Lecture 2, the lecturer explained the lecture contents by displaying slides, which lasted about 42 minutes and 45 minutes, respectively. The concept maps and comprehension tests used in the developed system were created by the lecturer, and the property of the concept maps in Lectures 1 and 2 were almost the similar as shown in Table 1, with the numbers of 69 and 67 labels , the numbers of the fill-in-the-blank labels of 26 and 29, and the numbers of 76 links in both.

4.2 Laboratory Experiment

In the laboratory experiment, two of the 15 lectures in the “Information Networks” course which was the same course as the field experiment were used for video-based learning using the developed system. One of the lecture videos was Lecture 2, which was the same as the field experiment, and the other was Lecture 3, which was different from the field experiment. The participants in the laboratory experiment were 16 undergraduate and graduate students who had never taken this course. 8 of them learned in Lecture 2, and the other 8 learned in Lecture 3.

First, as in the field experiment, the students were orally given an explanation of how to use the developed system with the instruction material, and then, at different time slots from the other students, they learned by using the developed system on their own PCs. After learing each lecture, comprehension tests of 29 and 26 correct/incorrect questions for Lecture 2 and Lecture 3 were administered to confirm the students’ understanding of the learning contents. A post-questionnaire was also conducted on the video-based learning using the developed system, which was the same as one used in the field experiment. The history of the students’ system operations during the learning using the developed system was also recorded in a file.

The videos in Lecture 2 and 3 were both approximately 45 minutes in length, and the properties of their concept maps were similar as shown in Table 1, with the numbers of 67 and 77 labels, the number of the fill-in-the-blank labels

Table 1 Property of concept maps used in the experiments

	Lecture 1	Lecture 2	Lecture 3
Number of labels	69	67	77
Number of blank labels	26	29	35
Number of links	76	76	83

Table 2 Average number of system operations in the experiments

	Field Experiment				Laboratory Experiment			
	Lecture 1		Lecture 2		Lecture 2		Lecture 3	
	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.
Moving from the label to the video playback position	7.07	9.27	10.71	11.69	8.13	6.23	10.8	6.61
Displaying identification of labels related to video playback	29.50	29.74	20.07	25.60	27.38	21.82	11.17	20.69
Answering the fill-in-the-blank questions of the labels*	39.14	15.99	37.79	4.83	35.00	2.00	48.17	6.31
Checking the answers to the fill-in-the-blank questions (the first time)**	18.86	16.29	14.79	14.03	4.75	5.26	4.33	3.20
Rechecking the answers to the fill-in-the-blank questions	19.07	17.20	12.21	11.72	6.25	4.38	6.25	6.98
Number of changes to the video playback position	37.14	35.56	36.79	34.51	18.13	17.21	10.83	6.62

∗∗: significant difference at the 5 % level of t-test, ∗: significant difference at the 10 % level of t-test, no mark: no significant difference at the 10 % level of t-test.

Table 3 Results of the post-questionnaire on the developed system (5 Likert scale)

	Field Experiment		Laboratory Experiment	
	Ave.	S.D.	Ave.	S.D.
Satisfaction with his/her own learning	3.43	0.82	3.69	0.58
Level of understanding to the learning contents**	2.93	0.80	3.56	0.70
Sufficiency of the learning time**	3.43	0.62	3.88	0.78
Effectiveness of the system function "Moving a video playback position from the label"	4.43	1.05	4.75	0.56
Effectiveness of the system function "Identification of labels related to the current video playback position"	4.29	1.03	4.63	0.60
Effectiveness of the system function "Concept-map with the fill-in-the-blank questions" in understanding the learning contents	3.86	0.99	4.19	0.63
Usefulness of learning style to manipulate concept maps while watching learning videos	3.36	1.17	3.88	0.63
Difficulty in learning content "Lecture 1"	3.29	0.70	-	-
Difficulty in learning content "Lecture 2"	3.21	0.67	-	-

∗∗: significant difference at the 5 % level of t-test, ∗: significant difference at the 10 % level of t-test, no mark: no significant difference at the 10 % level of t-test.

of 29 and 35, and the numbers of 76 and 83 links.

5. Results and Discussions

The results of the comprehension test, the operating history of the developed system, and the results of the post-questionnaire are shown in Fig. 4, Tables 2, and 3, respectively.

As shown in Fig. 4, there was little difference in average scores of comprehension test of students in Lecture 2 between the field experiment and laboratory experiment (23.13 and 22.57, respectively). On the other hand, comparing the average scores of the comprehension test of students between the lectures of the same experiment, there were little differences between Lectures 1 and 2 in the field experiment (25.57 out of 32 and 22.57 out of 29, respectivly), and between Lectures 2 and 3 in the laboratory experiment (22.57 out of 29 and 20.38 out of 26, respectivly). In the laboratory experiment of the other study [9], it was confirmed that the developed system supports the students' understanding of learning content while watching learning movie. Thus, the developed system supports a student to understand a learning contents while watching a learning video as in the laboratory experiment, even when it is introduced into the actual learning environment.

Next, we checked the number of using the system operations in the case of the developed system. As shown in Table 2, the average number of "moving from the label to the video playback position" was 7.07-10.71 in the field and laboratory experiments, indicating a similar behaviors

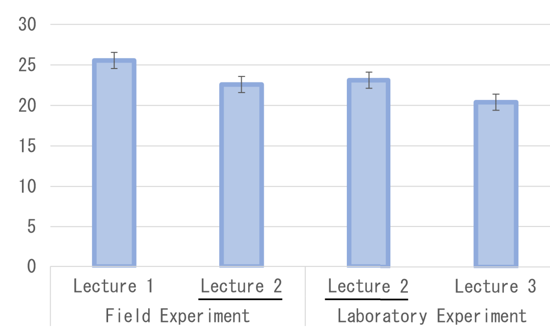

Fig. 4 Average scores of learners' comprehension tests in the experiments.

between both the experiments. On the other hand, the average numbers of "checking the answers to the fill-in-the-blank questions (the first time)," "rechecking the answers to the fill-in-the-blank questions," and "changing to the video playback position" were 14.79-18.86, 12.21-19.07, and 36.79-37.14 in the field experiment, respectively, while in the laboratory experiment they were 4.33-37.14, 4.33-10.71, and 10.83-18.13, respectively, indicating an increasing tendency in the field experiment. In lecture content 'Lecture 2' used in both experiments, we confirmed statistically significant differences between the experiments for each of these three items of the system operations by welch's t-test (($t(19) = 1.812$, $p = 0.086$, $r = 0.685$), ($t(18) = 2.297$, $p = 0.034$, $r = 0.856$), and ($t(20) = 1.613$, $p = 0.122$, $r = 0.630$)). Thus, a student who uses the developed system in the actual video-based learning checks the answers to the questions more frequently and rechecks the video content more often than in the laboratory

Table 4 Correlation matrix of questionnaire items and comprehension test score

	Score of comprehension test	Satisfaction with his/her own learning	Level of understanding to learning content	Usefulness of learning style to manipulate concept maps	Difficulty in learning content
Score of comprehension test	1.000				
Satisfaction with his/her own learning	0.272	1.000			
Level of understanding to learning content	-0.025	0.696***	1.000		
Usefulness of learning style to manipulate concept maps while watching learning videos	0.177	0.748***	0.598***	1.000	
Difficulty in learning content	0.161	0.559***	0.528***	0.535***	1.000

∗ ∗ ∗: significant difference at the 1 % level of t-test, no mark: no significant difference at the 10 % level of t-test.

experiment.

As shown in Table 3, the post-questionnaire on the development system showed that the usefulness of each function of the development system was highly evaluated in both the field and laboratory experiments, with an average of 3.8 or higher. Also, the satisfaction with his/her own learning and the sufficiency of the learning time when using the development system were rated highly in both the field and laboratory experiments, with averages of 3.43 and 3.69 to 3.88. Among them, the ratings of "Sufficiency of the learning time," "Level of understanding to learning content," and "Usefulness of learning style to manipulate concept maps while watching learning videos" in the field experiment were 0.2 lower than those in the laboratory experiment, respectively; there are statistically significant differences between the experiments (($t(28) = 2.106$, $p = 0.044$, $r = 0.792$), ($t(26) = 2.212$, $p = 0.036$, $r = 0.846$), and ($r(22) = 1.675$, $p = 0.108$, $r = 0.652$)). Thus, students who have used the developed system in actual learning have found the usefulness of the system's functions, the high level of learning satisfaction, and the efficiency of learning time, although these were lower than in the laboratory experiment.

In addition, to investigate the relationship between the influences of the developed system on learning in the field experiment, we calculated the correlations between the rating of each item of the post-questionnaire in the field experiment and the comprehension score of the learning content. Table 4 shows the correlation matrix between the post-questionnaire items with correlation coefficients of 0.5 or higher and the comprehension score of the learning content. As shown in Table 4, there were statistically significant positive correlations between each of the following items.

- "level of understanding to the learning content" and "satisfaction with his/her own learning" ($t(25) = 4.842$, $p = 0.000056$, $r = 0.642$),
- "usefulness of learning style to manipulate concept maps while watching learning video" and "satisfaction with his/her own learning" ($t(25) = 5.639$, $p = 0.0000072$, $r = 0.036$),
- "usefulness of learning style to manipulate concept maps while watching learning video" and "level of understanding to the learning content" ($t(25) = 3.732$, $p = 0.001$, $t = 0.477$),
- "difficulty in learning content" and "satisfaction with his/her own learning" ($t(25) = 3.367$, $p = 0.002$, $r = 0.244$),
- "difficulty in learning content" and "level of understanding to the learning content" ($t(25) = 3.106$, $p = 0.005$, $t = 0.452$),
- "difficulty in learning content" and "usefulness of learning style to manipulate concept maps while watching learning video" (($t(25) = 3.164$, $p = 0.004$, $t = 0.152$).

On the other hand, the correlation coefficients between these items and comprehension scores ranged from −0.025 to 0.272, indicating that there was little correlation. It is assumed that students who scored high in both "understanding of the learning content" and "difficulty with the learning content" attempted to understand the learning content more deeply during their learning than those who scored low in both items. Thus, regardless of their level of understanding of the learning content, students who tried to thoroughly understand the learning contents were highly satisfied with their own learning, indicating the effectiveness of the learning style provided by the developed system.

Overall, the developed system that supports video-based learning using a concept map with fill-in-the-blank questions provided to support the understanding to learning content and the usefulness of each function in the field experiment, as in the laboratory experiment. On the other hand, the students who used the developed system in the field experiment gave lower scores in the post-questionnaire than those in the lab experiment, suggesting that the students who tried to thoroughly understand the learning contents in the field experiment were fewer than those in the lab experiment. This may be related to the attitudes of the students who participated in the field experiment. They checked their answers immediately after answering and frequently checked the video learning content. The reason for this may be that they did not give much consideration to how their answers related to the surrounding answer labels on the concept map since they check the answer immidiately after answering each question. Investigating these attitudes and the usages of the functions of the developed system is in our future work.

6. Conclusion

E-learning through video streaming is widely used in education and business. However, in this learning environment, learners are likely to become passive, and learners who are incompatible with this learning style have difficulty understanding the learning content. Thus, we developed 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 developed 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 blank question labels. We confirmed in the laboratory experiment that the developed system encouraged a learner to better understand the learning contents while watching the learning video and provided the usefulness of functions of the developed system. Furthermore, a field experiment is needed to investigate the use and effectiveness of the developed system in actual environments in order to boost the practicality of the developed system. In this study, we introduced the developed system into the two class of the uviversity course and investigated the level of understanding to the learning contents, the system operations, and the usefulness of the developed system by comparing with those in the laboratory experiment. The results showed that the developed system provided to support the understanding to learning content and the usefulness of each function in the field experiment, as in the laboratory experiment. On the other hand, the students in the field experiment gave lower usefulness of the developed system than those in the lab experiment, suggesting that the students who attempted to thoroughly understand the learning contents in the field experiment were fewer than those in the lab experiment from their system operations during the learning.

In our future works, we will conduct more case studies of the developed system to obtain more findings on the learning effects and attitudes of the students in practical envrionments. For example, we would like to investigate how the learners' attitudes toward video learning change and how their understanding of the learning content is affected through the continuous use of the developed system in a video learning course. We would also like to investigate the influences of the developed system on the learners' ability to manage their own learning through a video learning course in which the learners decide their own learning schedule.

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References

[1] K.M. Alraimi, H. Zo, and A.P. Ciganek, "Understanding the MOOCs continuance: The role of openness and reputation," Computers & Education, vol.80, pp.28–38, 2015.
[2] K.E. Chang, Y.T. Sung, and S.F. Chen, "Learning through computer-based concept mapping with scaffolding aid," Journal of Computer Assisted Learning, vol.17, no.1, pp.21–33, 2001.
[3] L. Cimolino and J. Kay, "Verified Concept Mapping for Eliciting Conceptual Understanding," Proc. ICCE2002, pp.1561–1563, 2002.
[4] L. Combs, "The Design, Assessment, and Implementation of a Web-Based Course," Association for the Advancement of Computing in Education, vol.12, no.1, pp.27–37, 2004.
[5] A.C. Dalmolin, G.A. O. Mackeivicz, M.T. Pochapski, G.L. Pilatti, and F.A. Santos, "Learning styles preferences and e-learning experience of undergraduate dental students," Revista de Odontologia da UNESP, vol.47, no.3, pp.175–182, 2018.
[6] K.E. DeLeeuw and R.E. Mayer, "A comparison of these measures of cognitive load: Evidence for separable measures of intrinsic, extraneous, and germane load," Journal of Educational Psychology, vol.100, no.1, pp.223–234, 2008.
[7] J. Grau and J. Minguillon, "When procrastination leads to dropping out: analysing students at risk," eLC Research Paper Series, vol.6, pp.63–74, 2013.
[8] P.J. Guo, J. Kim, and R. Rubin, "How video production affects student engagement: an empirical study of MOOC videos," Proc. first ACM Learning@ scale conference, pp.41–50, 2014.
[9] T. Hasegawa and T. Hayama, "Developing a Video-based e-Learning System Incorporating a Fill-in-the-blank Question-type Concept Map," Proc. International Conference on Computers in Education 2023, pp.34–39, 2023.
[10] Y. Hayashi, "Open Information Structure Approach to Learning Support and Management with Kit-build Concept Map," The 4th International Conference on Education and Management (COEMA 2019), PB - Atlantis Press, pp.82–88, 2019.
[11] T. Hayama and S. Sato, "Supporting Online Video e-Learning with Semi-automatic Concept-Map Generation," In: P. Zaphiris and A. Ioannou (eds), Learning and Collaboration Technologies. Designing, Developing and Deploying Learning Experiences. HCII 2020, Lecture Notes in Computer Science, vol.12205, pp.64–76, 2020.
[12] T. Hirashima, K. Yamasaki, H. Fukuda, and H. Funaoi, "Kit-Build Concept Map for Automatic Diagnosis," Proc. AIED2011, Lecture Notes in Computer Science, vol.6738/2011, pp.466–468, 2011.
[13] E. Huang, S. Lin, and T. Huang, "What type of learning style leads to online participation in the mixed mode e-learning environment? A study of software usage instruction," Computers & Education, vol.58, no.1, pp.338–349, 2012.
[14] H. Khalil and M. Ebner, "MOOCs Completion Rates and Possible Methods to Improve Retention - A Literature Review," Proc. World Conference on Educational Multimedia, Hypermedia and Telecommunications 2014, pp.1236–1244, 2014.
[15] R.F. Kizilcec, K. Papadopulolos, and L. Sritanyaratana, "Showing face in video instruction: Effects on information retention, visual attention, and affect," Proc. Annual SIGCHI Conference on Human Factors in Computing Systems, pp.2095–2102, 2014.
[16] C. Liu, J. Kim, and H.-C. Wang, "ConceptScape: Collaborative Concept Mapping for Video Learning," Proc. 2018 CHI Conference on Human Factors in Computing Systems, Paper N.387, pp.1–12, 2018.
[17] R.E. Mayer, "Principles of multimedia learning based on social cues: Personalization, voice, and image principles," In: R.E Mayer (ed), The Cambridge handbook of multimedia learning, Cambridge University Press, pp.201–212, 2005.
[18] N. Mduma, K. Kalegele, and D. Machuve, "Machine learning approach for reducing students dropout rates," International Journal of Database Theory and Application, vol.9, no.8, pp.119–130, 2016.
[19] J.D. Novak, "Concept Mapping: A Useful Tool for Science Education," Journal of Research in Science Teaching, vol.27, no.10, pp.937–949, 1990.
[20] A.S. Ozdemir, "Analyzing Concept Maps as an Assessment (Evaluation) Tool in Teaching Mathematics," J Soc Sci, vol.1, no.3, pp.141–149, 2005.
[21] R. Schmid and G. Telaro, "Concept Mapping as an Instructional Strategy for High School Biology," The Journal of Education Research, pp.78–85, 2015.
[22] O. Simpson, "22% - can we do better?" In: The CWP Retention Literature Review, p.47, 2010.
[23] O. Simpson, "Student retention in distance education: Are we failing our students?," Open Learning: The Journal of Open, Distance and e-Learning, vol.28, no.2, pp.105–119, 2013.
[24] A. Tominaga and C. Kogo, "Developments and issues in practical

studies of e-learning," The Annual Report of Educational Psychology in Japan, vol.53, pp.156–165 (in Japanese), 2014.
[25] W. Wunnasri, J. Pailai, Y. Hayashi, and T. Hirashima, "Reciprocal Kit-Building of Concept Map to Share Each Other's Understanding as Preparation for Collaboration," Proc. Artificial Intelligence and Education (AIED), pp.599–612, 2018.
[26] K. Yamasaki, H. Fukuda, T. Hirashima, and H. Funaoi, "Kit-Build Concept Map and Its Preliminary Evaluation," Proc. ICCE2010, pp.290–294, 2010.

Takumi Hasegawa received the B.S. in Infomration and Management Systems Engineering of Nagaoka University of Technology in 2022. Currently he is a master course student in Infomration and Management Systems Engineering of Nagaoka University of Technology. His research interests include education engineering, e-learning support system, and visual thinking support tool.

Tessai Hayama received his B.E. degree in Knowledge Engineering from Doshisha University in 2001, and M.E. and Ph.D. degrees in Knowledge Science from Japan Advanced Institute of Science and Technology in 2003 and 2006, respectively. From 2006 to 2012, he was an Assistant Professor with Knowledge Science of Japan Advanced Institute of Science and Technology. From 2012 to 2016, he was an Associate Professor with Information Engineering of Kanazawa Institute of Technology. From 2016 to 2022, he was an Associate Professor with Information and Management Systems Engineering of Nagaoka University of Technology. Currently he is a Professor with Information and Management Systems Engineering of Nagaoka University of Technology. His research interests include knowledge systems, creative support systems and human interface.