

Lecture Support System using Digital Textbook for Filling in Blanks to Visualize Student Learning Behavior

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Abstract: - In this study, we develop a system that generates a digital textbook to fill in blanks from PDF files. The system also gathers and visualizes student behavior logs such as filling in blanks in the textbook, underlining and taking notes during a lecture. Using this system, in real time during a lecture, faculty members can determine the students' level of comprehension, degree of engagement in the lecture, or whether the pace of the class is appropriate and improve classes based on this information. In this paper, we provide an outline of this system and the results of applying it to an actual class.

Key-Words: Lecture support, Filling in blanks, Learning behavior, Real-time feedback, Retrospection

1 Introduction

In lectures, such as those delivered at a university, as the duration of the teacher's explanation (i.e., listening time) becomes longer, the number of students who cannot concentrate on the lecture increases. In order to sustain student concentration, many teachers give students time to think and move their hands i.e., fill in blanks, take notes, underline, and so on by conducting their classes according to the "Monta Method[1]" (presentation method where blanks are displayed for each explanation using textbook to fill in) or by incorporating problem-solving exercises during the lecture.

However, it is difficult to ascertain how many students are actually filling in the materials in a class of 100 or more students. Students feel that it is impossible to catch up with the lecture when the teacher moves to the next slide while the students have not finished filling in their answers. Where the student has already finished their answer, if the teacher does not move on to the next slide, the student may feel that the pace of the lecture is too slow. Furthermore, if lecture materials are distributed as electronic data, students must print them out or they have to install software in order to write directly into electronic materials.

On the other hand, LMS (Learning Management System)[2][3][4] for managing lecture materials and students' reports on the network is spreading along with the recent increases in the capacity and speed of information infrastructure. In addition, interest in learning analytics[5][6][7] is also growing. Learning analytics is way of analyzing and visualizing a

student's learning behavior based on viewing a log of teaching materials on LMS. This makes it possible to predict the future learning outcomes of learners and discover hidden learning problems. However, the learning behavior log acquired by the current e-learning system comprises coarse grain tasks such as login date, the browsing history of teaching materials, the number of answers to a question, and so on. Also, the types of logs that can be acquired are limited. Therefore, a satisfactory analysis cannot be performed.

Based on these background factors, in this research, we are developing a lecture support system using a fill-in textbook. We aim to easily create lecture materials (fill-in textbook), and aim at ascertaining engagement in the lecture, and the students' level of comprehension or suitability of the pace of the lesson from the detailed student behavior logs. In this paper, we provide an outline of this system and the results of applying it to an actual class.

In Section 2, we describe current problems and approaches to solving them, and Section 3 outlines the lecture support system using the fill-in textbook applying these approaches. Section 4 summarizes the results and contains a consideration on how it can be applied to actual classes.

2 Problems and Approach

2.1 Targeted Lecture and Associated Problems

In this study, we focus on face-to-face lecture classes that are commonly held at private Japanese

universities. Classes are generally held in classrooms that accommodate from 100 to 200 people and these classrooms are often held in the staircase classroom. The teacher stands at front on a stage and lectures while writing on a board or using slides prepared with presentation software. Students listen to lectures and write down essential facts in the textbook and take notes. In order to sustain the concentration of students, faculty members may conduct their classes according to the "Monta Method", incorporate problem solving exercises during the lecture, and set aside time for students to think and time to write.

However, in a large number of classes, it is difficult to ascertain how many students are engaged in filling in the blanks or tackling exercises, and to distinguish between students who are not working on exercises and students who have finished answering. Especially in a staircase classroom, faculty members do not know how many students are taking notes because students' hands are usually not visible. The lecturer will move on to the next step while trying to gauge the state of the students, but if the lecture proceeds too quickly, the following requests for improvement are made by the students: "The lecture moves on too quickly to the next step", "I cannot digest what is being said if spoken while I am still filling in the answer", "The time to think about exercises is too short", "I was unable to complete the answer to the exercise"

2.2 Approach

In order to solve these problems, we are developing a lecture support system using a fill-in textbook. Our objective is to easily create a fill-in textbook with the aim of ascertaining engagement in the lecture, and the students' level of comprehension or suitability of the pace of the lesson from the detailed student behavior logs.

In this research, in order to collect the logs containing details of student's learning behavior, instead of distributing materials, the teacher uploads teaching materials to the web. Students browse the teaching materials with the web browser on their laptops, listen to lectures while filling in blanks, and solve exercises. Also, while students conventionally had underlined key points and taken notes using paper-based materials, with this system, they do something similar but using their browser. Furthermore, questions and comments are input from the same screen.

As the teaching material, we used the kind of PDF document that teachers are already accustomed to. The system provides an environment that allows teaching materials to be easily created from PDF documents and collects learning behavior logs that

include filled-in blanks, underlined words, and memos.

2.2.1 Creating the Fill-in Textbook from PDF Documents

When a PDF document is registered in the system, the faculty member can create blanks in arbitrary portions of the PDF document from the Web browser as shown in Fig.1. In addition, the PDF document can be displayed on the Web browser, and underlines, memos such as questions / comments / impressions can be written in the PDF document.

Teachers can create teaching materials in the familiar Word and PowerPoint formats without having to expend the time and effort required when traditional e-learning materials are created. In addition, they can utilize the teaching materials already stored in the system to make a fill-in textbook.

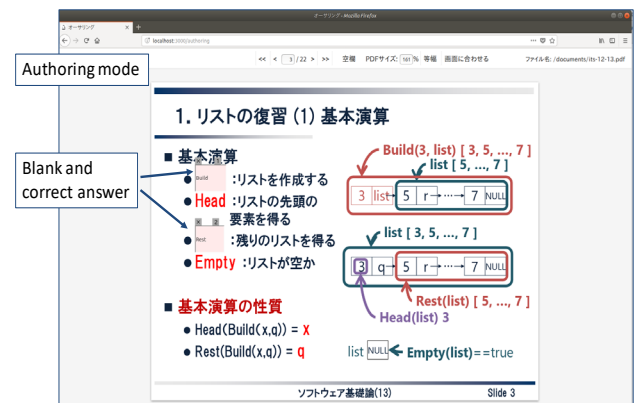


Fig.1 Fill-in Textbook

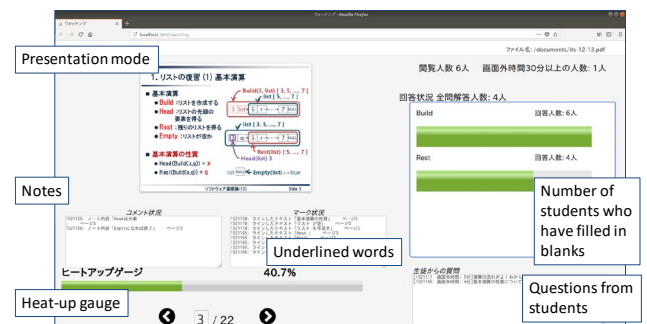


Fig.2 Realtime Visualization of Student Behavior

2.2.2 Real-time Feedback by Collection and Visualization of Learning Behavior Logs

This system collects and visualizes logs such as when and where the blanks are filled in, underlinings, if notes are attached, and presents it to teachers as shown in Fig.2. In this study, in addition to the times at which pages are turned, information that was collected in our previous research [8][9], character strings with underlines and the times at which this occurred, memos attached to the underlines, the details of any changes and deletion of the memo and

the time this occurred, the character string and time the blanks were filled in, the time when the system is used (the time when the window was activated), keyboard strokes, and mouse operation are all collected as logs.

This makes it possible for teachers to ascertain the level of comprehension during the class, the attitude of the class, the appropriateness of the pace of the lesson, and the level of learning before and after the class.

Based on this information, teachers can adjust the amount of detail and the level (or difficulty) of the explanation during the lecture. In particular, since teachers can ascertain progress in filling in blanks and exercises in real time, progressing to the next topic prematurely or making the exercise time too short can be avoided.

2.2.3 Retrospective Support by Visualization of Class Attitude

If we can measure the level of student engagement during classes in a time series, teachers will gain useful information that can be reflected in their subsequent lessons and improve the quality of their teaching. There are many studies on how the degree of concentration can be measured; this can be gauged by such methods as self-evaluation, image recognition[10] or by using sensors[11].

In the class using the fill-in textbook, students always take classes while manipulating the teaching materials. This makes it easier to judge whether students are seriously engaged in the lecture compared to the other methods described above. In this research, it can be determined from the student's keyboard and mouse operations, activation of the system's window, and the page being referenced whether the student is seriously working during the class. This is presented schematically in Fig. 3.



Fig.3 Retrospective Representation of Class Engagement

Teachers can refer to the time series to find out how many students were concentrating while a slide

was being explained. Also, it allows students to look back on their classes as a form of revision. Self-monitoring for learners is important. Obtaining feedback on their work often leads to improvements [12][13].

3 System Overview

In this study, based on the approach described in Section 2, we develop a lecture support system using a fill-in textbook.

This system has four modes: the authoring mode, browsing mode, presentation mode, and analytics mode. Moreover, it has a user management function and digital textbook management function similar to other lecture support systems. As shown in Fig.4, a teacher uploads a PDF document (authoring mode) and creates fill-in textbook by adding blank spaces. Students browse the fill-in textbook (browsing mode). In the presentation mode, the system visualizes learning behavior logs accumulated during browsing and provides them to the lecturer. In the analytics mode, learning behavior logs are visualized by classifying them into three types: for all students, for each student, and for each page. Details of each mode are provided below.

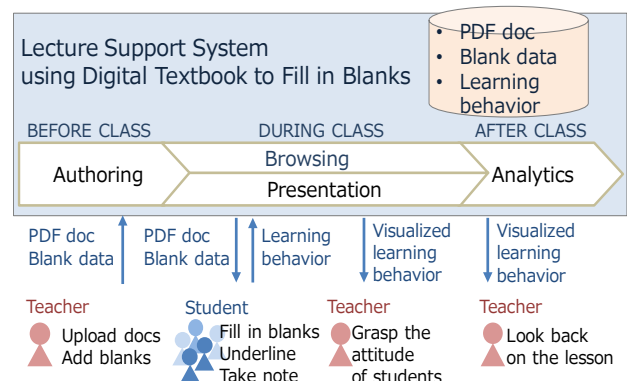


Fig.4 System Overview

(1) Authoring mode

The authoring mode is the mode that allows faculty members to insert blanks into PDF documents. To insert a blank space, specify the character string to be blanked out in the PDF document and click the blank button. In order to compare answers automatically by comparing the character string that was originally included in the blank space with the character string entered in the blank, when inserting a blank space, register a pair of blank identifiers and the specified character strings in the system in advance.

This allows the student to immediately know whether his input is correct or not. Also, when teachers create exercises, it is not necessary to separately register question sentences and answers in

the system. This is particularly effective when creating a fill-in textbook.

(2) Browsing mode

The browsing mode is the mode that students use during classes and before / after classes. Students can take notes, fill in blanks, underline, and comment while browsing PDF documents. Next to the display window of the PDF document, there is a comment column for the entire document, a comment column for each page, and a controller panel with buttons for turning pages and underlining.

In the browsing mode, operations such as page turning and filling in blanks, underlining, commenting, keyboard tapping, mouse clicking, activating and inactivating of the system's window, and the time taken for these operations are recorded in the system as a log of the learning behavior.

(3) Presentation mode

The presentation mode is the mode used when giving a presentation, and at the same time, a learning activity log is visualized in real time. During the lecture, the teacher conducts classes while monitoring student's learning behavior on the presentation mode screen.

This mode employs two screens: a presentation screen displaying only the slide as shown in Fig. 1 and a learning behavior visualization screen displaying slides and various data as shown in Fig. 2. The presentation screen is what the student sees via a projector etc., and the second screen is displayed on a laptop PC used by the teacher.

If the teacher clicks on one of the two screens, the blank space disappears according to the deletion order set in the authoring mode. If there are no blank spaces to be deleted in the slide, the screen shifts to the next slide. Also, the two screens work in sync with each other, i.e. when a blank is deleted or there is transition to the next slide performed on one screen, the other screen automatically reflects these changes.

In the learning behavior visualization screen shown in Fig. 2, student learning behavior logs are visualized in real time. The number of students using the system, the status of blanks being filled in, the percentage of students engaged in the class, the content of questions, the content of notes for the entire document and for each page, and the underlined character string are sent to the teacher's screen in real time. By referring to them, the teacher can tailor the lecture in response to the learning behavior of the students, such as adjusting the pace of the lecture based on how quickly blanks are being filled in, giving students hints to the correct answer

when the percentage of correct answers is low during exercises.

(4) Analytics mode

In the analytics mode, learning behavior logs are visualized in three categories: for all students, for each student, and for each page.

For all students, the number of clicks, the number of keyboard taps, the number of times notes are taken, the number of underlines, and off-screen time are represented by bar graphs. Furthermore, the frequency at which words are underlined is represented by a histogram. In addition, the number of keystrokes and mouse clicks is represented by a chronologically arranged line graph. Fig. 5 shows an example of a histogram screen depicting the frequencies of underlined character strings. By referring to this information, it is possible to gain a clear understanding of the learning behavior of all students and any tendencies that may be present.

For each student, as shown in Fig.3, the number of clicks, the number of keyboard taps, the number of notes taken, and the number of underlines are displayed together with the average numbers for the entire class. Page transition is displayed as a line graph in chronological order. By referring to this information, it is possible to find out if the student was fully engaged in the lecture.

For each page, the number of clicks, the number of keyboard taps, and the number of underlines are displayed together with the average numbers for the entire class. The frequency at which words are underlined is displayed as a histogram. By referring to this information, it is possible to ascertain if students are concentrating on a particular page.



Fig 5 Histogram of Underlined Words

4 Experimental Trial in Real Class

In this chapter, experiments conducted using the system are described.

4.1 Objectives of the Experiment

This experiment is aimed at clarifying the following:

- (1) Whether the student's learning behavior log reflects differences in the level of student engagement in the class.
- (2) Whether teachers were able to proceed based on student understanding and whether they were able to proceed more efficiently than in ordinary lectures
- (3) Whether students were able to participate in lectures in a relaxed atmosphere and have a better understanding of the content than in ordinary lectures.
- (4) To evaluate server load and performance when the system is accessed by ten people.

4.2 Overview of Experiment

Eleven undergraduate students and one faculty member participated in an actual lecture (90 minutes) using this system.

The teacher prepared the fill-in textbook beforehand using the authoring mode and gave a lecture using the presentation mode on the day of the lecture. We gave students an approximately 5-minute explanation on how to use the system at the beginning of the lecture. Next, after their user information had been registered, the teacher gave a lecture using the presentation mode.

During the experiment, the teacher displayed the presentation mode screen using a projector, monitored the learning behavior visualization screen on a laptop computer kept close at hand, and delivered the lecture. After the lecture, a questionnaire survey was administered to both students and the teacher.

4.3 Experimental Results and Discussion

The experimental results are presented for each of the four objectives outlined in 4.1.

4.3.1 Analysis of Learning Behavior Log

From among the students, three students were selected: one who performed numerous operations, one who performed a few operations, and one who performed a very low number of operations, and graphs of their learning behavior are shown in Figs. 6, 7, and 8. The horizontal axis is time, the vertical axis on the left is the sum of the number of mouse clicks and the number of keystrokes, and the vertical axis on the right is the page number. The bar graph is the sum of the number of mouse clicks and the number of keystrokes per minute, and the line graph is page transition.

Fig.6 shows the learning behavior of the student who performed the highest number of operations among all students. The number of keystrokes was much higher than the average, and the number of clicks was also very high, about 3 times the average number of clicks. The reason for the large number of

clicks is due to operations such as page transition buttons and underline buttons being used in addition to filling in blanks. Furthermore, it is thought that the number of keystrokes also increased as a result of using the note function. Actually, only this student used the system's note function. The page transition graph shows a marked zigzag pattern. This is because the button for slide transition was pushed frequently to compare the slides before and after the current slide, or to review the previous slide. From this information, it can be seen the student not only filled in the blanks, but also attempted to seriously engage in the lecture by taking notes and reviewing the slides.

Fig.7 shows learning behavior data of the student who performed a few operations. Both the number of clicks and keystrokes are close to half the average. Since there is a keystroke, it is thought that the blanks were being filled in to some degree, but, since this student only fills in the blanks, there are few keystrokes. Also, the slide transition shows a less pronounced zigzag pattern compared to the student of Fig.6. Zigzags were confined to 11:46 and 12:01 which coincides with the exercise time. From this, it can be concluded that since this student only filled in the blanks, he did not understand the content of the lecture, he could not solve the exercise problem, and he was attempting to solve the problem while looking at the previous slide. Apart from the exercise slide, this student just filled in the blanks, so no zigzag pattern is apparent. From this information, it can be concluded that this student was just filling in the blanks, and he was not actively engaged in the lecture.

Fig.8 shows the data from the student with a very low number of operations. Since none of the blanks were filled in, the number of key operations is 0. The first page transition is to a slide in the middle of the document and from that point the student was not engaged in using the system for approximately 30 minutes from 11:41 to 12:08. From this information, it is clear that this student was not at all motivated to participate in the lecture.

As described above, we were able to confirm differences in learning motivation for each student from the learning behavior log collected by this system.

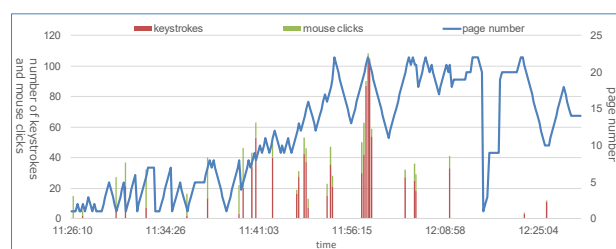


Fig.6 Student Who Performed Numerous Operations

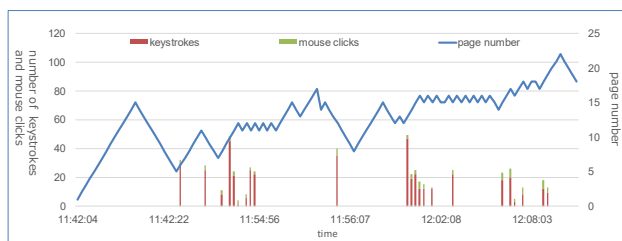


Fig.7 Student Who Performed a Few Operations

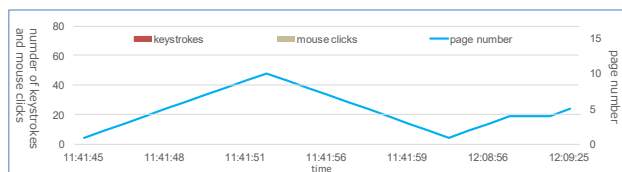


Fig.8 Student Who Performed Almost no Operations

4.3.2 Results of Teacher Questionnaire

After the lecture, the teacher was asked to provide answers to a questionnaire. The answer was positive for the question concerning how easy it was to add blanks in the authoring mode. However, there was a problem with the blank addition function. The teacher said that it was necessary to rewrite the slide because the system does not support the insertion of blanks for mathematical formulae such as fractions and Greek letters such as sigma.

Regarding the presentation mode, to the question "Do you feel that it is easy to lecture while viewing student learning behavior data?" the teacher answered that it was "easy to do". However, to the question "Were you able to tailor your lecture based the student's situation by looking at the the student's data", the response was that "It is the same as before". This is because during the experiment, the display showing the status of filling in blanks and the display showing the index of student engagement did not work well, and it was not possible to provide teachers with sufficient information. There was also a problem with the method used to visualize the filling-in situation.

4.3.3 Results of Student Questionnaire

After the lecture, a questionnaire was administered to the students. The results of the questionnaire are shown in Table 1. Nine out of eleven students answered "Yes" to the question "Is this application an aid to the lecture?" In addition, 10 people out of 11 answered "Yes" to the question "Do you think you would like to use this system in ordinary lectures?" From this, we confirmed that this system is an effective way to support lectures.

However, to the question "Was your comprehension of the lecture content improved compared to a conventional lecture?" and to the

question "Was your ability to focus improved compared to a conventional lecture?", answers in the affirmative and in the negative were evenly split. When we asked the students why they answered No to the former question, the response was "There is no function to help understanding", and for the latter question the response was "I cannot concentrate on the lecture while simultaneously trying to use a PC". Thus, it was confirmed that the current system aids classes, but the function to help understanding is lacking.

Table 1 Results of student questionnaire

questions	yes	no
Is this application an aid to the lecture?	9	2
Do you think you would like to use this system in ordinary lectures?	9	2
Did you understand the content of the lecture more readily than in a conventional lecture?	6	5
Was your concentration improved compared to a conventional lecture	6	5

5 Conclusion

In this study, we developed a system that generates a digital textbook to fill in blanks from PDF files. The system also gathers and visualizes student behavior logs such as filling in the blanks in the textbook, underlining and taking notes during a lecture. We conducted an experiment using this system in an actual lecture with eleven students and confirmed that the students' level of engagement in the lecture can be identified from the learning behavior log. In addition, from the questionnaire after the lecture, we also confirmed that this system is an effective way to support lectures.

In the future, after improving the system's ease of use and improving the server performance, we will conduct a trial experiment involving more than 100 student classes.

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