Training, Education, and Learning Sciences, Vol. 59, 2022, 109–115
https://doi.org/10.54941/ahfe1002390

Development of a Method to Visualize the Approximate Synchronization Ratio of a Teaching Material Clickstream in Class

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ABSTRACT

This study proposes a method for a large number of university students to analyze the synchronization ratio in opening teaching materials in classes using Moodle learning management system (LMS) and online teaching materials. Furthermore, this research analyzes the results in terms of both educational technology and ergonomics and discusses the improvement in the interaction between teachers and learners. Learners' reactions are influenced not only by the teacher's instructions, but also by various factors such as the quality of the content, the method of presenting the teaching materials, the performance of the software, and the performance of the monitor screen. Therefore, using the proposed method, the analysis was limited to the clickstream of the teaching material accumulated in the LMS. The time-series cross-section displays the synchronization ratio of teaching materials in the class in graphs and tables at intervals of between 1 to 5 minutes. Moreover, since the synchronization ratio is based on the time-series cross-section for each learner, one can observe the synchronized learners, the learners who open the teaching materials late, and the learners who never open the teaching materials.

Keywords: Synchronization ratio, Online teaching materials, Lesson improvement, Clickstream, Moodle, Time-series, Cross-section, Visualization

INTRODUCTION

Since there are various educational goals and methods, there are many situations where real-time synchronization is required in the interaction between teachers and learners. Regardless of the learner's age or the type of educational institution, teachers must grasp individual learners' reactions in order to proceed smoothly with the lesson. Previously, in a large class, it was recognized that it was a difficult task even for a skilled teacher to properly grasp the behavior and reaction of the learner. However, with the development of LMS and the understanding of how to use them, it is becoming possible to partially grasp and analyze learning behavior individually, even with a large number of learners in a class (Arnold and Pistilli, 2012). Therefore, in this study, the Moodle LMS was used to check the synchronization between a

teacher's instructions and the learners' reactions, and the learning logs for the teaching materials were collected.

It is also necessary to be able to grasp the mode of synchronization that reflects the passage of time and analyze it in real-time. The lessons in this paper were conducted in a computer classroom, and the teaching materials were uploaded to the Moodle LMS. The synchronization ratio of viewing teaching materials according to the teacher's instructions is discussed for classes where university students learn the basics of data science using the spreadsheet software Excel. In this class, it is necessary to adjust the progress speed of the lesson so that the whole class is synchronized as much as possible, and the instructor must always pay attention to the learners' behavior.

Related Research

In recent years, LMS such as Moodle have been actively used, and efforts are being made to analyze the learning logs. Due to the Coronavirus 2019 (COVID-19) pandemic, many educational institutions have conducted distance learning. This has increased the importance of LMS in distance learning, and research analyzing accumulated learning logs has become more and more active. Many studies have analyzed learning logs and have used them to improve education (Romero and Ventura, 2020), which is also the purpose of this paper. Research analyzing learning logs is evolving primarily in the areas of Educational Data Mining (EDM) and Learning Analytics (LA) (Blikstein and Worsley, 2016; Namoun and Alshanqiti, 2021; Ray and Saeed, 2018; Viberg et al. 2018). In the field of education, many dashboard studies have also been conducted on themes such as applying data mining and visualization technology, monitoring the progress of learning, and tracking learning behavior (Bodily et al. 2018; Verbert et. al. 2013; Vieira, Parsons and Byrd, 2018). In addition, Nguyen et al. proposed the development of a system for integrating learning analytics functions into existing information systems and dashboards and developed a system for visualizing learner involvement (Nguyen, Rienties and Whitelock, 2022).

Course Signals is a system developed at Purdue University that individually predicts students' grades from data and test scores stored in Blackboard LMS. Warning signals colored according to traffic signals are posted on the students' homepages to draw their attention and prevent stumbling blocks in their learning (Arnold and Pistilli, 2012). Shimada et al. developed a real-time lecture support system, conducted lessons using the Moodle LMS and e-book system, analyzed the learning logs of teachers and learners in real-time, and conducted research to provide feedback during the lesson. With their system, the heat map displayed on the teacher's computer showed the synchronization status of the material browsing, showing that the teacher could adjust the speed of the lecture (Shimada, Konomi and Ogata, 2018).

LEARNING LOGS AND LESSON OUTLINE

Experimental Environment and Teaching Materials

A learning log is influenced by various factors such as how to proceed with the lesson and its teaching materials. When analyzing it, it is necessary to

clarify the experimental environment as much as possible. Although this paper is mainly aimed at classes conducted in computer classrooms, Moodle is also used to distribute teaching materials online, so the method presented in this paper can also be applied to learners who take distance lessons at home. This section outlines the teaching materials used to collect learning logs, how the lessons proceeded, and the experimental environment. The class covered in this paper is a subject called "China Data Analysis". Classes were held 15 times over 120 days from September 14, 2021, to January 11, 2022. There were 55 students enrolled in the class, 45.5% of whom were female and 54.5% of whom were male. The number of registrants was mixed from the 1st school year to the 4th school year: the ratio was 25.45% for the 1st school year, 10.91% for the 2nd school year, 47.27% for the 3rd school year, and 16.36% for the 4th school year. The purpose of this class is to use the data from the Chinese Statistical Yearbook published on the web to learn the basics of statistics. In the semester, the students mainly learn how to operate Excel, including graphing, mean, deviation, variance, standard deviation, moving average, pivot table, frequency distribution, etc.

Link Structure and Section Transitions

The teaching materials were created for half a year of the university course and consisted of 13 chapters, with 95 sections and 183 total pages, and a PDF file was created to upload to Moodle for each section. The number of sections per chapter was 7.3, and the number of pages per section was 1.9. The author created 13 chapters and 95 sections in topic mode in Moodle and entered the name of each chapter and the name of the section. The link to the teaching material sends the learner to the first page of each section, that is, to the section transition. Therefore, when they move the page within the section, they must move the page or thumbnail of the PDF file displayed on the web browser up and down. In addition, all links to the materials are provided on the course gateway page, so if the learner wants to move to another section, they need to go back to the entry page and click the destination section from there. For the clickstream that is the subject of analysis in this paper, only the clicks opening the teaching materials used in the lesson were extracted and analyzed.

EXPERIMENT

In this section, we provide an example to visualize the synchronization ratio with a time-series cross-section and a graph from the lessons held in the fall semester of 2021. The synchronization ratio was calculated by dividing the number of people who opened the teaching materials by the number of attendees (49 learners) present that day. Figure 1 shows a bar graph created by aggregating the clicks of section transitions every minute and calculating the synchronization ratio. Schedules and graphs can be created not only every 1 minute, but also every 2 minutes, 3 minutes, 4 minutes, and 5 minutes. Due to the limited space in this paper, Figure 1 is divided into four screens, the parts necessary for writing this paper are colored manually by the author, and explanations are provided in Excel balloons.

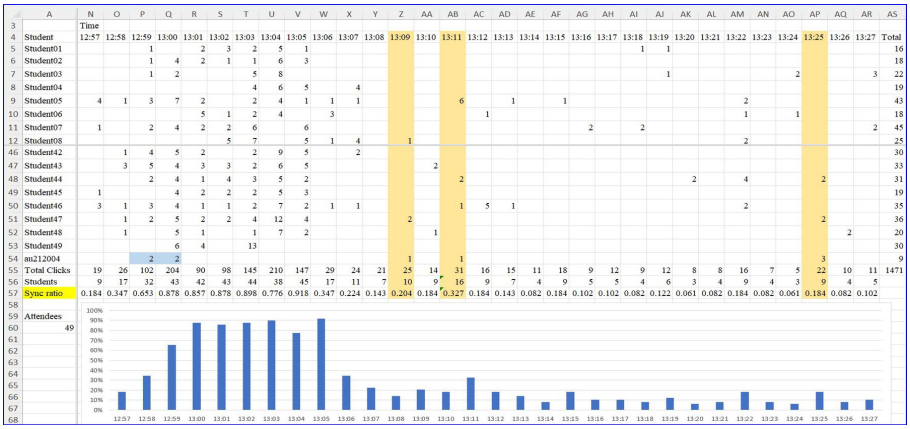

Figure 1: Example table and graph showing time-series cross-sections and synchronization ratios for section transitions (Minute-by-minute, 2021/11/2, China data analysis, 49 attendees).

Column A in Figure 1 shows the anonymized learner's ID, and column B (hidden in the table) to column AR show a summary of section transitions. The fourth row at the top of the screen is an example displaying the time every minute. Cells containing a number indicate how often the teaching material was opened. The rightmost AS column shows the total number of clicks until 13:27, and the 56th row at the bottom of the table shows the number of learners who opened the material. Furthermore, the synchronization ratios calculated in 57th row are shown, which are the original data for the bar graph. After the quiz, the author opened the teaching materials at 13:06 and proceeded with the lesson, but the colored three columns (Z, AB, and AP) in the table show when the author opened the teaching materials on the computer of the teacher's desk and instructed the learners and the time when the commentary started. Cells P54 and Q54 show when the author (cell A54, au212004) opened the table of contents of the course and the entrance to the quiz in preparation for the lesson.

Since the quiz was given at the beginning of the lesson, many learners were synchronized at that time, so high numbers are displayed in the tables and graphs. The time limit was 5 minutes, and the higher end value for the quiz in the bar chart refers to when learners clicked to open the quiz score confirmation page. Classes started at 13:00, but Figure 1 shows tables and graphs from 3 minutes before the class started (12:57) until 13:27. Additionally, since the synchronization ratio can be calculated for each teaching material, Figure 2 shows a graph for only the clickstream of the quiz. Figure 2 was created manually from the original data in Figure 1. It can be seen that about 30% of the learners completed the quiz just before the end of the allotted time (13:04). In addition, it can be seen that about 90% of the learners viewed the results immediately after the quiz, and after that, several people opened the quiz page by 13:26.

Below, a graph of the synchronization ratio of only the teaching materials used in one day (see Figure 3) and a time-series cross-section of section transitions (see Figure 4) are shown. In Figure 3, it can be seen that some

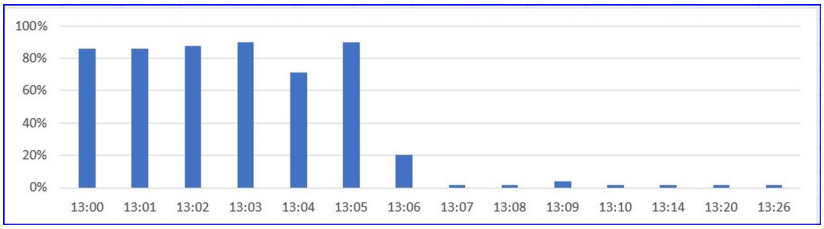

Figure 2: Synchronization ratio for the quiz (minute-by-minute, 2021/11/2, China Data Analysis).

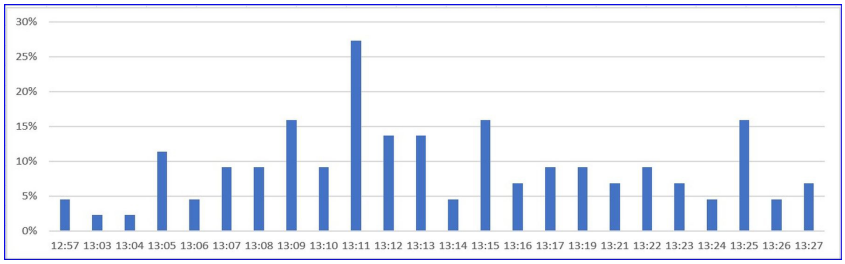

Figure 3: Example of synchronization ratios for section transitions of teaching materials (minute-by-minute, 2021/11/2, China Data Analysis).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		Time																
2	Teaching material	12:57	13:03	13:04	13:05	13:06	13:07	13:08	13:09	13:10	13:11	13:12	13:13					
3	File: 07.01 Deviation, Variance, Standard Deviation	2	1	1	5	1	2	4	6	3	15	6	4					
4	File: 07.02 Calculating Variance	1	1			1	3	1	5	2	1	1	5					
5	Total	3	2	1	5	2	5	5	11	5	16	7	9					
6																		
7						13:14	13:15	13:16	13:17	13:19	13:21	13:22	13:23	13:24	13:25	13:26	13:27	Total
8						1	2	2	1	2	1		1	3			1	67
9						2	5	1	3	3	2	4	2		8	3	4	60
10						3	7	3	4	5	3	4	3	3	8	3	5	127

Figure 4: Example of time-series cross-section of section transitions by teaching material (minute-by-minute, 2021/11/2, China Data Analysis; the columns that do not display the time indicate that there is no clickstream at that time.).

learners opened the teaching items scheduled to be used on that day during the quiz (13:03, 13:04), and these bar graphs can also be confirmed by the numerical values in Figure 4. In addition, the values for 13:11 (column AB) and 13:25 (column AP) in Figure 3 are higher than the values before and after. These are the times when the author opened the teaching material and instructed the learners, and it can be seen that the synchronization ratio is slightly higher at these times. On the day of the lesson, the first half of the lesson was conducted using the teaching materials in two sections: "07.01 Deviation/Variance/Standard Deviation" and "07.02 Calculating Variance" (see Figure 4).

From Figure 4, it can be seen that at 13:11, 15 learners opened and synchronized the "07.01 Deviation/Variance/Standard Deviation" material. The "07.02 Calculating Variance" material was opened by the author at 13:25, and in Figure 4, it can be seen that many learners had already opened this material before this time, and only eight learners were in sync with the author's instructions. The value in the bar graph is high at 13:15, but this was

because five people opened the latter teaching material. In class, the use of the "07.01 Deviation/Variance/Standard Deviation" teaching material occurred until around 13:25, and after that, it can be seen that the class moved to the "07.02 Calculating Variance" teaching material.

DISCUSSION

In Figure 1, data are aggregated at 1-minute intervals, but if the intervals are lengthened to 2 minutes or 3 minutes, the synchronization ratio will naturally increase. However, the scattered details could then become lost and invisible, which can lead to overlooking learners who open the material after the teacher's instructions. On the contrary, the interval can be shortened, for example, to 30 seconds, which will decrease the synchronization ratio. However, the scattered details will become easier to see, increasing the chances of finding out-of-sync learners. In engagement studies, learning behavior relating to opening materials is considered to be one of the factors that directly influence test scores (Steinmayr et al. 2019), and it is important to set the interval appropriately when considering correlations with the synchronization ratio.

Since the time-series in this paper is divided by clock time, even a difference of 10 seconds or less from the teacher's instruction may be included in the adjacent time range. This makes it difficult to consider synchronization by strictly dividing the time-series by the elapsed time. In addition, since the teaching materials may be opened by prereading the teacher's instructions, time ranges must be considered until just before the instructed time. Deciding how to divide the time-series depends on the content of the lesson and how to proceed, but it seems necessary to proceed with the lesson flexibly while using an interval of about 1 to 3 minutes. Shimada et al. give an example of a lecture-style class using an e-book in which the synchronization ratio could be increased if the instruction speed is adjusted by teaching while looking at a heat map showing the degree of concentration of the learners (Shimada et al. 2018).

The author recommends that learners open the Moodle and Excel screens at the same time and use split-screen view. However, there are many learners who open teaching materials and Excel on full-screen view. When the learner opens Excel in full screen, it seems that there is a difference in the time spent browsing the teaching materials, but the learners' use of full-screen view did not decrease even if the author intervened. Both the author and the student wanted to operate the personal computer on a widescreen.

CONCLUSION

In the example given in this paper, the synchronization ratio of the reading materials can explain some of the learners' behaviors, but further analysis is needed to investigate the relationship with other factors such as grades. However, since the synchronization ratio can be observed in real-time during the lesson, it is possible to adjust the progress speed of the lesson according to the students and to advise students who are behind.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Numbers 18K11588 and 21K12183.

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