Learning Analytics Based on the Number of Synchronous Viewings of Online Teaching Materials in a Face-to-Face Blended Course

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Abstract

In face-to-face classes that utilize online teaching materials, learners often open the teaching materials according to the instructor's instructions. When teachers use a learning management system (LMS) to give instructions to learners, the LMS accumulates learning logs and clickstreams for viewing teaching materials. The learning log of teaching material can be considered a record of the interactions between teachers and learners. When a teacher uses teaching materials to provide class instructions, it is possible to calculate the synchronization rate. When more learners open the material at the same time, the synchronization rate tends to be higher. The synchronization rate is an indicator of the overall trend of class effort, but by aggregating the synchronization counts of teaching materials for each learner, basic data can be obtained to analyze each individual's effort in class. Therefore, in this study, a method was proposed for the use of an LMS and online teaching materials for around 60 university students in an introductory data science class held in a computer classroom in order to analyze the number of synchronizations when browsing teaching materials. The effect of the number of synchronous viewings of teaching materials on learning effectiveness is discussed. It is hypothesized that learners' reactions are simultaneously influenced by various factors in addition to the teacher's instructions, depending on the classroom in which they attend the class. Therefore, this study mainly focused on the number of synchronous viewings of educational materials recorded in the LMS and quiz scores and analyzed the relationship between them.

Keywords
synchronization, online teaching material, learning management system, time series, clickstream

1. Introduction

The synchronous state discussed in this study is when learners perform learning actions almost simultaneously in response to a teacher's instructions during blended learning using online teaching materials. This mainly refers to learning behaviors such as opening online teaching materials as instructed by a teacher during class and having everyone answer quizzes that were prepared in advance at the same time. When using an LMS and online learning materials, the state of synchronization among learners can be visualized as a graph of the synchronization rate [6, 8, 16].

However, in this study, the synchronization count is newly de-fined for the synchronization status of each learner. In other words, in this study, the number of synchronizations means the number of times that a learner responds appropriately to the teacher's instructions during class and opens the teaching material. The synchronization rate when viewing teaching materials is a function equivalent to a meta-view of the entire class and is an index showing the entire class's degree of concentration when browsing teaching materials. On the other hand, the synchronization count serves as an index for observing the behavior of individual learners and corresponds to a macro-view.

Blended learning using computers is already an established field and is routinely implemented in many educational organizations [2]. Particularly in computer education for beginners, in the past, to teach the use of computers and software, a paper textbook containing theories and operating methods was prepared in advance. In recent years, the format of teaching materials has changed significantly, and classes that incorporate and utilize digital teaching materials in LMSs have become widespread. Furthermore, as long as they are connected to the Internet, learners can now study on their own at home using online learning materials, such as in massive open online courses (MOOCs). In this way, blended learning that utilizes online teaching materials is expected to continue to expand in various fields.

There are many classes where many learners follow the teacher's instructions using online teaching materials, and all learn the same content. In such classes, it is important that the teacher's instructions and the learners' actions are synchronized, and this is one of the factors for increasing educational effectiveness.

However, it has been empirically observed that some learners do not synchronize with the teacher's instructions and lag behind them. This kind of situation in classes is thought to be extremely common, and synchronization during classes is relevant to many of them.

The research in this study was based on the use of computers and online materials, and the subject of the experiment was a class in a computer classroom for university students. The main purpose was to quantitatively understand the synchronization of individual learners with the teacher's instructions during class and to obtain useful knowledge for improving classes. Online teaching materials and an LMS were utilized to collect learning logs in blended-learning-style experimental classes, and how the number of synchronized viewings of teaching materials was related to other learning logs was analyzed. The performance of learners who viewed the teaching materials in sync with the teacher's instructions during class was compared, and the kinds of educational effects that could be expected were considered. Therefore, the research question was set as follows.

RQ: What method should we consider to measure the number of synchronizations for each learner using an LMS and online teaching materials and to analyze the relationship with learning logs?

2. Related research

The phenomenon of synchronization has been observed in various fields and is not unrelated to the synchronization discussed in this study. For example, if one runs a large number of metronomes, most pendulum movements will become synchronized within a few minutes. Furthermore, in daily human behavior, lining up at a famous restaurant can be observed as a synchronous phenomenon. Examples of synchronization in which some animals, such as dolphins, act in groups are often observed.

Although there are various types of synchronization, the focus here is on synchronization in classes. When having both learners and teachers view the same teaching materials almost simultaneously during class, synchronous viewings of teaching materials can be recorded in learning logs. For this reason, in this paper, online teaching materials distributed through Moodle have been developed and are commonly used in classes.

Kent's research shows that the most effective classroom instruction occurs when all students in the room are in sync with each other. He also stated that teaching is a natural cognitive process that requires human interaction, and that interaction is optimal when there is synchronicity [10].

An intelligent support system called "Sync Class" developed by Fujii et al. is a system that allows teachers to quantitatively under-stand how well students are synchronized in the classroom. A web camera was installed in the front and center of a classroom to observe the facial expressions of the teacher and students, and their engagement and attentiveness in class were determined according to changes in their facial expressions [8].

Shimada et al. developed a real-time learning analysis system, taught classes to university students using a learning management system and e-books, and analyzed the synchronization rate when reading materials. They investigated the synchronization rate of students' e-book viewing during class at regular intervals and found that it increased as the intervals, such as 1 minute, 3 minutes, and 5 minutes, became longer [16].

Dobashi et al. developed a system that displays the rate of synchronization of learners' viewing of learning materials in real time by downloading Moodle learning logs and processing them in chronological order. Synchronization rates were higher when learners answered quizzes or when teachers gave instructions to open learning materials. Furthermore, it could be observed from the graph that the synchronization rate dropped significantly during a period in which students performed individual exercises in the latter half of the class [6].

Chen et al. proposed an online synchronous learning model using the Internet and provided necessary guidelines for synchronous instruction for teachers and learners. The guidelines envisage a wide range of usage scenarios, such as synchronous lectures and a mode for office hours, and they state that this method not only saves time and costs but is also more effective than traditional face-to-face education [5].

3. Method

3.1. Introductory class on data science

The subject of the experiment in this study was an introductory data science class for university students at Aichi University in Japan. Regular classes were held using the Moodle LMS. The Moodle LMS was used to provide online learning materials and quizzes to learners and, at the same time, collect browsing histories and accumulate learning logs by administering quizzes. Classes were held 15 times in a computer classroom, where students used computers and Excel every week to learn the basics of statis-tics and data science. The contents of the class included how to use spreadsheet software, graph creation, probability, simulation, frequency distribution, attribute correlation, covariance, correlation analysis, and regression analysis.

The learning logs in this study were collected from Sep. 2023 to Jan. 2024. Online learning materials were

uploaded using Moodle's topic mode and were viewed by learners during class. When learners followed the teacher's instructions and clicked on the table of contents of the online teaching materials, learning logs related to quizzes and the reading of the teaching materials were collected, and these data were used to analyze learner synchronization.

The initial enrollment in the class was 57, but the number of students who took the final exam decreased to 47, and the average attendance for the 15th week was 49.8. The gender ratio of the registrants was 36.8% female and 63.2% male, and the majority of the participants were between 18 and 22 years old. Many of the learners had previously taken classes that covered basic training, such as typing, Word, and Excel.

3.2. Definition of the synchronization counts

In Moodle's topic mode, when a learner views online learning materials, the learner's ID and viewing time are recorded. There-fore, the teacher logged in to Moodle in the same way as the learners and demonstrated how to use computers and Excel to the learners in the classroom. The students were then instructed to open the online teaching material, and the teacher opened the same teaching material on their computer at their desk. This al-lowed Moodle to store logs of both the teachers' and learners' viewing of teaching materials and quiz answers.

Time-series processing was performed on the learning logs down-loaded from Moodle at one-minute intervals, and the time intervals in which teachers and learners browsed the teaching materials at the same time were considered synchronized; these were count-ed for each learner and defined as the synchronization counts. These synchronous counts included clicks when learners responded to the teacher's instructions during class.

These included the clickstream when opening the online learning materials on Moodle, the clickstream of quiz answers, and the clickstream one minute immediately after the end of the quiz. The clickstream immediately after the quiz ended involved a click for the learner to check their score. These times were also times when the synchronization rate was high, as many learners browsed the learning materials at the same time.

3.3. Mining method

An overview of the flow of data mining for the synchronization counts is shown below (Figure 1). All online teaching materials were uploaded in Moodle's topic mode. The teaching materials were mainly created in PDF format, and the students were asked to view the teaching materials and answer quizzes in class. The quiz consisted of a pretest, weekly test, and final test. The quizzes were created from the teaching materials, and all had the format of choosing one correct answer from five questions.

The pretest and final test had the same content, with 30 questions being asked within a 30 minute time limit. A weekly test was given every week at the beginning of the lesson, and it consisted of five questions to be answered in five minutes. We downloaded weekly learning logs from Moodle, displayed one-minute time-series cross-sections in a pivot table, and manually extracted the time intervals in which the teacher and learners synchronized.

Figure 2 shows a conceptual diagram of the method for counting the number of synchronizations. The upper diagram in Figure 2 shows the clickstream of the downloaded Moodle learning log re-aggregated in the form of a time-series cross-section at one-minute intervals. In the upper and lower diagrams of Fig. 2, the numeric character indicates the number of times the learner clicked on the link to the teaching material. The colored cells at the bottom display the teacher's clickstream, and it can be seen that the clickstreams of a relatively large number of learners were synchronized at this time. Therefore, as shown in the top diagram in Figure 2, only the times with high synchronization rates were retained, the clickstreams in the non-synchronized time periods were deleted, and the number of
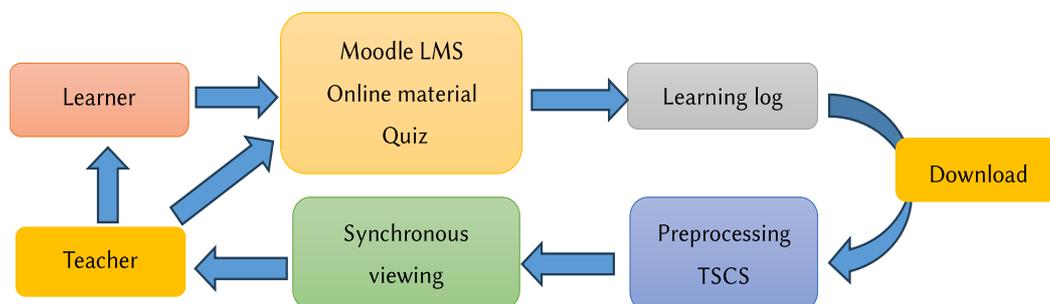

Figure 1: An overview of the flow of data mining for the synchronization counts （TSCS: time-series cross -section）
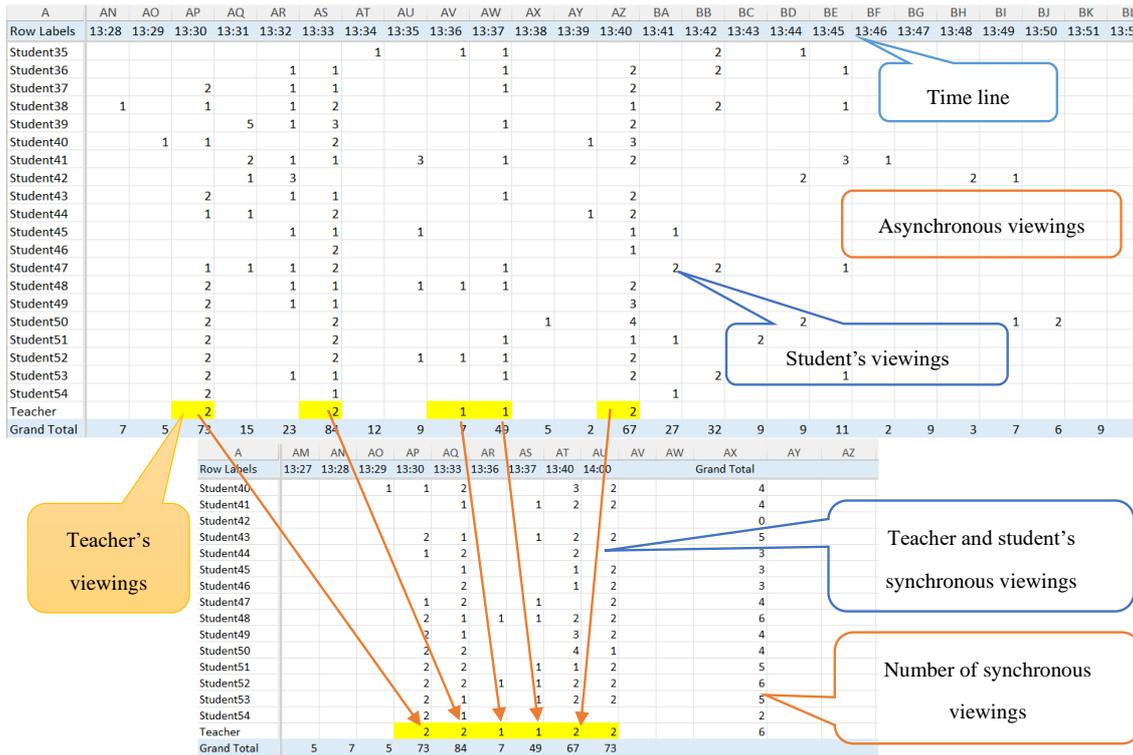
Figure 2: Image of the method used to tally the number of synchronizations for each learner. The numeric character in the figures indicates the number of times the learner clicked on the link to the teaching material.

synchronizations was tallied, as shown in the bottom diagram of Figure 2.

4. Results

The learning log for the day of the class was downloaded from Moodle, and the number of times the learning materials were browsed synchronously was mined according to the method de-scribed in the previous section and summarized in a table (Table 1).

In Table 1, Column A shows the anonymized ID of the learner who participated in the class, Column B shows the sync count, Column C shows the pretest score, column D shows the final test score, Column E shows the number of material clicks, Column F shows the total score of the weekly quiz, and Column G shows the quiz time taken (in seconds) for the total pretest, weekly quizzes, and final test.

Column H shows the z-score of the sync count was used to calculate outliers to investigate the relationships with other learning logs. Column I shows outliers based on the 3σ method, and column J shows outliers based on the interquartile range (IQR) method. When we tested the normality of the weekly sync count distribution, we found that it was hardly normally distributed. However, in the learning logs in this study, the final test score and the total number of material clicks were normally distributed.

Therefore, we used both the 3σ method and the IQR method to detect outliers in the sync count, but the results were the same. When creating a scatter plot from the z-score of the sync count, outliers can be seen at the bottom of the graph (Figure 3). Furthermore, among the items of the learning log listed in Table 1, the relationships were examined by calculating Pearson correlation coefficients for the four items: sync count, click total, score total, and time taken (Table 2). As a result, it was found that there was a strong correlation between the items in the learning log in Table 1, and the correlation coefficient values ranged from 0.7 to 0.9.
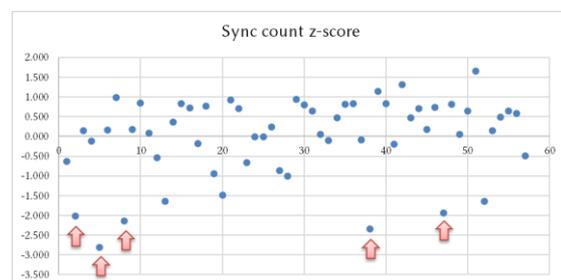
Figure 3: Scatter plot of z-score for synchronization counts

Table 1
The results for sync counts, pretest, final test, total material clicks, total quiz scores, quiz time taken (in seconds), z-scores of sync counts, and outliers of sync counts (3σ, IQR).

A	B Sync count	C Pretest	D Final test	E Click total	F Score total	G Time taken	H Sync count Z-score	I Sync count outlier x>σ*3	J IOR
Student01	130	14	17	495	87	5048	-0.628		
Student02	56	12	-	178	30	1648	-2.011	outlier	outlier
Student03	171	11	18	775	125	7247	0.139		
Student04	157	15	23	889	152	7268	-0.123		
Student05	13	-	-	426	4	280	-2.815	outlier	outlier
Student06	172	9	21	660	96	6166	0.157		
Student07	203	19	26	840	155	6188	0.980		
Student08	49	16	-	166	32	1514	-2.142	outlier	outlier
Student09	173	19	25	541	154	7215	0.176		
Student10	209	12	20	609	130	6679	0.849		
Student11	168	19	22	549	125	5200	0.083		
Student12	135	-	24	511	86	3634	-0.534		
Student13	76	16	-	542	60	2495	-1.637		
Student14	183	9	20	843	83	6111	0.363		
Student15	208	15	15	939	114	5071	0.831		
Student16	202	18	26	887	152	5718	0.718		
Student17	154	13	24	499	119	5910	-0.179		
Student18	205	10	18	869	130	7411	0.774		
Student19	113	-	-	348	82	2322	-0.946		
Student20	84	-	17	289	79	3710	-1.488		
Student21	213	15	21	1296	158	7388	0.924		
Student22	201	19	22	949	149	5043	0.700		
Student23	128	17	25	358	106	4186	-0.665		
Student24	163	15	25	574	134	5031	-0.011		
Student25	163	11	23	484	110	6105	-0.011		
Student26	176	10	22	803	128	5330	0.232		
Student27	117	19	-	502	69	2819	-0.871		
Student28	110	-	-	346	54	2014	-1.002		
Student29	214	17	23	940	140	6473	0.943		
Student30	206	22	25	1050	161	6891	0.793		
Student31	198	14	19	755	121	5889	0.644		
Student32	166	18	22	710	160	6458	0.045		
Student33	158	10	20	598	86	5762	-0.104		
Student34	189	14	21	865	111	6213	0.475		
Student35	207	17	26	1063	151	6956	0.812		
Student36	208	11	24	1060	139	6927	0.831		
Student37	159	20	24	665	134	5725	-0.086		
Student38	38	13	-	75	19	1700	-2.348	outlier	outlier
Student39	225	22	30	902	176	7305	1.148		
Student40	208	12	25	795	125	6930	0.831		
Student41	153	-	22	648	120	4248	-0.198		
Student42	234	14	18	1142	122	7247	1.317		
Student43	189	11	18	510	95	5652	0.475		
Student44	201	15	19	750	136	6545	0.700		
Student45	173	14	23	664	123	5799	0.176		
Student46	203	17	23	909	136	5501	0.737		
Student47	60	16	-	170	30	1536	-1.937	outlier	outlier
Student48	207	16	21	558	133	6051	0.812		
Student49	166	13	21	734	114	5483	0.045		
Student50	198	10	24	1145	146	6793	0.644		
Student51	252	20	24	1084	166	6889	1.653		
Student52	76	10	-	243	42	2394	-1.637		
Student53	171	16	22	582	122	4569	0.139		
Student54	190	13	18	819	125	5956	0.494		
Student55	198	18	17	526	115	7083	0.644		
Student56	195	13	18	681	113	6540	0.587		
Student57	137	18	24	483	122	4817	-0.497		
Mean	163.4	14.8	21.8	671.8	112.0	5282.2	0.000		
MAX	252	22	30	1296	176	7411	1.653		
MIN	13	9	15	75	4	280	-2.815		
Variance	2839.3	11.9	9.6	75412.6	1595.5	3417521.3	1.0		
SD	53.3	3.5	3.1	274.6	39.9	1848.7	1.0		

Table 2
Pearson correlation coefficients between sync count, click total, score total, and time taken.

	Sync count	Click total	Score total	Time taken
Sync count	1	$p=0.000$	$p=0.000$	$p=0.000$
Click total	0.8298	1	$p=0.000$	$p=0.000$
Score total	0.8812	0.7762	1	$p=0.000$
Time taken	0.9036	0.7656	0.8722	1

The Pearson correlation coefficient was also examined between sync count, pretest, and final test, and it was shown that there is no correlation between sync count and pretest, and between sync count and final test. However, it was shown that there was a weak correlation between the pretest and the final test (Table 3).

Table 3
Pearson correlation coefficients between sync count, pretest, and final test.

	Sync count	Pretest	Final test
Sync count	1	$p=0.180$	$p=0.259$
Pretest	0.1608	1	$p=0.001$
Final test	0.0153	0.4757	1

Pearson correlation coefficients were also examined for the pretest, weekly quizzes, and final test, and it was shown that there was a weak correlation between these items (Table 4).

Table 4
Pearson correlation coefficients between pretest, weekly quiz, and final test.

	Pretest	Weekly quiz	Final test
Pretest	1	$p=0.011$	$p=0.001$
Weekly quiz	0.3200	1	$p=0.001$
Final test	0.4757	0.4385	1

5. Discussion

When pretests, weekly tests, and final tests were conducted in the classes in this study, they were counted in the number of synchronous sessions, but no logs were recorded for learners who finished the quizzes early. Therefore, the number of synchronizations tended to be lower than for learners who worked until the end of the time limit. In this study, the synchronization rate and number of synchronizations were measured every minute in a time-series cross-section.

However, it became clear that there was a time difference of about two minutes between the learner who synchronized the earliest and the learner who synchronized the latest. Time-series cross-sections could be generated at intervals of 30 seconds, two minutes, three minutes, etc. in addition to one minute, so depending on how the class progressed, we could select intervals other than one minute.

However, as the interval became longer, the synchronization rate increased, which increased the probability that learners who were not sufficiently engaged in the lesson would also be considered synchronized. On the other hand, if the interval was shortened to 30 seconds, it was more likely that learners who were actively engaged and concentrating on the lesson would be selected.

A correlation analysis among the number of synchronizations, the quiz scores, and the quiz answering times revealed that there was no correlation between the number of synchronizations and the results of the pretest or final test. However, a strong correlation was observed between the cumulative score of the weekly test and the total score of the weekly test and final test. Furthermore, a strong correlation was observed with the total quiz answering time.

Furthermore, when observing the data of the learners who corresponded to the outliers in Table 1, it was found that outliers occurred only in smaller values. However, no outliers appeared in larger values. This indicated that many learners were well engaged in learning and that the differences between learners were small in quiz scores, material clicks, and the time required for quizzes.

On the other hand, the five learners who were considered outliers had a common tendency to have extremely low values about mate-rial clicks, quiz scores, and quiz time taken. They dropped classes in the middle of the semester and did not take the final test. Table 1 shows the results after the end of the semester, so if the appearance of outliers is detected early, there is a higher possibility of preventing students from dropping out of classes. Furthermore, the analysis results shown in Tables 1 and 2 are only relevant to the classes discussed in this study. However, it was confirmed that the number of synchronizations proposed in this study plays just as important of a role as other learning log items.

New learning spaces are being researched and developed that leverage the latest networking technology, allowing on-site and remote students to participate in learning activities simultaneously in an online synchronous hybrid or blended learning environment. In these learning environments, how to set up online synchronous hybrid learning has become an important research topic [3, 12, 13, 14].

Raes et al. pointed out that while synchronous hybrid learning has the potential to create a flexible and engaging learning environment, it does present some pedagogical and technological challenges. Although some design guidelines have been developed for synchronous hybrid learning, many existing studies are exploratory and qualitative [14]. Compared to such research, the approach in this paper aims to quantitatively measure the state of synchronization from the aspects of synchronization rate and number of synchronizations, and we believe it contains new ideas.

Synchronous hybrid learning environments have become an even more important research topic after COVID-19, and various studies are being developed from both pedagogical and technological aspects [7, 9,

11]. These studies include the issue of how to synchronize teachers and learners to achieve educational objectives.

In addition, how to synchronize educational methods with new technologies has become an important research topic from both a theoretical and practical perspective [1, 4, 15]. The content of this paper was conducted in an online blended learning environment and is closely related to these recent research trends, so we believe that the method of this paper could contribute.

6. Conclusion

The results of the learning log analysis based on the number of synchronizations proposed in this study revealed that this number is closely related to other elements of the learning log. In addition, if the number of synchronizations is counted early, this may lead to the discovery of learners who are not making enough of an effort. By analyzing this in conjunction with other learning logs, one can more efficiently prevent students from dropping out of classes and increase learning effectiveness.

In quizzes, when the response time becomes shorter, the number of synchronizations and the scores of learners tend to decrease. Teachers can utilize the results of the analysis of the number of synchronizations described in this study to help guide individual learners. Furthermore, teachers need to prepare high-quality teaching materials that match the lesson content, and when using them in class, they need to devise clear instructions so that the reading of the materials is synchronized.

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References

[1] L. Angelone, Z. Warner, and J. M. Zydney, Optimizing the Technological Design of a Blended Synchronous Learning Environment, Online Learning 24.3 (2020) 222-240.

[2] N. Bergdahl, J. Nouri, T. Karunaratne, M. Afzaal, and M. Saqr, Learning analytics for blended learning: A systematic review of theory, methodology, and ethical considerations, International journal of learning analytics and artificial intelligence for education, 2.2 (2020) 46-79.

[3] M. Bower, B. Dalgarno, G. E. Kennedy, M. J. Lee, and J. Kenney, Design and implementation factors in blended synchronous learning environments: Outcomes from a cross-case analysis, Computers & Education 86 (2015) 1-17.

[4] A. Carruana Martín, C. Alario-Hoyos, and C. Delgado Kloos, A study of student and teacher challenges in smart synchronous hybrid learning environments, Sustainability 15.15 (2023) 11694.

[5] N. S. Chen, H. C. Ko, Kinshuk, and T. Lin, A model for synchronous learning using the Internet, Innovations in Education and Teaching International, 42.2 (2005) 181-194.

[6] K. Dobashi, C. P. Ho, C. P. Fulford, M. F. G. Lin, and C. Higa, Synchronization ratio of time-series cross-section and teaching material clickstream for visualization of student engagement. in: International Conference on Artificial Intelligence in Education, Cham: Springer International Publishing. 2022 July, pp. 125-131.

[7] C. J. Fernandez, R. Ramesh, and A. S. R. Manivannan, Synchronous learning and asynchronous learning during COVID-19 pandemic: a case study in India, Asian Association of Open Universities Journal, 17.1 (2022) 1-14.

[8] K. Fujii, P. Marian, D. Clark, D. Y. Okamoto, and J. Rekimoto, Sync class: Visualization system for in-class student synchronization. in: Proceedings of the 9th augmented human international conference, 2018 February, pp. 1-8.

[9] J. Kim, Learning and teaching online during Covid-19: Experiences of student teachers in an early childhood education practicum, International journal of early childhood, 52.2, (2020) 145-158.

[10] A. Kent, Synchronization as a classroom dynamic: A practitioner's perspective. Mind, Brain, and Education, 7.1 (2013) 13-18.

[11] R. Khalil, A.E. Mansour, W.A. Fadda, et al.. The sudden transition to synchronized online learning during the COVID-19 pandemic in Saudi Arabia: a qualitative study exploring medical students' perspectives BMC medical education, 20 (2020) 1-10.

[12] S. Ma, T. Zhou, F. Nie, and X. Ma, Glancee: An adaptable system for instructors to grasp student learning status in synchronous online classes, in: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems, 2022 April, pp. 1-25.

[13] J. L. McBrien, R. Cheng, and P. Jones, Virtual spaces: Employing a synchronous online classroom to facilitate student engagement in online learning, International review of research in open and distributed learning 10.3 (2009) 1-17.

[14] A. Raes, L. Detienne, I. Windey, and F. Depaepe, A systematic literature review on synchronous

hybrid learning: gaps identified. Learning environments research 23 (2020) 269-290.

[15] A. Raes, P. Vanneste, M. Pieters, I. Windey, W. Van Den Noortgate, and F. Depaepe, Learning and instruction in the hybrid virtual classroom: An investigation of students' engagement and the effect of quizzes. Computers & Education 143 (2020) 103682.

[16] A. Shimada, S. I. Konomi, and H. Ogata, Real-time learning analytics system for improvement of on-site lectures, Interactive Technology and Smart Education, 15.4 (2018) 314-331.