Yang, C. C. Y., & Ogata, H. (2023). Lag Sequential Analysis for Identifying Blended Learners' Sequential Patterns of e-Book Note-taking for Self-Regulated Learning. *Educational Technology & Society*, *26* (2), 63-75. https://doi.org/10.30191/ETS.202304_26(2).0005

Lag Sequential Analysis for Identifying Blended Learners' Sequential Patterns of e-Book Note-taking for Self-Regulated Learning

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(Submitted April 18, 2022; Revised August 23, 2022; Accepted September 17, 2022)

ABSTRACT: Blended learning (BL) is regarded as an effective strategy for combining traditional face-to-face classroom activities with various types of online learning tools (e.g., e-books). An effective feature of e-books is the ability to use digital notes. When e-books are used in BL, the strategic adoption of note-taking provides benefits that influence the learners' progress for self-regulated learning (SRL) and course achievements. However, learners tend to be unsure about how note-taking is performed using online learning materials and lack knowledge of effective strategies for SRL. Furthermore, few studies have investigated blended learners' sequential patterns of e-book note-taking for SRL. Thus, in this paper, an exploratory study was conducted in an undergraduate course that implemented the BL design. The learning task for the blended learners in the present study was to study the learning material using BookRoll, an e-book system, during in-class and out-of-class learning sessions. Lag sequential analysis of the e-book learning behavior data was conducted to identify the blended learners' sequential behaviors of e-book note-taking for the cognitive strategy use of SRL. Moreover, the difference between higher- and lower-achievement blended learners in terms of their sequential behaviors of e-book note-taking for SRL was revealed. This study can help educators provide evidence-based educational feedback to learners regarding the identified sequential patterns of e-book note-taking that can be applied as effective strategies for promoting the cognitive strategy use of SRL and improvement of course achievement in BL.

Keywords: Lag sequential analysis, Sequential pattern, Note-taking, Blended learning, Self-regulated learning

1. Introduction

Blended learning (BL) is regarded as an effective combination of face-to-face and online learning experiences, and this new education domain emphasizes the need to reflect on traditional learning experiences to redesign learning and teaching strategies (Garrison & Vaughan, 2008). BL aims to combine traditional face-to-face classroom activities with various types of online learning resources, and it enables learners to achieve improved learning outcomes through a well-defined interactive strategy.

In the early stages of BL development, time- and cost-related factors were major challenges (Míguez-Álvarez et al., 2020). However, studies have demonstrated that the effective use of online learning technologies in BL has a positive impact on improving learner learning engagement (Castro, 2019), learning performance (Yang et al., 2021), motivation (Álvarez et al., 2013), and self-efficacy (Moon & Hyun, 2019). In the online learning activities of a BL course, learners' interaction with various online educational platforms provides a massive amount of learning interaction data that can be captured and analyzed by educational technologies. These advanced educational technologies have been employed to automate the processes for information delivery by offering a personalized learning experience for the individual learner to enhance their engagement in learning (Castro, 2019).

BL describes a learner-centered, self-paced, and flexible digital environment in which traditional face-to-face classroom activities are supported by offline or online activities via educational technologies (Tang & Chaw, 2016; Anthonysamy et al., 2020). Consequently, the promotion of self-regulated learning (SRL) in BL contexts is essential since SRL generally refers to "self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals" (Song et al., 2021; Zimmerman, 2000, p. 14). Studies have examined instructional materials that foster learners' specific strategies for SRL including self-monitoring (e.g., Kauffman et al., 2008) and note-taking (e.g., Igo & Kiewra, 2007; Igo et al., 2005).

Note-taking behavior can be regarded as a reflection of the progress of learner learning. Thus, the analysis of note-taking plays a role in tracking and monitoring the learning process of learners who participate in BL or fully online courses (Nakayama et al., 2021), which may also promote the cognitive strategy use of SRL. The taking

of digital notes on online materials has been indicated as an essential strategy for learners studying online materials using educational tools (e.g., e-books) (van de Sande et al., 2017). Observations of learners in classrooms have revealed various note-taking strategies, some of which involve learners meeting their personal learning needs by modifying the materials given to them by faculty members. The note-taking behavior of learners is a topic that warrants further exploration (Stacy & Cain, 2015). Furthermore, note-taking behavior is correlated with achievement (Luo et al., 2018; van de Sande et al., 2017) because it improves retention and recall (Fisher & Harris, 1973), increases attention to material (Kane et al., 2017), and provides several memory benefits (i.e., storage and encoding; Peverly & Wolf, 2019). When learners do not apply effective note-taking techniques during lectures, they may overlook key concepts and content (Boyle, 2010). Note-taking is an essential skill that all learners must have to achieve success in a classroom. Learners should use the note-taking medium that maximizes their willingness and ability to achieve a delicate balance between practicality, ease of implementation, and efficacy concerning note-taking strategies (Dror, 2008).

In the present exploratory study, to understand blended learners' interactions with the note-taking systems (e.g., e-books) for the cognitive strategy use of SRL, lag sequential analysis (LSA) was applied to analyze learner-generated e-book learning behavioral data collected in a BL environment since LSA was proposed by Sackett (1978) as an effective method that has been used to conduct detailed investigations of the sequential behaviors of learners in the educational domain (Yang et al., 2018; Zarzour et al., 2020; Zhang et al., 2021). Moreover, the difference between higher- and lower-achievement blended learners in terms of their sequential behaviors of e-book note-taking for SRL was revealed and discussed. The analytical results are expected to offer opportunities for educators to effectively understand learners' interactions with e-books and provide learners with evidence-based educational feedback regarding note-taking strategies for the promotion of SRL and improvement of course achievement in BL. The results are also expected to be considered as a basis by teachers at every education level and learners for adjusting their teaching and learning strategies in BL, respectively. In the present study, the following two research questions are addressed:

- To what extent can the blended learners' sequential patterns of e-book note-taking for SRL be identified by using LSA?
- What are the differences between higher- and lower-achievement blended learners in terms of their sequential patterns of e-book note-taking for SRL?

2. Literature review

2.1. Note-taking strategies for SRL

In higher education, note-taking is regarded as an effective strategy for learners to enhance their learning (Wu, 2020). The appropriate self-regulatory strategies regarding the certain actions and processes that individuals adopt to succeed is a key element for being self-regulated (Zimmerman, 1989). According to Pressley and Woloshyn (1995), the cognitive strategy use of SRL involves cognitive operations for the process of carrying out a task. A strategy that fosters students' abilities to efficiently locate and organize knowledge from the learning materials is important (Kauffman et al., 2011). Therefore, note-taking has been recognized as a key part of the organization aspect of a cognitive SRL strategy that aims at retaining information from the learning materials and monitoring the learning process of learners (Cengiz-Istanbullu & Sakiz, 2022; Pintrich et al., 1991).

Trevors et al. (2014) implied that learners with different self-regulatory skills may exhibit different behaviors of note-taking and note-reviewing. Hence, different patterns in the content of notes recorded were shown. Learners' patterns of note-taking may differ according to their level of prior knowledge, metacognitive awareness, capabilities of adopting effective self-regulatory strategies, and the instructional support available to them (Moos & Azevedo, 2008). Therefore, their results suggested that note-taking is an essential and challenging skill for learners to master and for scholars to uncover in the context of the learning process and achievement.

Given the importance of considering note-taking as an SRL strategy and the challenges of implementing these strategies, Alvi et al. (2016) conducted a qualitative study on 37 university learners in a two years Master's degree program to uncover the SRL strategies used by the learners. Their results suggested that learners tend to use a variety of SRL techniques ranging from the shallow strategy (i.e., repetition for memorization) to the cognitively deep processing strategy (i.e., note-taking and consulting notes). Particularly, high-achieving learners exhibit superior meta-cognitive awareness of taking and consulting notes. Therefore, they indicated that there is a need to guide and assist learners in moving beyond the traditional practice of note-taking to promote SRL.

The above studies demonstrated the role played by note-taking strategies for promoting the cognitive strategy use of SRL. However, SRL should be viewed as an ongoing process that is developed by learners over time (Azevedo et al., 2010). Analyzing sequence data can reveal the transitional relationships between the different categories of learning behaviors and the temporality perspective of the learning process of learners rather than using count-based measures to quantify learner behavior in specific contexts (Chen et al., 2017) such as SRL. In this sense, few studies have investigated the sequential patterns of note-taking of learners for SRL. Moreover, since the development of SRL strategies is essential for learners undergoing BL, there is a need to particularly uncover the sequential patterns of note-taking of blended learners.

2.2. Identification of patterns of e-book note-taking

With the increasing use of technology in education, e-books are gradually replacing traditional textbooks and changing the way learners learn, think, and interact with learning materials (Casselden & Pears, 2020; Sung & Wu, 2017; Wright et al., 2013). For e-book-based learning, note-taking strategies are useful for helping learners to understand online learning materials. Numerous studies have demonstrated that enriching learning activities with various advanced educational technologies lead to enhanced reading ability (Wu, 2016) and improved comprehension outcomes for learners (Huang & Liang, 2015). E-book-based learning systems have positive effects on aspects such as learning motivation, perceived usefulness and ease of use, rapid knowledge construction, and level of comfort during particular course activities, all of which can increase the engagement of learners in a learning process (Lin et al., 2018).

With the increasing and widespread use of e-books, learners can now take notes digitally through various electronic devices (e.g., laptops, tablets, or mobile phones) instead of using pen and paper (Chiu et al., 2013). Note-taking can enhance the learning activities of learners during a course by directing their attention and building both internal and external connections (Du, 2004). Studies have demonstrated a positive correlation between the frequency of annotation use by learners and their academic performance during e-book learning (Yang et al., 2021). To achieve success in e-book-based BL, learners must strategically record their notes in their online learning materials. However, for learners who study in traditional face-to-face teaching sessions, note-taking is still a challenging task (Hanafin et al., 2007). For learning to occur, learners must actively listen to their teachers, memorize relevant information, and connect and relate this new information to the ideas that they learned in their classes (O'Hara, 2005).

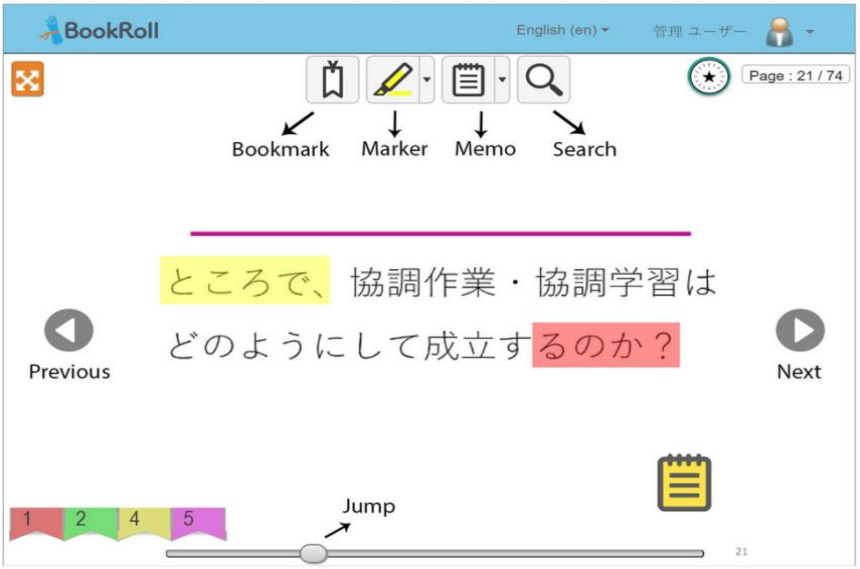
Although strategic digital note-taking is generally recommended for online learning materials, Dunn (2015) reported that learners were unsure about how they can take notes and lacked knowledge of the effectiveness of their strategies for learning. Analyzing learners' sequential patterns of note-taking may offer opportunities for educators to effectively understand learners' interactions with note-taking systems (e.g., e-books) and provide learners with corresponding interventions regarding note-taking strategies for learning. However, few studies have empirically investigated the sequential patterns of the note-taking performed by learners when they are using an e-book in a BL environment.

3. Method

3.1. Participants and context of the exploratory study

An exploratory study was conducted in an undergraduate course called Accounting Information Systems. This course implemented the BL design with a total of 88 undergraduate learners participating. These participants were from the Department of Accounting. They had an average age of 21 years, and 30 (34.1%) and 58 (65.9%) of them were male and female, respectively. No participant dropped out of the study. The learning task designed for the participants in the present study was to study the learning material using BookRoll, an e-book system, which was developed by the Ogata et al. (2015). Figure 1 shows an example of the user interface of BookRoll. In addition to traditional face-to-face learning activities, the participants who enrolled in this course studied the learning material uploaded by the instructor before their classes; they achieved this by using various electronic devices (e.g., desktops, laptops, and mobile phones) to access the BookRoll system during in-class and out-of-class learning sessions. The system had several functions such as page-turning, marker drawing, memo taking, and page jumping. Data on the learning behaviors of the participants when they were using BookRoll were stored in its database. The functions of BookRoll are discussed in detail in a previous study by the Ogata et al. (2015).

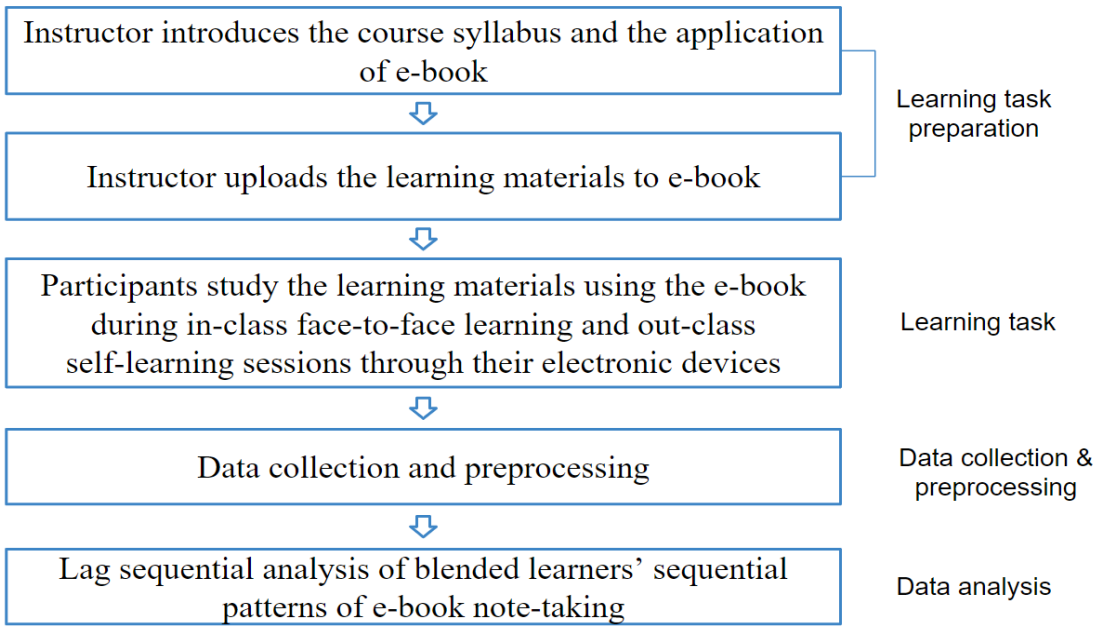
Figure 1. Example of BookRoll user interface



3.2. Procedure

The present study was conducted following the research procedure presented in Figure 2. The duration of the learning task designed for the present exploratory study was 6 weeks. First, the course instructor introduced the course syllabus and the use of BookRoll. Second, the instructor uploaded the course learning materials to BookRoll and assigned several learning tasks to the participants taking the blended course. Third, the participants studied the learning materials by using the BookRoll system during both in-class face-to-face learning sessions and out-of-class self-learning sessions, and they accessed the system through their electronic devices (e.g., desktops, laptops, and mobile phones). In this stage, the participants were highly encouraged to take notes using the memo function of the BookRoll system to enhance their understanding of the knowledge contained in the learning materials. Fourth, after the participants completed their 6-week learning task, data on their learning behaviors while using BookRoll were collected from BookRoll's database and preprocessed for follow-up data analysis. Last, the collected learning behavior data of the participants were coded, such that an LSA could be performed to extract sequential patterns of note-taking behaviors. The extracted sequential patterns of e-book note-taking behaviors of higher- and lower-achievement participants were compared based on their learning achievements during the course.

Figure 2. Research procedure



3.3. Data collection, preprocessing, and analysis

In the present study, 82,443 data of the learning behaviors of learners while using the BookRoll system were collected from the system's database. To reduce redundant information during data analysis, each type of learning behavior was only counted once when it was observed to have occurred more than once over a continuous period. For example, if the learning behavior "ADD MEMO" consecutively occurred three times during a single learning session, it was still only counted as a single instance of the behavior. Furthermore, to improve the homogeneity of the collected learner data, data preprocessing was performed to remove outlier data relating to learning sessions (i.e., multiple successive learning actions performed in BookRoll). Specifically, data related to overly short sessions (i.e., those that involved only one type of learning behavior) and overly long sessions (i.e., those in which the number of learning behaviors observed was greater than those observed in 95% of all examined sessions) were removed (Jovanović et al., 2017). Table 1 provides an example of the collected BookRoll learning behavior data. Each piece of behavioral data of BookRoll interactions included user ID, content ID, operation name, and operation date information. The learning behavior data of the learners, which were collected using BookRoll, were coded to enable the subsequent sequential pattern mining of note-taking behaviors. The coded BookRoll learning behavior data and their corresponding descriptions are presented in Table 2. Notably, in the present study, only behavioral data on page-turning and the use of memos, markers, and bookmarks, were collected for the pattern analysis of e-book note-taking. In addition to the collection of BookRoll learning behavior data, a final examination was conducted to measure the learners' learning achievements for the course. The participants' scores for the final examination were compiled by the course instructor at the end of the learning task. The examination comprised 40 multiple-choice items, and a maximum score of 100 could be obtained. For each correctly answered item, 2.5 points were awarded; no points were awarded for incorrectly answered items. The final examination had a Kuder–Richardson Formula 20 value of 0.59, indicating that it had acceptable internal consistency (Cortina, 1993).

To analyze the sequential e-book note-taking behaviors of the blended learners, LSA was performed using the Generalized Sequential Querier (GSEQ) software (Bakeman & Quera, 1995). To further explore the differences between higher- and lower-achievement blended learners in terms of their sequential patterns of e-book note-taking, all the participants were classified into a higher-achievement group and a lower-achievement group by applying the percentile rank transformation method to classify their learning achievements (i.e., final examination scores). For example, learners A and B received final examination scores of 40 and 80, respectively, and they were ranked in the 40th and 80th percentiles, respectively, of the scores of all the learners in the course; thus, they were classified into the higher- and lower-achievement groups, respectively. Next, descriptive statistics of the BookRoll behaviors for higher- and lower-achievement groups were analyzed. Finally, LSA was performed to reveal the adjusted residuals of BookRoll sequential behaviors for the two groups. The analysis results are discussed in the next section.

Table 1. Examples of collected BookRoll learning behavior data

User_ID	Content_ID	Operation_Name	Operation_Date
15920	ec645f3851e	OPEN	2021/5/10 10:03:52
15920	ec645f3851e	ADD MEMO	2021/5/10 10:04:32
15920	ec645f3851e	CHANGE MEMO	2021/5/10 10:07:03
15929	ec645f3851e	OPEN	2021/5/10 11:27:14
15929	ec645f3851e	NEXT	2021/5/10 11:27:20

Table 2. Coding scheme of the BookRoll behavioral data

Code	BookRoll behavioral data	Description
NE	NEXT	A learner advances to the next page of the e-book learning material.
PR	PREV	A learner returns to the previous page of the e-book learning material.
AM	ADD MEMO	A learner adds a memo to the e-book learning material.
DM	DELETE MEMO	A learner deletes a memo in the e-book learning material.
CM	CHANGE MEMO	A learner modifies a memo in the e-book learning material.
AH	ADD MARKER	A learner adds a marker to the e-book learning material.
DH	DELETE MARKER	A learner deletes a marker in the e-book learning material.
AB	ADD BOOKMARK	A learner adds a bookmark to the e-book learning material.
DB	DELETE BOOKMARK	A learner deletes a bookmark in the e-book learning material.

4. Results

4.1. Sequential patterns of e-book note-taking

In the present study, LSA was applied to uncover the sequential behaviors of blended learners concerning e-book note-taking. Table 3 presents the collected frequency and percentage data of the BookRoll behaviors of all the blended learners. Among the 2,740 BookRoll-related behavioral data pieces that were collected, there were 882 occurrences of "NEXT," 336 occurrences of "PREV," 832 occurrences of "ADD MEMO," 109 occurrences of "DELETE MEMO", 107 occurrences of "CHANGE MEMO", 428 occurrences of "ADD MARKER", 28 occurrences of "DELETE MARKER", 18 occurrences of "ADD BOOKMARK", and 0 occurrence of "DELETE BOOKMARK". The top 3 behaviors that occurred most frequently were "NEXT" (32.19%), "ADD MEMO" (30.36%), and "ADD MARKER" (15.62%). These findings indicate that "ADD MEMO" and "NEXT" occurred with similar frequencies because the learners in this BL course were highly encouraged to take notes in the learning materials when using BookRoll for both in-class face-to-face and out-of-class self-learning sessions.

Table 3. Frequency and percentage data of the BookRoll behaviors for all the blended learners

Category	Frequency	Percentage (%)
NEXT (NE)	882	32.19
PREV (PR)	336	12.26
ADD MEMO (AM)	832	30.36
DELETE MEMO (DM)	109	3.98
CHANGE MEMO (CM)	107	3.91
ADD MARKER (AH)	428	15.62
DELETE MARKER (DH)	28	1.02
ADD BOOKMARK (AB)	18	0.66
DELETE BOOKMARK (DB)	0	0

Figure 3. Behavioral transition diagram for all the blended learners

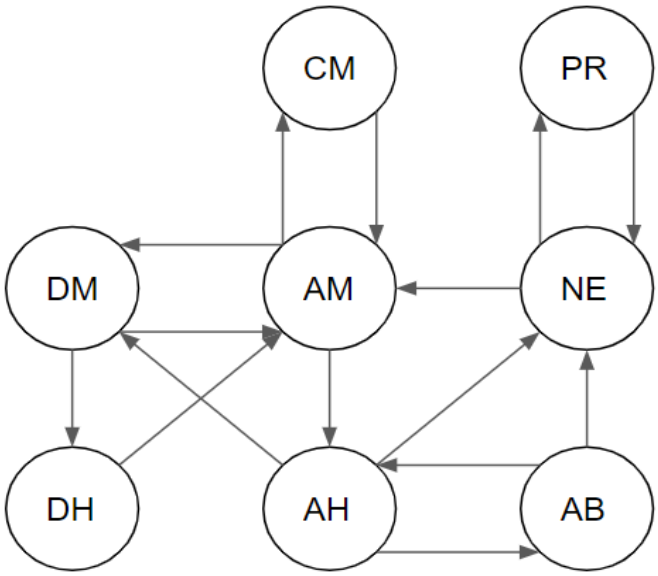


Table 4 is an adjusted residual table of the BookRoll sequential behaviors for all the blended learners, and Figure 3 depicts their behavioral transition. A z-score of more than 1.96 indicates the presence of a significant sequential relationship between two analyzed items (Bakeman & Gottman, 1997), which is represented with an arrow icon. In the present study, 15 sequential behaviors were revealed to be significant based on their z-score values. The significant sequential behaviors that started with "NEXT" were NE → PR (z-score = 22.09) and NE → AM (z-score = 27.42). The significant sequential behavior that started with "PREV" was PR → NE (z-score = 14.8). The significant sequential behaviors that started with "ADD MEMO" were AM → DM (z-score = 5.5), AM → CM (z-score = 10.23), and AM → AH (z-score = 32.22). The significant sequential behaviors that started with "DELETE MEMO" were DM → AM (z-score = 3.25) and DM → DH (z-score = 25.48). The significant sequential behavior that started with "CHANGE MEMO" was CM → AM (z-score = 11.55). The significant sequential behaviors that started with "ADD MARKER" were AH → NE (z-score = 23.48), AH → DM (z-score = 3.4), and AH → AB (z-score = 5.37). The significant sequential behavior that started with "DELETE

MARKER" was DH → AM (z-score = 3.89). The significant sequential behaviors that started with "ADD BOOKMARK" were AB → NE (z-score = 2.1) and AB → AH (z-score = 2.66).

Table 4. Adjusted residuals of BookRoll sequential behaviors for all the blended learners

Code	NE	PR	AM	DM	CM	AH	DH	AB
NE	-24	**22.09***	**27.42***	-5.29	-6.11	-15.1	-3.62	-2.9
PR	**14.8***	-6.75	-1.54	-2.07	-1.62	-8.21	-1.97	-1.58
AM	-1.78	-10.62	-22.54	**5.5***	**10.23***	**32.22***	-3.57	0.72
DM	-2.74	-1.95	**3.25***	-2.21	-0.11	-4.63	**25.48***	-0.89
CM	-4.29	-3.03	**11.55***	-0.6	-2.07	-4.47	-1.07	-0.86
AH	**23.48***	-5.57	-13.42	**3.4***	-2.42	-9.49	-2.28	**5.37***
DH	-1.22	-0.47	**3.89***	-1.02	0.07	-2.15	-0.52	-0.41
AB	**2.1***	-1.53	-2.81	0.3	-0.86	**2.66***	-0.45	-0.36

Note. $^{*}p < .05$.

4.2. Difference of the sequential patterns of e-book note-taking for SRL between blended learners in higher- and lower-achievement groups

Table 5 presents the collected frequency and percentage data of the BookRoll behaviors for higher- and lower-achievement groups. The top 3 behaviors that occurred most frequently for the higher-achievement group were "ADD MEMO" (31.79%), "NEXT" (30.93%), and "ADD MARKER" (16.61%). The top 3 behaviors that occurred most frequently for the lower-achievement group were "NEXT" (33.51%), "ADD MEMO" (28.87%), and "ADD MARKER" (14.58%). These descriptive statistics results reveal that the percentage of BookRoll behavior of page-turning (i.e., "NEXT" and "PREV") for the lower-achievement group (33.51% and 14.21%) is higher than that for the higher-achievement group (30.93% and 10.41%). Moreover, the percentage of BookRoll behavior of taking and reviewing notes (i.e., "ADD MEMO", "ADD MARKER", "ADD BOOKMARK", CHANGE MEMO, and DELETE MARKER) for the higher-achievement group (31.79%, 16.61%, 0.71%, 4.63%, and 1.07%) is higher than that for the lower-achievement group (28.87%, 14.58%, 0.6%, 3.14%, and 0.97%).

Table 5. Frequency and percentage data of the BookRoll behaviors for higher- and lower-achievement groups

Group	Category	Frequency	Percentage (%)
Higher-achievement group (n = 44)	NEXT (NE)	434	30.93
	PREV (PR)	146	10.41
	ADD MEMO (AM)	446	31.79
	DELETE MEMO (DM)	54	3.85
	CHANGE MEMO (CM)	65	4.63
	ADD MARKER (AH)	233	16.61
	DELETE MARKER (DH)	15	1.07
	ADD BOOKMARK (AB)	10	0.71
	DELETE BOOKMARK (DB)	0	0
Lower-achievement group (n = 44)	NEXT (NE)	448	33.51
	PREV (PR)	190	14.21
	ADD MEMO (AM)	386	28.87
	DELETE MEMO (DM)	55	4.11
	CHANGE MEMO (CM)	42	3.14
	ADD MARKER (AH)	195	14.58
	DELETE MARKER (DH)	13	0.97
	ADD BOOKMARK (AB)	8	0.6
	DELETE BOOKMARK (DB)	0	0

Table 6 and Table 7 are the adjusted residual tables of the BookRoll sequential behaviors for the higher-achievement group and lower-achievement group, respectively. Figure 4 depicts their behavioral transition. For the higher-achievement group, 14 sequential behaviors were revealed to be significant based on their z-score values. The significant sequential behaviors that started with "NEXT" were NE → PR (z-score = 14.83) and NE → AM (z-score = 20.4). The significant sequential behavior that started with "PREV" was PR → NE (z-score = 9.67). The significant sequential behaviors that started with "ADD MEMO" were AM → DM (z-score = 3.36), AM → CM (z-score = 8.85), and AM → AH (z-score = 23.04). The significant sequential behavior that started with "DELETE MEMO" was DM → DH (z-score = 19.1). The significant sequential behavior that started with

"CHANGE MEMO" was CM → AM (z-score = 10.16). The significant sequential behaviors that started with "ADD MARKER" were AH → NE (z-score = 17.27), AH → DM (z-score = 3.27), and AH → AB (z-score = 5.48). The significant sequential behavior that started with "DELETE MARKER" was DH → AM (z-score = 3.57). The significant sequential behaviors that started with "ADD BOOKMARK" were AB → NE (z-score = 1.97) and AB → AH (z-score = 1.97).

Table 6. Adjusted residuals of BookRoll sequential behaviors for higher-achievement group

Code	NE	PR	AM	DM	CM	AH	DH	AB
NE	-16.37	**14.83***	**20.4***	-3.38	-5.38	-10.96	-2.6	-2.12
PR	**9.67***	-4.11	-0.38	-2	-1.84	-5.5	-1.31	-1.06
AM	-1.7	-6.95	-17.04	**3.36***	**8.85***	**23.04***	-2.7	0.85
DM	-0.77	-1.57	0.73	-1.5	-0.35	-3.35	**19.1***	-0.65
CM	-3.97	-2.7	**10.16***	-0.94	-1.77	-3.6	-0.86	-0.7
AH	**17.27***	-3.68	-10.19	**3.27***	-1.79	-7.24	-1.72	**5.48***
DH	-1.24	-0.3	**3.57***	-0.73	-0.8	-1.63	-0.39	-0.32
AB	**1.97***	-1.07	-2.14	-0.64	-0.7	**1.97***	-0.34	-0.28

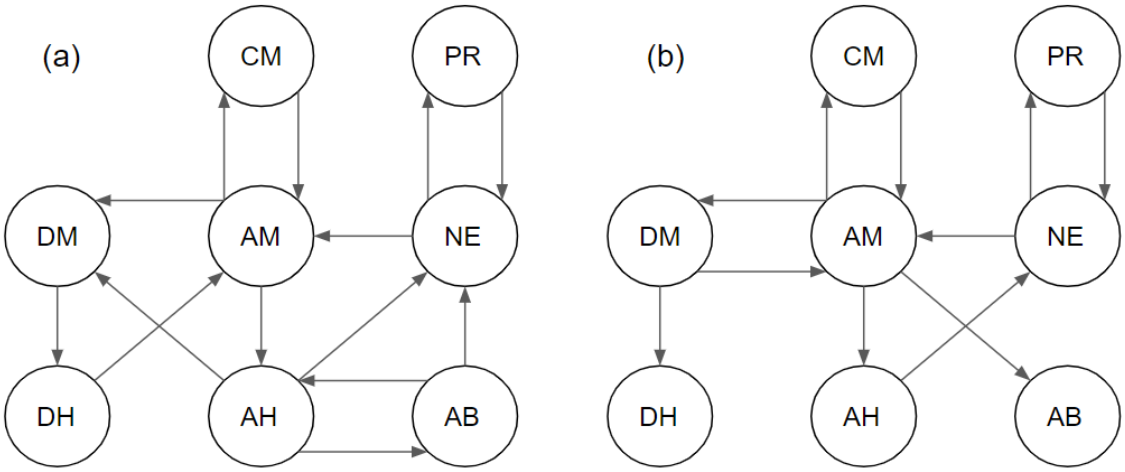
Note. $^{*}p < .05$.

Table 7. Adjusted residuals of BookRoll sequential behaviors for lower-achievement group

Code	NE	PR	AM	DM	CM	AH	DH	AB
NE	-17.62	**16.33***	**18.4***	-4.08	-3.02	-10.37	-2.52	-1.97
PR	**11.09***	-5.48	-1.66	-1.1	-0.24	-6.06	-1.47	-1.15
AM	-0.74	-8	-14.84	**4.45***	**5.16***	**22.5***	-2.35	**2.05***
DM	-3.09	-1.23	**3.88***	-1.62	-0.56	-3.19	**16.95***	-0.61
CM	-1.87	-1.48	**5.73***	0.2	-1.15	-2.7	-0.66	-0.51
AH	**16***	-4.14	-8.78	1.54	-1.71	-6.17	-1.5	1.84
DH	-0.46	-0.36	1.84	-0.71	1.15	-1.4	-0.34	-0.27
AB	0.97	-1.08	-1.83	1.13	-0.51	1.79	-0.29	-0.23

Note. $^{*}p < .05$.

Figure 4. Behavioral transition diagrams for (a) higher-achievement group and (b) lower-achievement group



For the lower-achievement group, 11 sequential behaviors were revealed to be significant based on their z-score values. The significant sequential behaviors that started with "NEXT" were NE → PR (z-score = 16.33) and NE → AM (z-score = 18.4). The significant sequential behavior that started with "PREV" was PR → NE (z-score = 11.09). The significant sequential behaviors that started with "ADD MEMO" were AM → DM (z-score = 4.45), AM → CM (z-score = 5.16), AM → AH (z-score = 22.5), and AM → AB (z-score = 2.05). The significant sequential behaviors that started with "DELETE MEMO" were DM → AM (z-score = 3.88) and DM → DH (z-score = 16.95). The significant sequential behavior that started with "CHANGE MEMO" was CM → AM (z-score = 5.73). The significant sequential behavior that started with "ADD MARKER" was AH → NE (z-score = 16).

These results reveal that the BookRoll sequential behaviors indicating the consecutively and combined use of taking and reviewing notes such as AH → DM, DH → AM, and AH → AB occurred significantly only for the higher-achievement group. Moreover, the BookRoll sequential behaviors indicating the follow-up action after

the use of bookmarks such as AB → AH and AB → NE occurred significantly only for the higher-achievement group.

5. Discussion and conclusions

5.1. Blended learners' sequential patterns of e-book note-taking for SRL

To address the first research question, the present study used LSA to identify the learners' sequential behaviors of e-book note-taking for SRL. The analytical results of the present study are generally consistent with those of other studies (e.g., Yang et al., 2018; Zarzour et al., 2020; Zhang et al., 2021), suggesting that the use of LSA to analyze learner behavior-related data is effective in revealing, mapping, and monitoring the online learning processes of learners. Moreover, the results of the present study echo those reported by Chen et al. (2017); in contrast to the count-based measures used by other studies to quantify learner behavior in specific learning contexts, an LSA can reveal the transitional relationships between different categories of learning behaviors and, sometimes, the temporality perspective of the learning process of learners. When the learners were reading the learning materials through the e-book format, they tended to repeatedly click the NEXT button to go to the next page and the PREV button to return to the previous page. This finding is consistent with those reported in previous studies, that is, learners review previous pages frequently when they are reading e-book learning materials in sequence (Yang et al., 2021; Yin et al., 2019). Moreover, the learners exhibited a variety of the combination of note-taking and note-reviewing strategies (e.g., changing memos after adding memos, adding memos after deleting markers, deleting memos after adding markers, etc) for the promotion of SRL. This finding is consistent with those reported by Alvi et al. (2016), that is, learners tend to use a variety of SRL techniques ranging from the shallow approach (repetition for memorization) to the cognitively deep processing approach (note-taking and consulting notes).

5.2. Comparisons of the sequential patterns of e-book note-taking for SRL between blended learners in higher- and lower-achievement groups

To address the second research question, the present study used LSA to uncover the differences between the blended learners in higher- and lower-achievement groups in terms of their sequential behaviors of e-book note-taking for SRL. The analytical results reveal that the percentage of BookRoll behavior of page-turning for the lower-achievement group is higher than that for the higher-achievement group. The percentage of BookRoll behavior of the taking and reviewing of notes for the higher-achievement group is higher than that for the lower-achievement group. Specifically, for the sequential patterns of note-taking, the analytical results reveal that the BookRoll sequential behaviors indicating the consecutively and combined use of taking and reviewing notes (e.g., adding memos after deleting markers, deleting memos after adding markers, etc) occurred more for the higher-achievement group compared with the lower-achievement group. Moreover, the BookRoll sequential behaviors indicating the follow-up action after the use of bookmarks (e.g., adding markers after adding bookmarks, turning to the next page after adding bookmarks, etc) occurred more for the higher-achievement group compared with the lower-achievement group.

The aforementioned findings are consistent with those reported by Alvi et al. (2016) and Effeney et al. (2013), that is, high-achievement learners tend to exhibit greater engagement in using wider cognitive strategies (e.g., note-taking and note-reviewing) than low-achievement learners. The findings are also consistent with those of other empirical studies, suggesting that learners who engage in the use of note-taking functions outperform those who do not (Kiewra et al., 1989; Kiewra et al., 1991) in terms of their learning achievements. In a specific context such as BL, the findings are consistent with those reported by Yang et al. (2021), suggesting that the taking and reviewing of notes have a considerable effect on the learning achievements of learners, and the act of browsing without taking notes is associated with poor learning achievements.

5.3. Theoretical and practical implications

The emergence of advanced educational technologies for classroom environments is changing the way learners take digital notes and process the knowledge that they acquire during class. The accountability of learners to the management of their learning processes may increase, which changes their study methods (Stacy & Cain, 2015). The appropriate adoption of note-taking strategies improves learners' capabilities of memorizing information and helps them to perform better on tests (Peverly et al., 2003).

The analytical results of the present study have several implications. First, the findings suggest that, in addition to the traditional navigation functions that allow learners to browse e-book learning materials, note-taking features (including the creation, deletion, and revision of memos, markers, and bookmarks) were identified as key behaviors for cognitive strategy use of SRL in BL contexts. Second, the present study demonstrated that LSA can be used to analyze sequential behavioral patterns to generate findings that enable e-book developers and instructional designers to better understand the actual cognitive operations and behavioral patterns of learners when using e-books. Moreover, LSA enables instructors and researchers to explore the hidden behaviors of learners and develop an effective instructional mechanism for the self-regulatory use of e-books in BL contexts through a visualized transition diagram.

For course scenarios, the findings suggest that teachers can guide and encourage learners with low levels of engagement in note-taking to apply strategies for combined use of taking and reviewing notes that improve their engagement level and learning achievements in BL. The findings also suggest that learners can increase their interaction with e-books by using more note-taking and note-review features to enhance their retention of the information in their learning materials. From this perspective, educational tools that allow learners to monitor and diagnose their learning process and receive personalized feedback on how they can improve their cognitive and metacognitive strategies for self-regulation abilities can be helpful; this issue was also highlighted in Yang and Ogata (2022).

In summary, the present study conducted an exploratory study in an undergraduate course that implemented the BL design. The learning task for the blended learners in the present study was to study the learning material using an e-book system during in-class and out-of-class learning sessions. The present study employed an LSA to investigate the blended learners' sequential patterns of e-book note-taking for the cognitive strategy use of SRL. Moreover, the present study revealed the difference between higher- and lower-achievement blended learners in terms of their sequential behaviors of e-book note-taking. The major contribution of the present study is to offer opportunities for educators to effectively understand learners' interactions with note-taking and note-reviewing systems (e.g., e-books) and provide learners with evidence-based educational feedback and corresponding interventions regarding the combined use of note-taking strategies for the promotion of SRL and improvement of course achievement in BL. Teachers at every education level can use the findings of the present study as a basis for adjusting their teaching strategies or materials to achieve personalized learning for their courses. The findings can be applied to help learners to adjust their adopted learning strategies, such that they can better adapt to changing learning environments and learning goals when they are receiving information from educators or digital learning platforms in the context of BL; this issue was also highlighted in the literature (Kundu et al., 2021; Luan & Tsai, 2021; Yang et al., 2021).

5.4. Limitations

The present study has several limitations. First, a sample size of only 88 participants was used in the present exploratory study. Therefore, the results, although significant, cannot be generalized to larger populations. A general analytical model is required to examine a larger sample size of learners through the application of similar analytics methods. Second, since the present study focused exclusively on identifying the sequential patterns of blended learners by examining e-book learning logs relating to note-taking, the number of types of learner learning behaviors and the awareness of SRL that could be identified were relatively limited. Therefore, future studies that apply similar analytic methods should integrate a greater variety of digital learning platforms and questionnaires to obtain a greater range of learner data relating to e-book learning and the awareness of SRL. Third, in the present study, GSEQ-based LSA was applied individually to identify the blended learners' sequential patterns of e-book note-taking. Future studies should incorporate other techniques (e.g., clustering and process mining) to enrich their analytical process and obtain further insights into the sequential patterns of e-book note-taking of learners undergoing BL. Finally, we did not take into account the influences of the blended learners' learning styles or personality traits on their behavioral engagement of e-book note-taking or learning achievement before the present exploratory study, which could cause some bias in the analytical results. When similar analyses are conducted in future studies, these potential influences should also be taken into account.

Acknowledgement

This work was partially supported by JSPS Grant-in-Aid for Scientific Research (S)16H06304 and NEDO Special Innovation Program on AI and Big Data 18102059-0 and Explainable AI P20006.

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