Chen, W. et al. (Eds.) (2017). Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

Learning Behavioral Pattern Analysis based on Students' Logs in Reading Digital Books

Chengjiu YIN [a*], Noriko UOSAKI[b], Hui-Chun CHU[c], Gwo-Jen HWANG [d], Gi-Zen Liu [e], Jau-Jian HWANG [c], Itsuo HATONO[a] ,Etsuko KUMAMOTO[a] & Yoshiyuki TABATA[f]

[a]*Information Science and Technology Center, Kobe University, Japan*

[b] *Center for International Education and Exchange, Osaka University, Japan*

[c] *Computer Science & Information Management, Soochow University, Taiwan*

[d] *College of Liberal Arts and Social Sciences, National Taiwan University of Science and Technology, Taiwan*

[e] *Department. of Foreign Languages & Literature, National Cheng Kung University, Taiwan*

[f] *Research Institute for Information Technology, Kyushu University, Japan*

*yin@lion.kobe-u.ac.jp

Abstract: In this paper, we presented a study developing a digital textbook system, which could be used anywhere, anytime. An experiment was conducted using the developed system to collect students' learning logs for analyzing their behavioral patterns on an Educational Technology course for graduate students. In the experiment, we assigned the students to read an academic English journal article. The lag-sequential analysis method was employed to analyze and infer their behavioral patterns. Several interesting behavioral patterns were found from the analysis results. The findings are helpful to the improvement of the digital textbook system; moreover, some behavioral patterns could provide helpful references for teachers to improve teaching materials in the future.

Keywords: Learning behaviors, lag-sequential analysis, learning log, digital textbooks

1. Introduction

Nowadays, smartphones have become very popular devices for communications and learning because the functions of these devices have been significantly improved in recent years and the physical size and weight have been better designed for increasing portability (Yin et al., 2016). By using mobile devices, digital textbooks can be conveniently accessed through Internet anywhere and anytime. With the development of e-publishing technologies and standards increasingly, more and more traditional textbooks have been replaced by digital ones (Rainie, et al., 2012, Yin et al., 2014).

In the past decade, various studies have been conducted to investigate the effectiveness of learning with digital textbooks. For example, Shepperd et al. (2008) compared efficacy between digital textbooks and traditional textbooks, and they indicated that students rated the usability of digital textbooks positively. Rockinson-Szapkiw et al. (2013) compared the learning effectiveness between digital textbooks and traditional textbooks. They found that digital textbooks are as effective for learning as traditional textbooks. Therefore, many researchers concur that digital textbooks have become a potentially effective pedagogic tool for supporting teaching, learning and scholarship (Hezroni, 2004; Reinking, 1997; Snyder, 2002).

In the meantime, learning analytics has become an important issue in education. Learning analytics plays an important role in providing helpful suggestions to policy makers, instructors or learners by analyzing learning logs or educational data (Baker & Inventado, 2014; Hwang et. al.,2017). The objective of learning analytics is to provide helpful information to optimize or improve learning designs, learning outcomes and learning environments based on the analysis results (Greller & Drachsler, 2012).

In this paper, a digital textbook system is developed to collect data in the classes. The system is named Digital textbook for Improving Teaching and Learning (DITeL). The DITeL system can be used

not only on personal computer, but also on smart phone. That is to say, this digital system can be used anywhere, anytime. Teachers and students can use DITeL system and read the digital textbook by using mobile devices such as iPad, iPhone, and Android. And their learning logs were collected for analyzing their learning behaviors to improve DITeL system.

In order to analyze learning behaviors, we designed an experiment using DITeL system to collect students' learning logs. The experiment was carried on Educational Technology course for graduate students. In the experiment, we assigned them to read an academic English journal article. After learning activities, we applied lag-sequential analysis to analyze and infer their behavior patterns. We found some behavioral patterns which may help to improve digital textbook system. We also found some behavioral patterns which may help teachers to improve their teaching material.

2. Literature Review

2.1 Previous Studies of Data Collection

Collecting data is the first step in learning analysis (Yin et al., 2013a; 2013b). In May 2015, we thus performed a review of previous research to survey the categories that can be classified in terms of data collection (Yin et al. 2016).

Based on the data source, previous studies on data collection could be classified into three categories: Questionnaire-based Data Collection (QDC), Manual Data Collection (MDC), and Automatic Data Collection (ADC) (Yin et al., 2014; Ren et al., 2017).

QDC. In this category, data are collected by using a predesigned questionnaire. Ho et al. (2013) used a questionnaire to investigate the teacher behavior on adopting mobile phone messages as a parent–teacher communication medium.

MDC. In this category, a manual data collection system is opened to users, who can employ the system and consciously provide data about their learning behaviors. For example, Chiang et al. (2014) provided an augmented reality (AR) system to guide students in knowledge sharing in inquiry learning activities. In this approach, students capture images from an authentic environment and share these with others.

ADC. In this category, learning behaviors log data are automatically recorded while reading e-documents. For example, Yin et al. (2015) analyzed learning behavior and identify students' learning style using student's digital textbooks reading logs data, which were recorded automatically. By using same digital textbooks logs data, Shimada et al. (2017) summarized lecture slides to enhance preview efficiency and improve students' understanding of the content, Mouri and Yin (2017) find some patterns for improving learning materials.

For categories QDC and MDC, the data are consciously collected. Therefore, data are affected by users' own subjective factors. For category ADC, the data is objectively collected, thereby removing the subjective factors that affect data authenticity. The present work falls under category ADC.

2.2 Behavioral Sequential Analysis

Behavioral sequential analysis is a statistical analysis method. Through a series of sequential analysis matrix calculations to determine behavioral transitions (Bakeman & Gottman, 1997; Hou, 2012).

There are many researches using a series of progressive sequential analyses to analyze learning behavioral patterns and they point out the benefit of using progressive sequential analyses (Hou, 2012; Hsieh et al., 2016; Hwang et al., 2017). Hou (2012) indicated that using a visualized behavior–transition diagram to explore learners' complex behaviors can help to develop a more effective instructional mechanism for game-based system. Therefore, we employed this method to improve digital textbook system.

3. Digital Textbook System

By using e-pub format, a web-based digital textbook system was developed and used for this research (Fig. 1, Fig. 2). Fig. 1 is an interface for students, and Fig. 2 is an interface for teachers. By using this online digital textbook reading system, we can collect data like "turning to next/previous page", "memo", "zoom in/out", "adding marker". All of these actions are stored to the database. These data were used to analyze learning behaviors.

Turning to next/previous page. Students can read the teaching contents again and again, they go to the next page by clicking "Next" button, and backtrack to the previous page by clicking "Prev" button.

Memo. While a user want to write some memo in the learning content, he will click "Memo" button, and a textbox will be shown. After he finished writing memo, the action name will be saved as "Memo".

Zoom in/out. The zoom in/out function can help students read the contents more clearly.

Adding marker. While a user want to highlight some text in the learning content, s/he will click "abc highlig" or "Under line" button, and the action name will be saved as "Highlight" or "Underline".

Teacher can register each student's name and student number into the system. Before the students login in the system, the digital textbook and other relevant materials have been uploaded to the system by the teacher.

Each student will have his/her own account to enter the system, so that he/she has a separate record of this course to learn.

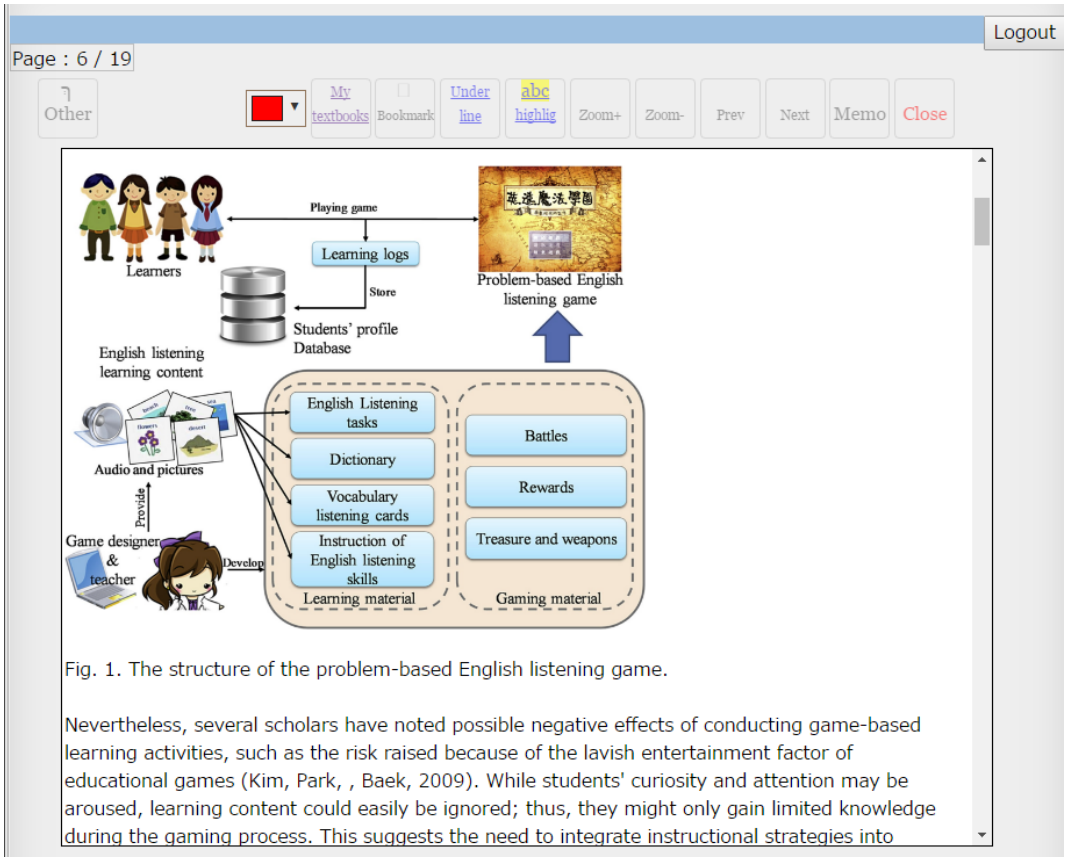

Fig. 1. The structure of the problem-based English listening game.

Nevertheless, several scholars have noted possible negative effects of conducting game-based learning activities, such as the risk raised because of the lavish entertainment factor of educational games (Kim, Park, , Baek, 2009). While students' curiosity and attention may be aroused, learning content could easily be ignored; thus, they might only gain limited knowledge during the gaming process. This suggests the need to integrate instructional strategies into

Fig. 1. Student interface of DITeL

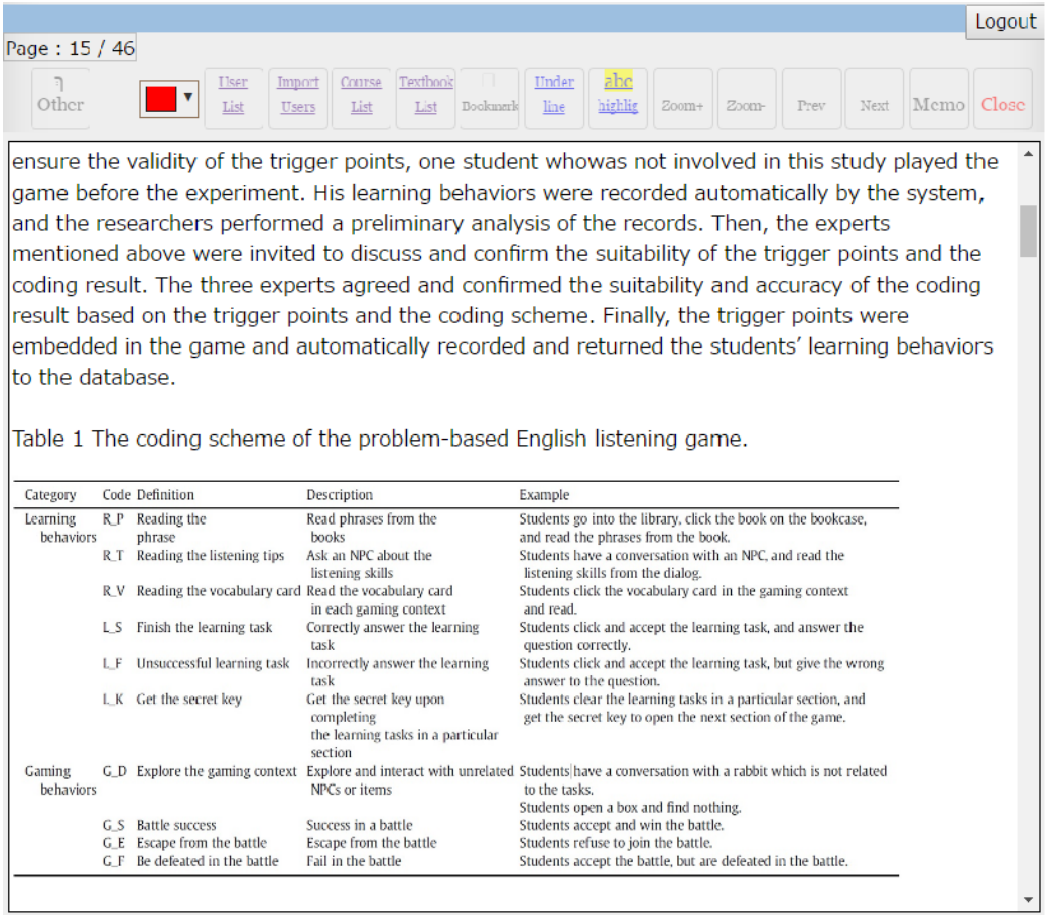

Fig. 2. Teacher interface of DITeL

4. Experimental Design

To analyze students' behavioral patterns in learning with digital textbooks, an experiment was designed using DITeL system to collect students' learning logs. The experiment was carried on an Educational Technology course for graduate students. The aim of the study was to explore the learning behaviors of students reading academic papers. The progressive sequential analysis was used to infer the learning behaviors of students when they were reading the academic papers.

4.1 Participants

A total of 21 graduate students participated in this study. The participants were asked to read an academic paper via the digital textbook system. The age of the participants was 23 on average. The experiment was carried about 1.5 hours.

To protect the participants, the experiment was conducted following the ethics criteria suggested by an authorized ethics committee in Japan. That is, the participants were protected by hiding their personal information during the research process; moreover, they knew that their participation was voluntary and that they could withdraw from the study at any time. As the result, we could use 17 participants to do learning analysis.

4.2 Coding Scheme

To do a progressive sequential analysis, a coding process is usually required. However, this study only analyzes the learning behaviors which ware recorded automatically, therefore, no coding process needed to be carried out in this system. That is, the coding is based on their operating behaviors in the digital textbook system.

5. Analysis of the Learning Behavioral Patterns

Totally 1,370 learning behaviors were recorded.

5.1 Analysis of the Frequency of Behavioral Patterns

Table 1 shows the frequency and percentage of the individual coded behaviors of the students. It was found that "go to next page" (NEXT) and “go to previous page” (PREV) were the most frequent behaviors. The percentage of “go to next page” was 39%, and “go to previous page” was 28%. These were most likely behaviors, as students needed to flip to read the textbook.

We also found that marker functions, “make underline” (UNDERLINE), and “make highlight” (HIGHLIGHT), were also used frequently. However, the percentage of “make underline” (6%) is less than, “make highlight” (22%). Although both are all marker functions, the students liked to use highlight better than underline.

Table 1: The frequency and percentage of coded behaviors of student.

Category	Frequency	Percentage(%)
PREV (PR)	390	28
NEXT (NX)	537	39
UNDERLINE (UL)	79	6
DEL UNDERLINE(DU)	15	1
MEMO(MO)	8	1
HIGHLIGHT(HL)	301	22
DEL HIGHLIGHT(DH)	29	2
BOOKMARKER(BM)	8	1
DEL BOOKMARKER(DB)	3	0

5.2 Analysis of the Learning Behavioral Patterns

To probe the behavioral patterns of the students in reading digital textbooks, a series of progressive sequential analyses was conducted to explore the behavioral patterns. As shown in Table 2, the rows represent the starting behaviors, and the columns represent the subsequent behaviors. A Z-value greater than 1.96 means that a behavior-sequence reaches the level of significance ($p < 0.05$) (Bakeman & Gottman, 1997; Hou, 2012).

Table 2: Sequential analyses table (n = 17)

Z-value	PR	NX	UL	DU	MO	HL	DH	BM	DB
PR	11.67	-2.70	-3.98	-1.31	-0.83	-5.15	-3.44	-1.79	-1.09
NX	-1.33	9.95	-4.98	-3.13	0.20	-6.19	-1.29	-0.10	-0.21
UL	-4.20	-5.13	15.61	2.37	-0.66	1.37	-0.55	-0.70	2.05
DU	-1.89	-2.05	3.45	7.01	-0.28	0.44	1.21	-0.30	-0.18
MO	-1.01	0.64	-0.71	-0.30	9.66	-0.65	-0.42	-0.22	-0.13
HL	-6.60	-4.07	0.48	1.08	-0.49	10.06	4.38	0.21	-0.92
DH	-3.03	-2.82	-0.56	1.21	-0.39	6.18	0.49	-0.42	3.73
BM	-1.79	-1.54	2.31	3.08	-0.20	0.21	4.47	-0.22	-0.13
DB	-1.10	-1.39	-0.43	-0.18	-0.13	-0.92	-0.26	22.44	-0.08

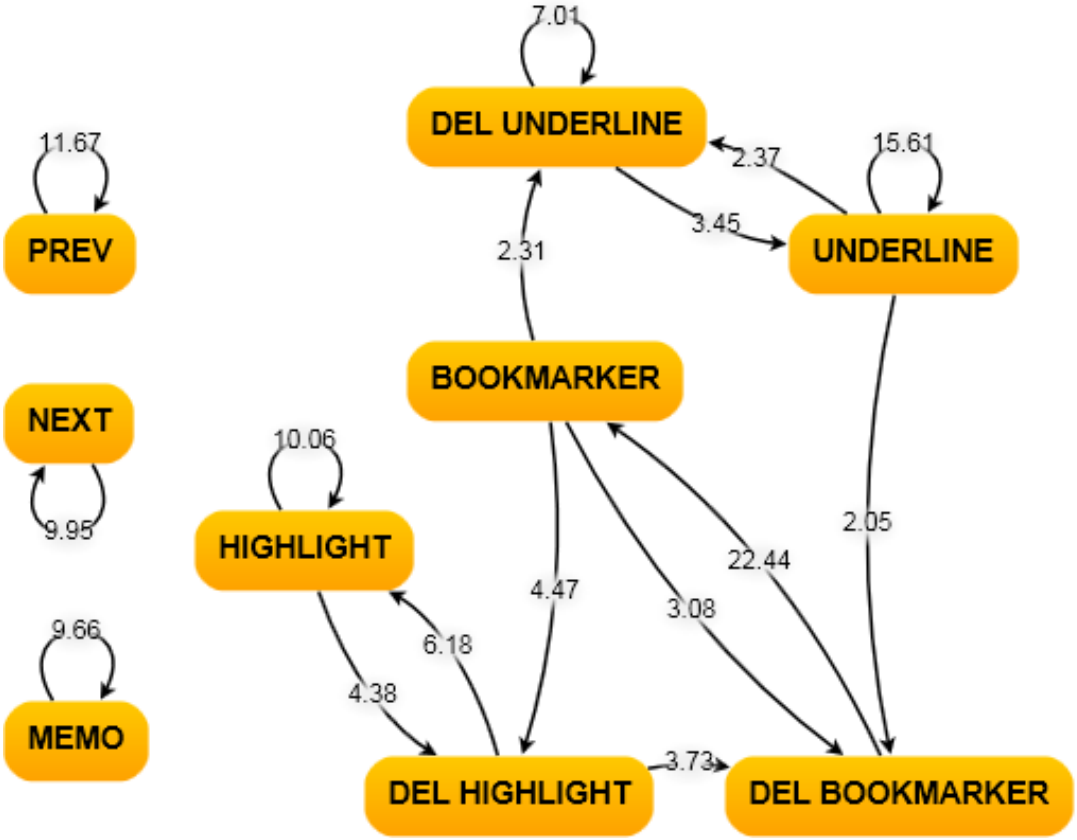

Fig. 3. Progressive behavioral patterns of the students.

Table 2 indicates there are 16 significant sequences that occurred during the reading digital textbooks. Based on the significant sequences, a diagram of behavioral-transition was prepared. Fig. 3 shows the behavioral transition diagrams of the students. All of the sequences in the diagrams are statically significant. The values above each line represent the z-score for the sequence, while the direction of the line represents the direction of the behavioral transition.

As shown on Fig. 3, it was beyond our expectation that PREV, NEXT and MEMO behaviors have no sequential correlations between other learning behaviors. However, they have sequential correlations with themselves (PREV → PREV; NEXT → NEXT; MEMO → MEMO). We also found some other learning behavioral patterns: LBP1-6 as shown in Table 3.

Table 3: learning behavioral patterns.

No	Learning Behavioral Pattern
LBP1	"HIGHLIGHT" has sequential correlations with itself and "DEL HIGHLIGHT"
LBP2	"BOOKMARK" has sequential correlations with "DEL BOOKMARK"
LBP3	"BOOKMARK" has sequential correlations and "DEL UNDERLINE"
LBP4	"BOOKMARK" has sequential correlations with "DEL HIGHLIGHT"
LBP5	"DEL HIGHLIGHT" has sequential correlations with "DEL BOOKMARK"
LBP6	"DEL UNDERLINE" has sequential correlations with itself and "DEL BOOKMARK"

We have shown the students the learning behavioral patterns (Table3) and carried out an interview to ask them why they took such actions.

5.2.1 LBP1

It was found that "After adding HIGHLIGHT, the students deleted the HIGHLIGHT, or after deleting HIGHLIGHT, they added HIGHLIGHT again"; Some of the students who had these learning behavioral patterns, stated their perceptions as follows:

1. *I highlighted it because I thought it was the main idea of the paragraph, but I realized it was wrong, so I deleted it.*
2. *Because I made a mistake in highlight position.*
3. *It was a mistake of my operation.*
4. *I highlighted on some words, after that, I found more meaningful words.*
5. *Because I thought it was an important place, after I read the rest of the paper, I found it was not important.*
6. *Because I made a mistake in the range of the highlight.*

From the interview, it was found that students often changed the important keywords when they were reading the textbook, and that it was difficult for them to identify which words were important. It suggests that it would be appropriate to mark the important places on the teaching materials before students read the contents.

5.2.2 LBP2

It was also found that, after adding BOOKMARK, the students would delete the BOOKMARK; after deleting BOOKMARK, they would add BOOKMARK again. Some of the students who had this learning behavioral pattern, stated their perceptions as follows:

1. *I thought it was an important page, but after I read the rest of the paper, I found it was not important, and added bookmark on another page.*
2. *I examined the importance of the pages again and removed those of less importance.*
3. *When I had some other things to do, which means I have to read the article later, I will add a new bookmark so that I can continue my work later.*

From the interview, it was also found that students often changed the important page while they were reading the textbook, they were often confused about which pages were important. It is suggested that it would be appropriate to mark the important pages on the teaching materials before students read the contents.

5.2.3 LBP3, LBP4

Another finding was that, after "add bookmarker", the students often "delete highlight" or "delete underline". This phenomenon may suggest that there are sequential correlations between "BOOKMARKER" and marker functions (UNDERLINE, HIGHLIGHT). Some of the students who had this learning behavioral pattern stated their opinions as follows:

1. *I can use highlight instead of using underlines, without any specific reasons. And there is also the bookmark function, so maybe it is not necessary to use underlines.*
2. *Because I thought it was not necessary to underline/highlight here. It is enough to write memo here.*
3. *When I found more important parts than the parts I underlined/highlighted, I added the bookmark there and deleted the underline/highlight.*
4. *If I add the bookmark, then it is not necessary to use underline.*
5. *It is not easy to use underline and highlight functions.*

From the interview, we found that some students preferred bookmark to highlights/ underlines. Some students preferred memo to mark. It suggests that the students preferred to use bookmark and memo functions to mark functions. And it seems that the underline and highlight functions of our system are hot user-friendly. The improvement of these functions is among our future works.

5.2.4 LBP5, LPB6

It was also observed that, after "deleting highlight/underline", the students often "delete bookmark". Some of the students who had this learning behavioral pattern share the following opinions:

1. *When I completed the reading of the paper, I felt that I understood all of them.*
2. *I thought the part which had been highlighted was not important anymore, so I deleted the highlight or the bookmark.*
3. *When I completed the reading of the paper, I felt the place that I marked was not so important.*
4. *When I had questions on the contents I marked it, after when I found the answer, I deleted them all.*

From the interview, we found that sometimes mark functions were used temporarily, such as if they had questions on some contents, then they added marks on these contents. After they found the answer, they deleted them. Therefore, if we add links between the related contents beforehand, students can read the textbook in a more efficient way.

6. Conclusion

With the development of e-publishing technologies and standards increasingly, more and more traditional textbooks have been replaced by digital textbook.

In this paper, we developed a digital textbook reading system, which could be used anywhere, anytime. Teachers can upload their teaching materials themselves and students can use the system to read textbooks. At the same time, students' reading logs were collected to analyze their learning behaviors. In order to probe the behavioral patterns of the students in reading digital textbooks, a series of progressive sequential analyses was conducted to explore the behavioral patterns.

We found some behavioral patterns which may help digital textbook system developers and instructional designers reach an in-depth understanding of the actual operations and behavioral patterns of learners. It also enables them to use a visualized behavior–transition diagram to explore learners' complex behaviors and develop a more effective instructional mechanism for digital textbook systems in the future.

Acknowledgements

Part of this research work was supported by the Grant-in-Aid for Scientific Research No.16H03078 from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan.

References

Bakeman, R., & Gottman, J. M. (1997). Observing interaction: An introduction to sequential analysis (2nd ed.). UK: Cambridge University Press.

Chiang, T.H.C., Yang, S.J.H., & Hwang, G.J. (2014). Students' online interactive patterns in augmented reality-based inquiry activities, *Computers & Education*, vol. 78, pp. 97-108.

Hezroni, O. E. (2004). Literacy and assistive technology for children with special needs. *Script*, 7-8, 195–218, (Hebrew).

Ho, L.H., Hung, C.L., & Chen, H.C. (2013). Using theoretical models to examine the acceptance behavior of mobile phone messaging to enhance parent–teacher interactions, *Computers & Education*, vol. 61, pp.105–114.

Hou, H.T. (2012). Exploring the behavioral patterns of learners in an educational massively multiple online role-playing game (MMORPG), *Computers & Education*, vol. 58, pp. 1225–1233.

Hsieh, Y. H., Lin, Y. C., & Hou, H. T. (2016). Exploring the role of flow experience, learning performance and potential behavior clusters in elementary students' game-based learning. *Interactive Learning Environments*, 24(1), 178-193.

Hwang, G. J., Hsu, T. C., Lai, C. L., & Hsueh, C. J. (2017). Interaction of problem-based gaming and learning anxiety in EFL students' English listening performance and progressive behavioral patterns. *Computers & Education,* 106, 26-42.

Mouri, K., Yin, C. (2017). E-book-based learning analytics for improving learning materials, *Proc. of the IIAI International Congress on Advanced Applied Informatics*, Hamamatsu, Japan,pp.9-13

Rainie, Lee, Kathryn Zickuhr, Kristen Purcell, Mary Madden, and Johanna Brenner (2012). The rise of e-reading. Washington D.C: Pew Research Center's Internet & American Life Project. http://libraries.pewinternet.org/2012/04/04/the-rise-of-e-reading/

Reinking, D. (1997). Me and my hypertext: a multiple digression analysis of technology and literacy (sic). *The Reading Teacher*, 50, 626–643.

Ren, Z., Uosaki, N., Kumamoto, E., Liu, G.Z. and Yin, C. (2017). Improving teaching materials through digital book reading log, *Proc. of the International Conference on Advanced Technologies Enhancing Education*, Qingdao, China, pp.90-96.

Rockinson-SzapkiwRockinson, A. J., et al. (2013). Electronic versus traditional print textbooks: A comparison study on the influence of university students' learning. *Computers & Education*, 63, pp. 259–266.

Shepperd, J. A., Grace, J. L., & Koch, E. J. (2008). Evaluating the electronic textbook: is it time to dispense with the paper text? , *Teaching of Psychology*, 35, 2–5.

Shimada, A., Okubo, F., Yin, C., Ogata, H. (2017). Automatic summarization of lecture slides for enhanced student preview -technical report and user study, *IEEE Transactions on Learning Technologies*, no.99, pp.1-1, doi: 10.1109/TLT.2017.2682086.

Snyder, I. (2002). Silicon literacies: Communication, innovation and education in the electronic age. London: Routledge.

Yin, C.J., Sung, H.Y., Hwang, G.J., Hirokawa, S., Chu, H.C., Flanagan, B., & Tabata, Y. (2013a). Learning by searching: a learning approach that provides searching and analysis facilities to support research trend surveys, *Journal of Educational Technology & Society*, vol. 16, no. 3, pp. 286–300.

Yin, C.J., Hirokawa, S., Yau, J., Nakatoh, T., Hashimoto, K. & Tabata, Y. (2013b). Analyzing research trends with cross tabulation search engine. *Int. Journal of Distance Education Technologies*, 11,1, pp. 31-44.

Yin, C., Okubo, F., Shimada, A., Kentaro, K., Yamada, M., Ogata, H., Fujimura,N.(2014). Smart phone based data collecting system for analyzing learning behaviors, *Proc. of International Conference of Computers on Education*, Nara, Japan, pp. 575–577.

Yin, C., Okubo, F., Shimada, A., OI, M., Hirokawa, S., Yamada, M., Kojima, K., Ogata, H., (2015). Analyzing the features of learning behaviors of students using e-books, *Proc. of International Conference of Computers on Education*, Nara, Japan, pp. 617–626.

Yin, C., Yau J.Y.-K., Uosaki, N., Hirokawa, S., Kumamoto, E.(2016). Measuring & evaluating digital textbooks through quizzes, *Proc. of the 24th International Conference on Computers in Education* , Mumbai, India, pp.374-379.