Design and Evaluation of Seamless Learning Analytics

Kousuke Mouri[1(✉)], Noriko Uosaki[2], and Atsushi Shimada[3]

[1] Tokyo University of Agriculture and Technology, Tokyo, Japan
mourikousuke@go.tuat.ac.jp
[2] Osaka University, Osaka, Japan
[3] Kyushu University, Fukuoka, Japan

Abstract. This paper describes a learning analytics perspective for designing to implement a seamless learning environment. Seamless learning has been focused on supporting learning across formal and informal learning contexts, individual and social learning and physical world and cyberspace. Majority of the current researches have realized a seamless learning environment by using the technologies such as smart-phone and GPS at schools or universities. However, utilization of the collected learning logs still remains a challenge yet to be explored. In this study, to construct a seamless learning environment, this study developed a system that integrated a digital textbook system called AETEL with a ubiquitous learning system called SCROLL. The system enables learners to bridge the learning between digital textbook learning and real-life learning. To analyze and visualize the relationships between them, this study developed an innovative system called VASCORLL 2.0 (Visualization and analysis System for Connecting Relationships of Learning Logs). An experiment was conducted to evaluate whether VASCORLL 2.0 can increase learners' learning opportunities. As a result, they were able to increase their learning opportunities by using VASCORLL 2.0. It contributed to enhancing learning activities in the seamless learning environment by utilizing the collected learning logs with well-designed analysis and visualization approaches.

Keywords: Seamless learning · Learning analytics · Digital textbook

1 Introduction

In recent years, seamless learning systems have been constructed using information technologies such as mobile devices, RFID tags, QR codes and wireless networks. Seamless learning has been recognized as an effective learning approach across various dimensions including formal and informal learning contexts, individual and social learning, and physical world and cyberspace [1]. One of its most important issues is how to bridge in-class and out-of-class learning because this is inevitable in designing both in-class and out-of-class activities to link what learners have learned in class with their daily life experiences and vice versa, particularly, to link what they have learned in their daily lives to their experiences in class.

N. Streitz and S. Konomi (Eds.): DAPI 2018, LNCS 10922, pp. 101–111, 2018.
https://doi.org/10.1007/978-3-319-91131-1_8

So far, majority of researches in the seamless learning focus on realizing a seamless learning environment at schools or universities [2, 3]. The advantages of the seamless learning environment are to enhance learners' learning opportunities and autonomy learning with sustaining their learning motivation.

However, it is yet to be visualized and analyzed the collected learning logs to enhance the quality of learning. This study contended that learning efficacy can be enhanced by utilizing their learning logs. First, we considered that the research issues of learning analytics based on seamless learning environments are as follows:

(1) How can we utilize the learning logs collected in a seamless learning system?
(2) How can analysis bridge the gap between formal and informal learning?
(3) How can analysis increase learners' learning opportunities?

To address these issues, our research project proposed a seamless visualization and analysis system called VASCORLL 2.0 (Visualization and Analysis System for Connecting Relationships of Learning Logs). The system seamlessly supports e-book-based learning and real-life learning by integrating a ubiquitous learning system called SCROLL with an e-book system. The rest of this paper is constructed as follows. Section 2 describes literature review for clearly identifying the difference between related works and our research. Section 3 describes our previous works regarding SCROLL and VASCORLL. Section 4 describes the design of VASCORLL 2.0. Section 5 describes the implementation of VASCORLL 2.0. Finally, Sect. 6 describes evaluation and our conclusion.

2 Literature Review

2.1 Design of Seamless Learning Environments

Seamless learning is used to describe the situations where students can learn whenever they want to in variety of scenarios and that they can switch from one scenario to another easily and quickly using one device or more per student as a mediator. Researchers in the seamless learning used mediating tools such as smart phone and PDA to realize a seamless learning environment. For example, Wong et al. [4] reported a seamless learning system called MYCLOUD (My Chinese UbiquitOUs learning Days), which allow students to learn the Chinese language in both in-school and out-of-school learning spaces using mobile devices. MYCLOUD consists of three components to bridge formal learning and informal learning: mobile dictionary, digital textbook and Social network service. In a formal learning setting, learners use the digital textbooks to highlight unfamiliar vocabularies and the vocabularies will be added to the mobile dictionary. In an informal learning setting, they use the social network service to record the artifacts (photo(s) + sentence(s)) of the experiences in their daily life. The seamless learning environment is realized by linking the vocabularies between the digital textbooks and the social network service.

On the other hand, Uosaki et al. [5] reported a seamless learning system called SMALL (Seamless Mobile-Assisted Language Learning support system) to support students who aimed to learn the English language in a formal and informal setting.

SMALL has been developed with newly functions added to SCROLL. In a formal setting, learners use digital textbook to record vocabularies that they want to remember and the vocabularies will be added to the SCROLL database. In an informal setting, learners can record the digital records (a vocabulary with a photo or a video) of their learning experiences in their daily lives. The seamless learning environment is realized by linking the vocabularies between digital textbook and SCROLL. Therefore, in designing seamless learning environments, researchers need to consider how formal and informal learning are linked with use of computer technologies.

To construct a seamless learning environment based on above reviews, this study designed and developed a seamless learning system by integrating the digital textbook system called AETEL (Actions and learning on E-TExtbook Logging) and SCROLL. As far, researchers have constructed a seamless learning environment and evaluated whether the seamless learning environment can be enhanced learners' learning efficacy and autonomy learning, while this study considers learning analytics perspective with designing successfully the seamless learning environment because the collected learning logs aren't utilized to support teaching and learning.

2.2 Authentic Learning with Learning Analytics

Many empirical researchers have found that classroom-only learning is not conductive to enhance learners' communicative skills, such as listening and speaking, sustaining their learning motivation. It is necessary to consider not only the design of in-class learning but also out-of-class-learning or authentic learning [6]. In this study, the term "authentic learning" is defined as either experimental learning or real-life learning.

In recent years, Learning Analytics (LA) have been focused to find useful information for improving and optimizing teaching and learning. The definition and aims of LA are discussed actively by researchers. The techniques and methods of LA include information visualization and social network analysis. The information visualization allows teachers and learners to see, explore and understand large amounts of information at once [7]. The Social Network Analysis (SNA) allows teachers and learners to discover the relationships between various elements such as learners and knowledge, and knowledge and locations [8].

Based on above reviews, this study analyzes learning logs collected by our developed seamless learning system with information visualization and SNA.

3 Previous Work

3.1 AETEL

This study developed a digital textbook system called AETEL [9]. Figure 1(Left) shows the interface of directories of AETEL. Teachers can create e-book contents using PowerPoint and Keynote prior to the class and use them in their courses. The uploaded e-book contents are converted to EPUB format and it is supported to access the contents by using smartphones and PCs. Figure 1(Right) shows digital textbooks uploaded by the teachers.

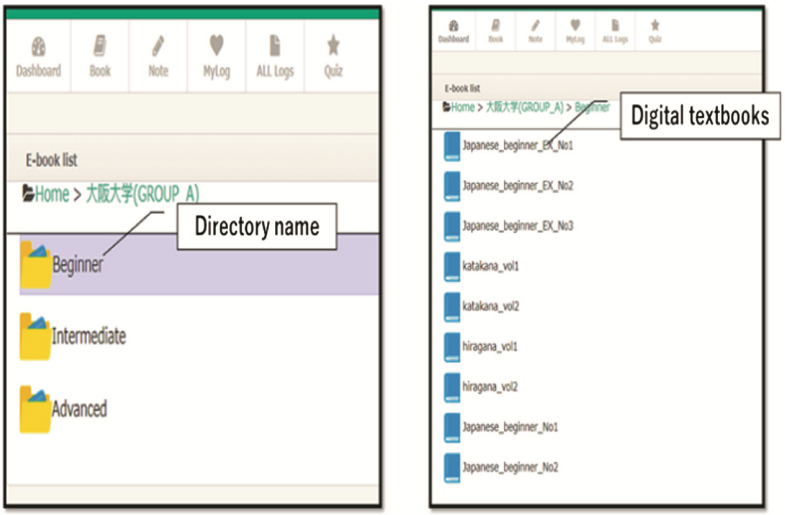

Fig. 1. Directories and digital textbooks in AETEL

Figure 2 shows the digital textbook viewer interface and slide descriptions. Learners can read the digital textbooks on their web browser anytime and anywhere. For example, when a learner clicks the memo button on the digital textbook viewer system, he/she can write a description concerning the target words as shown in Fig. 2(Right-top). When a learner clicks the highlight button, he/she can highlight the word. In addition, he/she can find the page number corresponding to the target word in the e-book by clicking the search button.

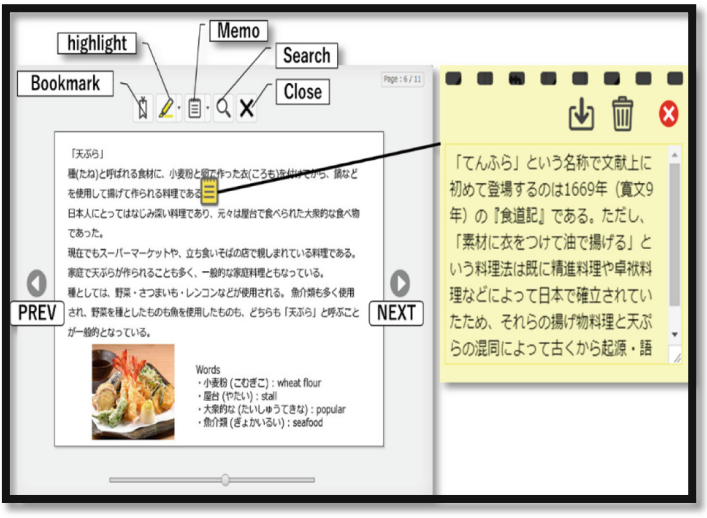

Fig. 2. Digital textbook viewer interface

3.2 SCROLL

SCROLL is to support real-life language learning for international students using ubiquitous technologies such as wireless networks, Global Positioning System (GPS) and QR codes. SCROLL provides a well-designed form to record a learning log. It adopts an approach to share contents with other users based on a LORE (Log-Organize-Recall-Evaluate) model proposed by [10].

For example, when an international student faces some problems such as how to read, write and pronounce words in their real life, they can record what they have learn with photo, location such as latitude and longitude, learning place (e.g. building name), and date and time of creation as a learning log as shown in Fig. 3. Figure 4 shows an example of the learning log. Learners can share the learning log each other.

Fig. 3. Add learning log

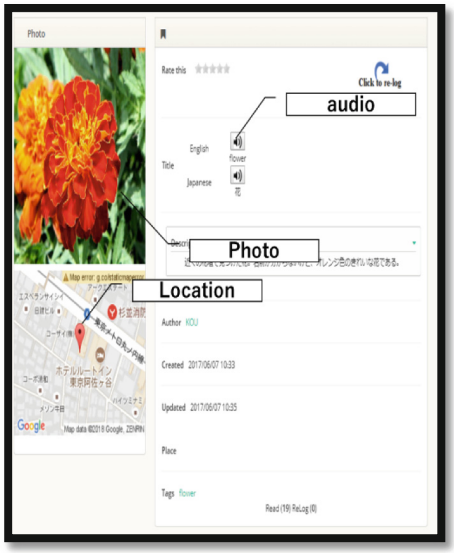

Fig. 4. A learning log

3.3 VASCORLL

Our previous VASCORLL could visualize and analyze learning logs accumulated in SCROLL to support real-life learning [11, 12]. For example, there is a learning log where a Japanese language learner learned “fan” at the university in the past. It means “扇風機 (mechanical fan)” in Japanese. There is another learning log where another learner learned the same word, “fan” in a different context in the past. In this case it means “うちわ (Uchiwa is a round, flat paper fan with a wooden or plastic handle)” in Japanese. Even if the English word is the same, the meaning might be different if the context is different. By using VASCORLL, they can learn such relationships.

The results of an evaluation experiment indicated that VASCORLL was a useful tool in detecting the correlations among learners, words and locations in a ubiquitous learning

environment. Furthermore, VASCORLL could increase learners' learning opportunities and learners can apply their own experiences to different learning places.

However, the system did not consider learning analytics in the seamless learning in order to find central words bridging digital textbook learning over real-life learning. Therefore, this study developed VASCORLL 2.0 based on the previous work.

4 VASCORLL 2.0

4.1 Design

The purpose of VASCORLL 2.0 is to support learners to apply what they have learned in digital textbooks to their real-life learning and vice versa. To link both digital textbooks learning and real-life learning, this study designed innovative visualization structures as shown in Fig. 5: Digital textbook Learning Structure (DLS) and Real-lie Learning Structure (RLS).

DLS consists of three layers, which are called "Digital textbook learner", "Words learned through digital textbooks", and "digital textbooks". RLS consists of three layers, which are called "Real-life learners", "Words learned in a real-life", and "Locations".

(1) Visualization method in the DLS: For example, when a learner read the learning contents in a digital textbook, he/she is likely to discover unfamiliar words. When he/she highlights the words in a digital textbook using AETEL, our visualization method will first create nodes indicating the learner, the word learned through the digital textbooks and the digital textbook. Secondly, it will connect the learner's node in the upper layer in the DLS to the word's node in the intermediate layer in the DLS. The word's node will be connected to the digital textbook node in the lowest layer in the DLS. By visualizing these links, teachers and students can grasp the following information: In the upper layer in the DLS, the learners' nodes with the large number of edges to words show that learners frequently highlighted words. In the intermediate layer in the DLS, the words' nodes with the large number of edges to learners' nodes and digital textbooks' nodes show that the words in the digital textbooks are frequently highlighted by the learners. In the lowest layer in the DLS, the digital textbooks' nodes with the large number of edges to the words' nodes show that the textbook contains many important words to be learned.
(2) Visualization method in the RLS: For example, when a learner records a learning log using SCROLL, our visualization method will first create nodes indicating the learner, the words learned in a real life, and the location. Secondly, it will connect the learner's node in the upper layer in the RLS to the word's node in the intermediate layer in the RLS. In addition, the word node will be connected to the location node in the lowest layer in the RLS. By visualizing these links, teachers and students can grasp the following information: In the upper layer in the RLS, the learners' nodes with the large number of edges to word nodes show that they recorded many learning logs in their real life. In the intermediate layer in the RLS, the word nodes with the large number of edges to the learner nodes and location nodes shows vital words that many learners recorded in their real life. In the lowest

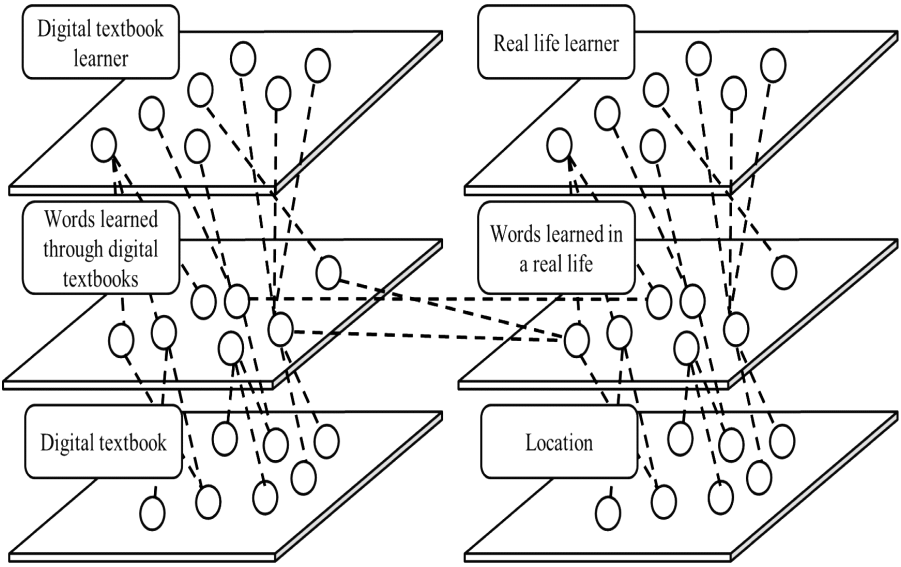

Fig. 5. Visualization structures in the seamless learning environments: Digital textbook Learning Structure (ELS) and Real-life Learning Structure (RLS)

layer in the RLS, the location nodes with the large number of edges to the word nodes show the locations where they can learn a lot of words.

To construct a seamless learning environment based on the above visualization structures, this study connects words learned through digital textbooks in the DLS to words learned in a real life in the RLS if both words are same. By connecting them, learners can learn the word in a real life related to it after learning a word in a digital textbook and vice versa. However, it is difficult to discover only connecting vital nodes which connect digital textbook learning and real-life learning only by connecting nodes. Therefore, this study presents the centralities using SNA as shown in Table 1. Degree, closeness and betweenness centralities are the fundamental measurement concepts for the social network analysis. Particularly, we hypothesize that the betweenness centrality could bridge the gap between digital textbook learning and real-life learning. For example, if a learner learns a word "natto" in a digital textbook, there would be various contexts where he/she can learn it such as supermarkets, shopping malls, and restaurants.

So far, the information on whether he/she can learn it in other contexts, or exact location information where he/she can learn it is yet to be provided. This study provides such information for learners.

Table 1. Centralities of social network analysis

Centrality	Formula (graph G: = (V,E) with V vertices and E edges)	Detail
Degree	$C_i^D = \frac{k_i}{N-1}$	Degree centrality is defined as the number of links incident upon a node. That is, it is the sum of each row in the adjacency matrix representing the network. N is the number of node and k_i is the degree of the node i
Closeness	$C_i^C = (L_i) = \frac{N-1}{\sum_{j \in G, j \neq i} d_{ij}}$	Closeness centrality is that the distance of a node to all others in the network. d_{ij} is the shortest path length between i and j, and L_i is the average distance from I to all the other nodes
Betweenness	$C_i^B = \frac{1}{(N-1)(N-2)} \sum_{j \in G, j \neq i} \sum_{k \neq i, k \neq j} \frac{n_{jk}(i)}{n_{jk}}$	Betweenness centrality is that the number of shortest paths between any two nodes that pass via a given node. n_{jk} is the number of the shortest path between j and k, and $n_{jk}(i)$ is the number of the shortest path between j and k that contains node i

5 Evaluation

5.1 Participants

Twenty international students who are studying at the University of Kyushu in Japan participated in the evaluation experiments. The students were from China, Malaysia, Thailand, and Mongolia and aged from 21 to 36 years old. Their length of stay in Japan ranged from 1 month to 5 years. The evaluation experiment was designed to evaluate the following point: Whether VASCORLL 2.0 can increase the participants' learning opportunities ("learning opportunities" denotes that the number of learning logs that they uploaded to the system during the evaluation period).

5.2 Procedure

An administrator uploaded digital textbook contents to the server prior to his/her class. The uploaded digital textbook contents were created according to JLPT (Japanese Language Proficiency Test). JLPT has been offered by the Japan foundation and japan education exchanges and services, as reliable means of evaluating and certifying the Japanese proficiency of non-native speakers.

This evaluation term was conducted for two weeks. At the first week, he/she had a briefing session on how to use AETEL with SCROLL since it was their first time to use it. Based on the uploaded learning logs during the first week, the participants were

divided into two groups as even as possible in terms of the keenness of language learning: Group A (Experimental group) and Group B (Control group).

Table 2 shows the number of learning logs that the participants uploaded during the first week. Group A participants uploaded 143 learning logs and group B participants uploaded 149 learning logs to the system. The means and standard deviations were 14.3 and 6.78 for Group A, and 14.79 and 6.51 for Group B. The t-test shows that there was no significant different between the two groups ($t = 0.201$, $p > 0.05$). This result indicates that the participants of the two groups have learning opportunities before using VASCORLL 2.0. Then, he/she introduced how to use VASCORLL 2.0. After evaluation experiment, this study considers the difference of learning activities between Group A and B using collected learning logs.

Table 2. Number of uploaded learning logs in the first week (practice period)

Group	Participants	Learning logs	Mean	SD	t	p
Group A	10	143	14.3	6.78	0.201	$p > 0.05$
Group B	10	149	14.9	6.51		

5.3 Result

Table 3 shows the means and standard deviations for experimental and control groups in the 1st and 2nd week.

Table 3. Number of uploaded learning logs in the second week

	1st week	2nd week	F	P
Group A	143 (6.78)	189 (6.41)	4.11	0.08
Group B	149 (6.51)	127 (6.75)		

The result of repeated measures analysis showed that interaction effect between group and time of measurements was significant, ($F = 4.11$, $p <= 0.1$). In other words, VASCORLL 2.0 was able to increase their learning opportunities. Figure 6 shows the number of their uploaded learning logs from the first to the second week. The horizontal axis represents the first and second week, and the vertical axis represents the number of their uploaded learning logs. The number of uploaded learning logs of Group A increased better than that of Group B. These results imply that VASCORLL 2.0 plays an important role to increase the number of their uploaded ULLs.

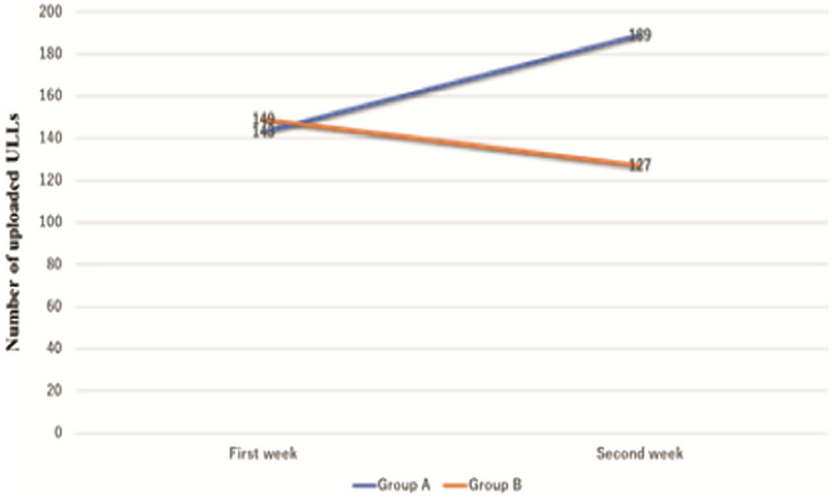

Fig. 6. Comparison between the number of the uploaded logs during the 1st and 2nd week

6 Discussion and Conclusion

In recent years, the design of seamless learning environments has been frequently discussed. Majority of the researches indicated that considering how to design and evaluate with using mobile and ubiquitous technologies in order to enhance learners' achievements and sustaining their learning motivation, while this study indicated that importance incorporated learning analytics perspective into seamless learning. An evaluation was conducted to examine whether learners' learning opportunities can be increased by providing the analysis and visualization results for them. The experimental results showed that our visualization and analysis significantly increased their learning opportunities.

Consequently, in our proposed visualization and analysis system, learners were likely to understand the relationships between a word in a formal learning setting and in an informal setting from visualization and analysis results and share them if they are interested in it.

However, it is yet to be conducted long-term evaluation experiment. It is necessary to evaluate whether learners can keep their learning motivations for a long term. VASCORLL 2.0 will be evaluated repeatedly, with considering long-term evaluation experiment in the future. In addition, we will extend our research based on recent outcome of learning analytics [13, 14] and other domains such as career support [15] and science education [16].

Acknowledgements. The part of this research work was supported by the Grant in-Aid for Scientific Research No. 16H06304 and No. 17K12947 from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan.

References

1. Wong, L.H., Looi, C.K.: What seams do we remove in mobile-assisted seamless learning? A critical review of the literature. Comput. Educ. **57**, 2364–2381 (2011)
2. Looi, C.K., Sun, D., Xie, W.: Exploring students' progression in an inquiry science curriculum enabled by mobile learning. IEEE Trans. Learn. Technol. **8**(1), 43–54 (2015)
3. Milrad, M., Wong, L.H., Sharple, M., Hwang, G.J., Looi, C.K., Ogata, H.: Seamless learning: an international perspective on next generation technology enhanced learning. In: Berge, Z.L., Muilenburg, L.Y. (eds.) Handbook of Mobile Learning, chap. 9, pp. 95–108 (2013)
4. Wong, L.H., Chai, C.S., Aw, C.P., King, R.: Employing the TPACK framework for research-teacher co-design of a mobile-assisted seamless language learning environment. IEEE Trans. Learn. Technol. **8**(1), 31–42 (2014)
5. Uosaki, N., Li, M., Hou, B., Ogata, H., Yano, Y.: Supporting an English course using handhelds in a seamless learning environment. In: Workshop of the 18th International Conference on Computers in Education (ICCE 2010), pp. 185–192 (2010)
6. Gasevic, D., Dawson, S., Siemens, G.: Let's not forget: learning analytics are about learning. TechTrends **59**(1), 64–71
7. Stuart, C.: Information visualization. In: The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications. Lawrence Erlbaum (2007)
8. Mouri, K., Ogata, H.: Ubiquitous learning analytics in the real-world language learning. Smart Learn. Environ. **2**(15), 1–18 (2015)
9. Kiyota, M., Mouri, K., Uosaki, N., Ogata, H.: AETEL: supporting seamless learning and learning log recording with e-book system. In: Proceedings of the 24th International Conference on Computers in Education, pp. 306–314 (2016)
10. Ogata, H., Hou, B., Li, M., Uosaki, N., Mouri, K., Liu, S.: Ubiquitous learning project using life-logging technology in Japan. Educ. Technol. Soc. J. **17**(2), 85–100 (2014)
11. Mouri, K., Ogata, H., Uosaki, N.: Analysis of ubiquitous learning logs using social network analysis. Int. J. Mob. Learn. Organ. **9**(2), 101–123 (2015)
12. Mouri, K., Ogata, H., Uosaki, N.: Visualization and analysis system for connecting relationships of learning logs. In: International Conference on Computer in Education (ICCE 2016), pp. 315–324 (2016)
13. Mouri, K., Okubo, F., Shimada, A., Ogata, H.: Bayesian network for predicting students' final grade using e-book logs in university education. In: 16th International Conference on Advanced Learning Technologies, pp. 85–89 (2016)
14. Shimada, A., Mouri, K., Ogata, H.: Real-time learning analytics of e-book operation logs for on-site lecture support. In: The 17th IEEE International Conference on Advanced Learning Technologies, pp. 274–275 (2017)
15. Uosaki, N., Ogata, H., Mouri, K., Lkhagvasuren, E.: Career support for international students in Japan using ubiquitous learning log system. In: The 15th International Conference on Advanced Learning Technology, pp. 78–82 (2015)
16. Ogata, H., Mouri, K., Bono, M., Joh, A., Takanashi, K., Osaki, A., Ochiai, H.: Supporting science communication in a museum using ubiquitous learning logs. In: Proceedings of Workshop on Computational Approaches to Connecting Levels of Analysis in Networked Learning Communities (2014)