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Visualization for Analyzing Learning Logs in the Seamless Learning Environment

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Abstract: This paper describes an innovative visualization method called Seamless Learning Visualization (SLV). As far, several researchers have introduced in the seamless learning environments in order to bridge formal learning over informal learning. However, their focus was the implementation of the seamless learning environment. Our proposed SLV is to visualize and analyze learning logs collected in the seamless learning environment. This paper describes how our visualization method could contribute to bridging the gap between formal and informal learning. An experiment was conducted to evaluate (1) whether SLV would be beneficial in terms of usability in finding words in the seamless learning environment and (2) Which visualization layout (Random layout, Force-directed layout, Yifan-multilevel layout and SLV) is effective in supporting learning in the seamless learning environment. Fifteen international students participated in the evaluation experiment in order to evaluate (1) and (2). In the experiment, it was found that SLV was very beneficial in terms of usability and effectiveness for learning than previous visualization methods.

Keywords: Seamless learning, ubiquitous learning, e-book, information visualization, learning analytics, ubiquitous learning analytics

1. Introduction

Seamless learning is a learning notion that emphasizes the bridging of different learning efforts across a variety of learning settings (such as formal and informal learning, individual and social learning, and learning in physical and digital realms), by leveraging mobile and ubiquitous technologies to assist individual students. Several researchers in the seamless learning field have pointed out that mobile and ubiquitous technologies have enabled students to learn continuously across different contexts. According to (Wong et al., 2015; Looi et al., 2015; Milrad et al., 2013), the main characteristics of seamless learning are shown as follows: (1) Encompassing formal and informal learning, (2) Encompassing personalized and social learning, (3) Across time, (4) Across locations, (5) Ubiquitous knowledge access, (6) Encompassing physical and digital worlds, (7) Combined use of multiple device types, (8) Seamless switching between multiple learning tasks, (9) Knowledge synthesis, (10) Encompassing multiple pedagogical or learning activity models.

One of its most important issues is how to connect formal learning with informal one, because this is inevitable in designing both in-school and out-of-school activities in order to link what they have learned in school with their daily life experiences and vice versa, that is to say, to connect what they have learned in their daily lives to their experiences in class. To tackle the issues, some researchers in the educational engineering have constructed in the seamless learning environment. For example, Wong et al. (2014) reported a seamless learning system called MyCLOUD (My Chinese UbiquitOUs learning Days), which allows students to learn Chinese language in both in-school and out-of-school learning spaces. Uosaki et al. (2010) reported a seamless learning system called SMALL System (Seamless Mobile-Assisted Language Learning support system) in order to support Japanese students who aim to learn English language in a formal and an informal setting.

Most of these studies focused on realizing a seamless learning environment at school or university. Once realized, the students' learning logs have been accumulated into their server. Therefore,

we contend that learning efficacy can be enhanced by visualizing their accumulated learning logs. So far, little attention has been paid to this aspect. The issues of learning analytics based on seamless learning are as follows:

(1) How to visualize learning logs in the seamless learning environments.
(2) How the visualization can bridge the gap between formal learning and informal learning.

To tackle these issues, this paper proposes an innovative visualization method called Seamless Learning Visualization (SLV), which supports learners to apply their own learning experiences in a formal setting to their own daily lives in an informal setting. This paper describes the design, the implementation and the initial evaluation of SLV.

2. Related works

2.1 E-book-based learning analytics

As a genetic term, an electronic book (variously: e-book, eBook, e-Book, ebook, digital book or e-edition) or a digital book is a book-publication in digital form, consisting of text, images, or both, readable on computers or other electronic devices. Some researchers at Kyushu University in Japan reported several analytics using a document viewer system called BookLooper. The objectives of their studies are as follows: (1) improving of learning materials, (2) analyzing learning patterns, (3) detecting the students' comprehensive level, (4) predicting final grades, and (5) recommending e-books in accordance with personalization (Yin et al, 2015; Ogata et al., 2015; Mouri et al., 2016). Also, Kiyota et al. (2015) proposed seamless learning system with EPUB (Electronic PUBlication: one of the e-book formats), which support international students to read contents in the e-book in a formal and in an informal setting.

The most common idea of those projects is to visualize and analyze either collected in a formal setting or an informal setting. However, our proposed SLV aims to visualize learning logs accumulated in both learning environments (formal and informal setting).

2.2 Ubiquitous Learning Analytics

Ubiquitous learning has been the focus of attention in educational researches across the world. One of the characteristics of u-learning allows learners to learn anytime and anywhere by using ubiquitous technologies such as RFID tags, QR-codes, wireless communications, mobile phones and wearable computers. These types of learning include not only in-class learning (formal learning), but also a variety of out-of-class learning (informal learning) in spaces such as homes, libraries, and museums. In such learning approaches, the majority of researchers have been constructing a context-aware u-learning system, which integrated learning materials and contextual information by using ubiquitous technologies.

For example, Hwang et al. (2011) developed a context-aware ubiquitous learning system with the attached RFID tag on the plants. The application domain of their studies is nature science. When a learner arrives in front of a plant with an RFID tag, the system asks him or her questions about the plant's features, such as its trunk, shape, and color after they received it using an RFID reader. This enables learners to understand deeply by connecting knowledge about the plant with the real life experience.

On the other hand, Ogata et al. (2014) developed their u-learning system called SCROLL (System for Capturing and Reminding of Learning Log), which allows users to share with others by recording what learners have learned in their daily lives using a web browser and mobile device anytime and anywhere. The application domain of their studies is mainly language learning. Using SCROLL, international students can learn new knowledge through their experiences in their daily life with photos, audios, and context such as location and place.

Aljohani et al. (2012) described learning analytics called Ubiquitous Learning Analytics (ULA) in order to analyze enormous learning data, including contextual information accumulated by using these u-learning systems. The value of the ULA is discussed by considering two possible kinds of interactions. The first is the interaction between learners and their contexts, referred to as learners-to-context interaction. The second is the interaction between learners and context-based knowledge, referred to as learner-to-context-based learning materials interaction. They suggested that

the use of learner contextual data can enhance the interaction between learners and their mobile devices, and between learners and objects in their learning environments. In addition, analyzing or visualizing contextual data has a potential to increase their learning opportunities by recommending the relationships between knowledge and contexts. One of the issues of the ULA is how to visualize and analyze two interactions: learners-to-context and learner-to-context-based words. With this in minds, Mouri et al. (2014, 2015a) tackled the issues and reported visualization and analysis system called VASCORLL. However, the focus of their studies was to visualize and analyze learning logs accumulated in ubiquitous learning environment (informal setting). Our SLV enables learners to bridge the gap between formal and informal learning by visualizing what they have learned in the classroom using e-book system and what they have learned outside the classroom using SCROLL.

3. System design

We have constructed the seamless learning environment to support international students aimed at language learning as shown in Figure 1. There are two ways of supporting learning activities in our framework:

(1) Supporting formal learning using SCROLL with e-book system: The teachers or instructors create e-book contents using PowerPoint and Keynote before class, and use them in their course in the university (Step 1 in Figure 1). International students can create an account and join the course (Step 2). After international students choose a target e-book in their course in accordance with their language level, they can read those learning materials on their web browser using e-book system as shown in Figure 2 (left). They can also use the e-book system before, during and after class. Their action logs such as opening a book, bookmark, zooming, and page turning are collected into databases. If international students do not know a word in the e-book, they can save the word using SCROLL, and their logs are accumulated into databases.

(2) Supporting informal learning using SCROLL with e-book system: In out-of-class activity, international students proactively observe things, grasp the meanings, review on their daily encounters, and apply what they have learned in an informal learning to other learning situations. For example, when international students learned how to read, write and pronounce “natto (a traditional Japanese food made from fermented soybeans)” in the e-book system, then they can save their experiences as learning logs using SCROLL. The learning log includes the author name, language, time of creation, location (latitude and longitude), learning place and tags. They actually apply it to their real-life experience at the places such as supermarkets and restaurants using SCROLL with SLV (Step 3). In addition, when they learn a word in an informal setting, they can find other learning materials where it is used (Step 4). It is expected to let learners have an interest to other learning materials. The teachers and instructors watch learners’ activities such as how often they log in, view contents, save learning logs and etc. and they can send message to encourage inactive learners to use the system by recommending some useful learning logs (Step 5).

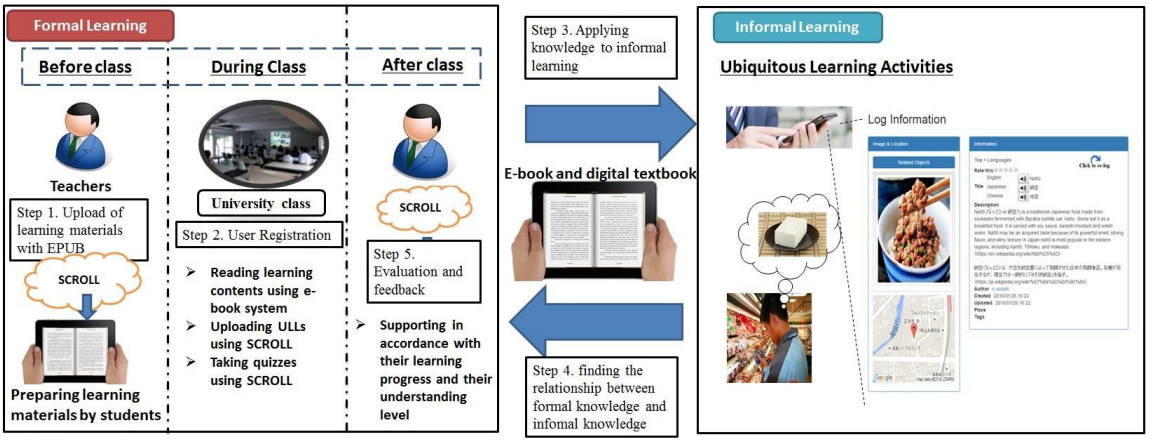

Figure 1. Design of the seamless learning system

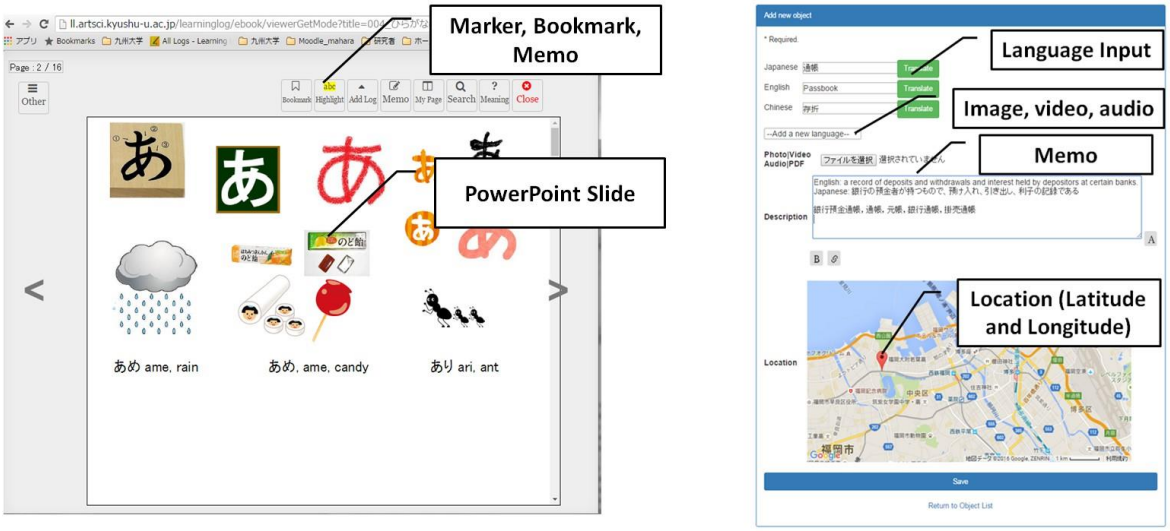

Figure 2. e-book system (left) and an example interface of adding learning log (right)

4. Seamless Learning Visualization Method

4.1 Visualizing learning logs in the seamless learning environment based on three-layer structure

In order to visualize learning logs collected in the seamless learning environment, this paper uniquely defines them as two types of three-layer structures as shown in Figure 3: Formal Learning Structure (FLS) and Informal Learning Structure (ILS).

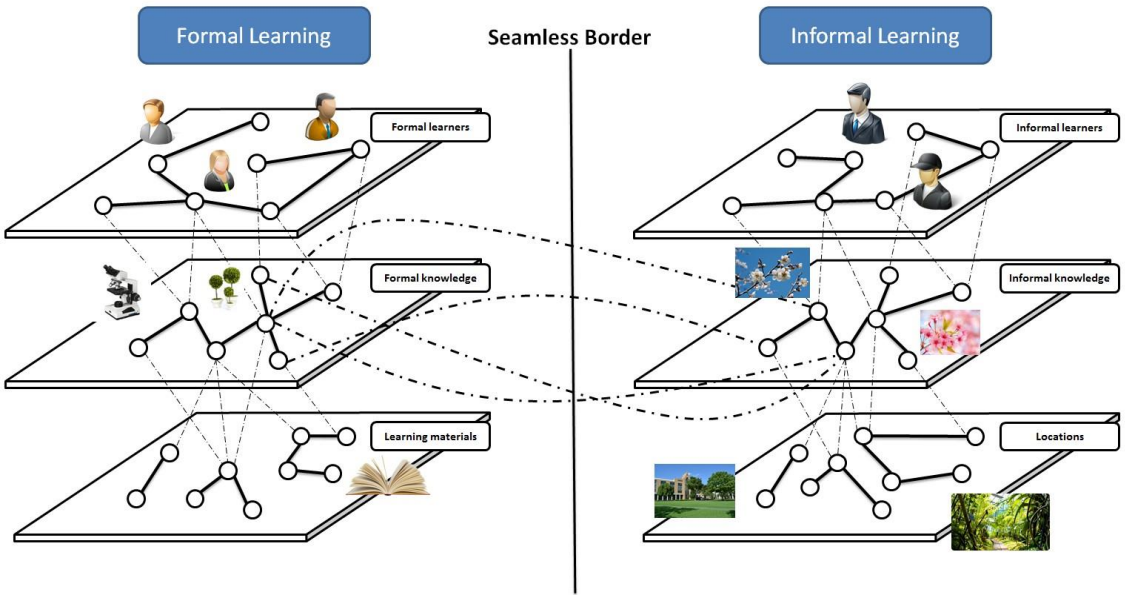

Figure 3. Visualization methods in the seamless learning environment: Formal Learning Structure (FLS) and Informal Learning Structure (ILS)

FLS includes three layers, which are called “formal learners”, “formal words”, and “learning materials”.

(1) Formal learners: The upper layer shows learners studying in a formal setting, such as lecture room and classroom.
(2) Formal words: The intermediate layer shows words that they have learned in a formal setting using SCROLL with e-book system.
(3) Learning materials: The Lowest layer shows learning materials uploaded by teachers or instructors.

In order to visualize the relationships among formal learner, formal words and learning materials, this paper visualizes the relationships using network directed graph. How our visualization method connects relationships of each node? For example, if a learner learns and saves a newly learned word using SCROLL with e-book system during class, our visualization method will connect the learner' node in the upper layer in the FLS to the word' node in the intermediate layer in FLS. Besides, the word' node will connect to the learning material nodes in the lowest layer in FLS. By visualizing these links, teachers and students can grasp which e-book and which page that word appears.

ILS includes three layers, which is called "Informal learners", "Informal words", and "Locations"

(1) Informal Learners: The upper layer shows learners studying in an informal setting such as museums, restaurants and city halls.
(2) Informal words: The intermediate layer shows words that they have learned in an informal setting using SCROLL.
(3) Locations: The lowest layer shows contextual data such as location and place where they have learned in an informal setting.

According to Mouri et al. (2015b, 2015c), how to connect the relationships in ILS are as follows: If a learner learns and saves a new word in an informal setting using SCROLL, it will connect the learner' node in the upper layer in ILS to the word' node in the intermediate layer in ILS. Then, the word' node will connect to the node of the location where they have learned it. For example, if the learner learned "natto" at the "supermarket", it will connect "natto" in the intermediate layer to "supermarket" in the lowest layer.

In order to bridge the relationships between FLS and ILS, the visualization will connect same words which appear in the intermediate layers both in the FLS and ILS (e.g. "natto" in the intermediate layer in FLS and "natto" in the intermediate layer in ILS). The analytics using two types of three-layers have the following advantages:

(1) On the FLS side, the formal words with a large number of links to related learning materials mean students learned it in many classes. For example, if a student learns the word "passbook" using a learning material during class, the visualization informs them of other learning material context where it is used. In addition, the formal words with a large number of links to the formal learners mean words which were learned by many students during class.
(2) On the ILS side, the informal words that are related to many places are the words can be learned in various places. When a learner experiences tea ceremony of a traditional Japanese culture, for instance at the university, they are likely to learn such tea ceremony related words as maccha (special tea for tea ceremony), seiza (to sit in the correct manner on a Japanese tatami mat). They can also be learned in other places. Maccha can be learned at the supermarket, and the seiza can be learned at the martial arts gym.

4.2 Color coding of the visualized nodes

To avoid having learners get confused when they see each node since there are many visualized nodes, it is definitely necessary to establish some criteria for the distinction of each node. To effectively distinguish each node, we created a color coding scheme for the nodes as shown in Table 3.

Table 1 Color coding to distinguish the kinds of nodes

Node	Layer	Node Color
Formal learners	Upper in FLS	Red
Formal words	Intermediate in FLS	Yellow
Learning materials	Lowest in FLS	Blue
Informal learners	Upper in ILS	Pink
Informal words	Intermediate in ILS	Green
Locations	Lowest in ILS	Light blue

5. Implementation

5.1 The layout types of network graph

In the field of network graph studies, the majority of them have focused on advantages such as good-quality results, flexibility, simplicity, and interactivity.

For example, a network graph called "Random layout" as shown in Figure 4 (1) is a simple algorithm generating then randomly on the network graph. The advantage of the random layout allows drawing very fast on the network graph. However, the disadvantage of that is that it is difficult to grasp position of the nodes.

A network layout called "Force-directed layout" as shown in Figure 4 (2) uses the force vector algorithm proposed in the Gephi software, appreciated for its simplicity and for the readability of the network, which helps visualization (Mathieu et al., 2014).

A network layout called "Yifan Hu multilevel" as shown in Figure 4 (3) uses a very fast algorithm to reduce complexity (Hu et al., 2001). The repulsive forces on one node from a cluster of distant nodes are approximated by a Barners-Hut calculation, which treats them as one super-node (Barnes et al., 1986). Therefore, it is easy to gather important nodes in the center of the graph.

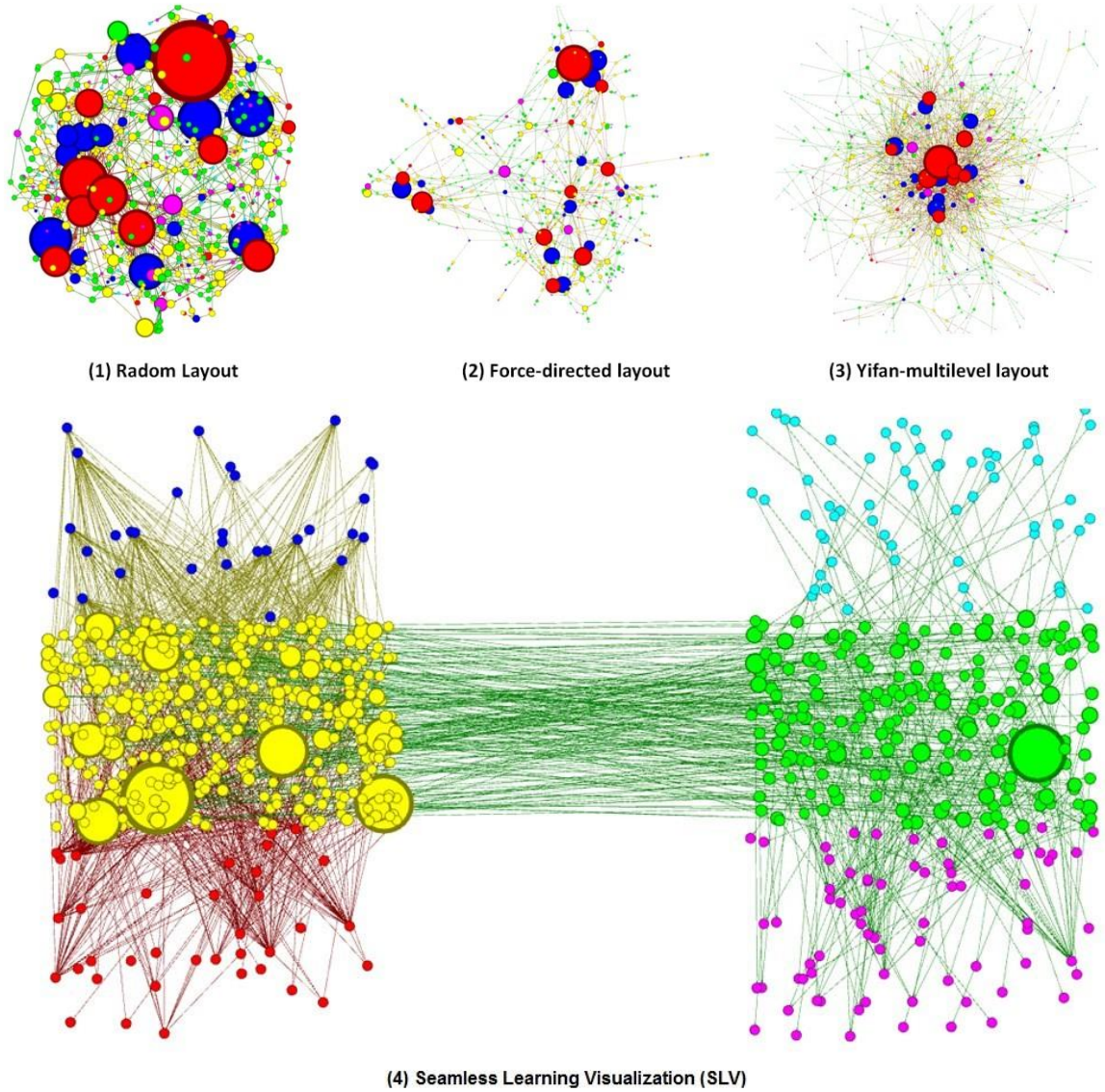

Figure 4. the types of network graph: random layout, force-directed layout, yifan-multilevel layout, seamless learning visualization

Figure 4 (4) shows the seamless learning visualization layout that we developed. It is divided into six areas as described in Section 4.1. The upper-left shows the nodes of formal learners. The center-left shows the nodes of formal words. The bottom-left shows the nodes of learning materials.

The upper-right shows the nodes of informal learners. The center-right shows the nodes of informal words. The bottom-right shows the nodes of locations.

5.2 A scenario of using SLV web interface

Figure 5 (left) shows the enlarged graph in both formal and informal word areas. There are two learning scenarios by utilizing the result of visualization, which are called "Learning via formal words" and "Learning via informal words" as shown in Figure 5 (right).

(1) Learning via formal words: As shown in Figure 5 (left), the word "natto" is the biggest size in the formal words areas. By clicking it, the system moves to the page where the word "natto" appears. That way, learners can grasp which e-book and which page includes it.

(2) Learning via informal word: After learning "natto" in the e-book contents, learners can find "natto" in the informal words areas. By clicking it, the system moves to the learning logs ("natto" pages of SCROLL) learned in the informal setting. Unlike the above learning method (1), by utilizing the ULL (Ubiquitous Learning Logs), they can learn other learners' learning experiences (not only words but also time, location and place information) that cannot be learned in the formal setting.

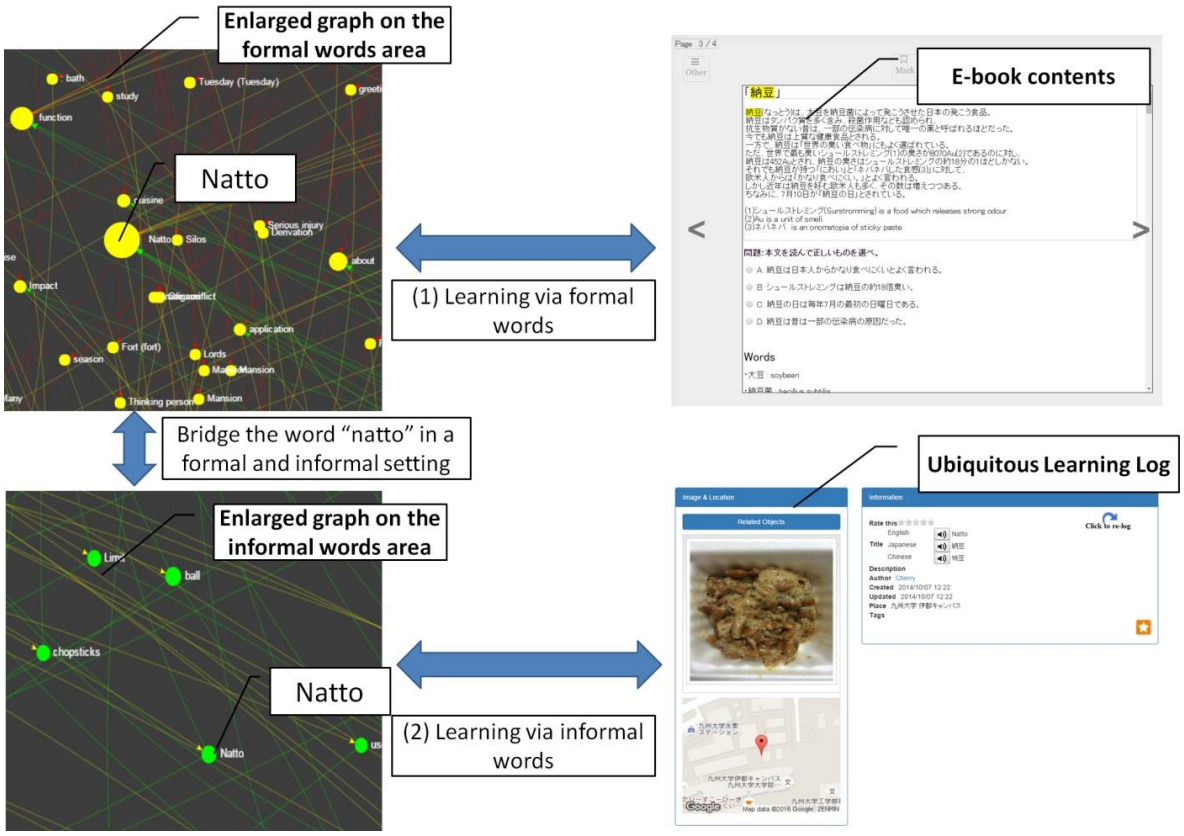

Figure 5. The enlarged graph in both formal and informal words and each hyperlink

6. Evaluation Experiment

6.1 Participants and the purpose of evaluation

Fifteen students studying at the University of Tokushima and Kyushu University participated in the evaluation experiment. The evaluation experiment was designed to evaluate the following two points:

(1) Whether SLV would be beneficial in terms of usability in finding words in the seamless learning environment.

(2) Which visualization layout (random layout, force-directed layout, yifan-multilevel layout and SLV) is effective in supporting learning in the seamless learning environment?

6.2 Method

Before the evaluation experiment began, a Japanese instructor uploaded e-book contents to SCROLL server. The uploaded e-book contents were created based on the JLPT (Japanese Language Proficiency Test). Since they had never used SCROLL with e-book system before, they practiced using it for one day before using SLV and other visualization layouts. After that, they practiced using SCROLL with all visualization layouts for one day. Participants used their own note-PC and smartphones (iPhone 5s or android device) to upload their learning logs in a formal and an informal setting anytime and anywhere. The mobile devices used in the evaluation experiment were ten iPhone 4s or 5s and four Samsung Galaxy Note 3s. When the participants used SLV during evaluation, they used their Note-PC because the screen size of smartphone is too small. The participants learned words using four visualization layouts: random layout, force-directed layout, yifan-multilevel layout and SLV. They were required to use the prearranged one layout (e.g. participants firstly had to use random layout).

After the evaluation, the participants were asked to complete a questionnaire that used a five-point-scale to evaluate the system's performance and usability, as well as the ease of understanding the content and finding other learning logs using SLV. In addition, we also evaluated the network layouts used in the previous layout and SLV. For the comparison, the participants were asked to complete the questionnaire.

6.3 Result and Discussion

The questionnaire results are presented in Table 2 (Best: 5; Wrong: 1). Q1 asks about whether the participants were able to find that the words that learners learned during class using e-book system were connected to the words that learners learned outside class. Similarly, Q2 asks about whether the participants were able to find that the words that learners have learned outside class were connected to the words that learners have learned in class. The results of Q1 and Q2 revealed that the participants found the relationships of words between formal and informal learning. For example, some students learned Japanese word, " 納豆(natto)" in e-book contents in class. By uploading "natto" to the system, the system could show them that other students had learned it at the shopping mall and supermarkets. That way SLV was able to connect the words between formal and informal learning.

Q3 asks about whether the system was easy to use. They were asked to evaluate the usability in terms of the operability and readability of the visualized graph. The response shows that many participants felt that the visualization functions were easy to use.

Table 2 Result of the five-point-scale questionnaire for evaluating usability of system

Question	Mean	SD
Q1. Were you able to connect words inside-class to out-side-class learning by using the system?	4.13	0.63
Q2. Were you able to connect words out-side-class to inside-class learning by using the system?	3.93	0.88
Q3. Was the system ease of use?	3.86	0.99

We also evaluated the network layouts used in the previous works and the SLV we developed. For the comparison, the participants used the conventional layouts and SLV during the evaluation and completed the questionnaire shown in Table 3.

Table 3 The questionnaire about layouts

Question
Q1. Which layout is the easiest to use?
Q2. Which layout is the most effective for learning?

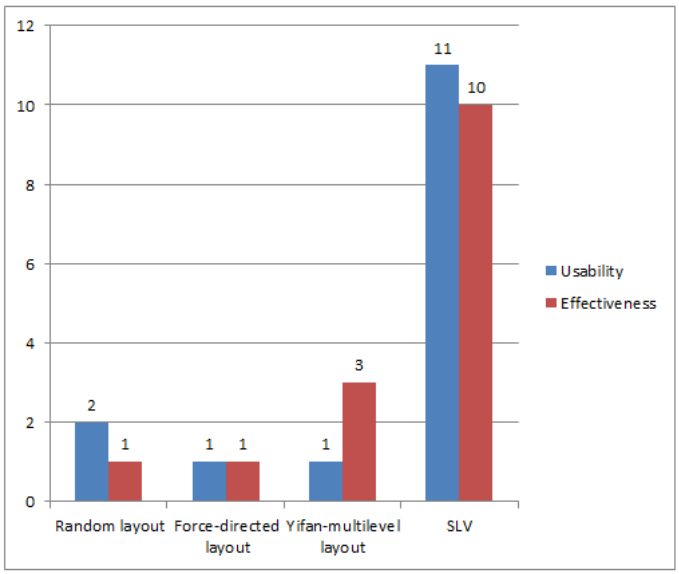

Figure 6. The number of selected layouts by each participants in the evaluation experiment

The aim of Q1 was to evaluate the usability of the layouts, and aim of Q2 was to evaluate the learning effectiveness. Figure 6 shows the results of the questionnaires about layouts. The results indicated that for both usability and effectiveness, majority of participants preferred the SLV than the other layouts. When comparing the SLV with random layout, the processing speed of the SLV is slow, but it is very useful in finding the relationships between words in the seamless learning environment. When comparing the SLV with the force-directed layout and Yi-fan multilevel layout, the SLV is highly regarded. We also asked the participants to comment on "why did you prefer to the SLV than other layouts?". The comments are as follows:

(1) I think that the speed of visualization of SLV is relatively slow. But, other layouts were not able to grasp the position of nodes on the graph. By using SLV, I was able to grasp the position of nodes. I select the SLV.
(2) It is very beneficial to find the relationships between formal words and informal words. Especially, visualizing links between informal words and location are impressive for learning.

Form these comments and questionnaires, SLV turned out a very good visualization method in the seamless learning in terms of easiness to find words bridging formal and informal learning. It was suggested the processing speed of the SLV should be improved. Taking the suggestion into account, our future works will be described in the next section.

7. Conclusion and future works

This paper described an innovative visualization method in the seamless learning environment, which is called Seamless Learning Visualization (SLV). SLV enabled teachers and learners to learn and find the relationships between words in the seamless learning environment. In the visualization structure, two types of three-layer structures called FLS and ILS were adapted. That way, teachers and students could easily grasp words bridging between words in FLS and ILS. This paper evaluated whether they were able to find the most pivotal words on the network graph using visualization methods such as "Random", "Force-directed", "Yifan-multilevel" and "SLV".

The evaluation was conducted after the implementation of SLV. A questionnaires with five-point-scale showed that SLV was a useful tool to find words in the seamless language learning. The results of questionnaires for evaluating each visualization layout showed the most effective visualization for learning was SLV.

SLV will be evaluated repeatedly. As described in Section 6, we will improve the processing speed of the SLV by utilizing ways such as data cleaning and filtering. In addition, our future works include applying SLV to other application domains such as math, physics, and science education (Ogata

et al., 2014b), and long-term evaluations with an enough number of participants. Also, we will consider that applying Onomatopoeia learning and career support for international students (Uosaki et al., 2015).

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