Learning Analytics in a Seamless Learning Environment

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ABSTRACT
This paper describes seamless learning analytics methods of VASCORLL (Visualization and Analysis System for CoNnecting Relationships of Learning Logs). VASCORLL is a system for visualizing and analyzing the learning logs collected by the seamless learning system, which supports language learning in the real-world. As far as several studies have been made 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 in education. This study focuses on visualizing and analyzing learning logs collected in the seamless learning environment. This paper describes how our analytics could contribute to bridging the gap between formal and informal learning. An experiment was conducted to evaluate 1) whether our developed VASCORLL is effective in connecting the words learned in formal learning to the ones learned in informal learning, 2) which social network algorithm is effective to enhance learning in the seamless learning environment. Twenty international students participated in the evaluation experiment, and they were able to increase their learning opportunities by using VASCORLL. In addition, it was found that the betweenness centrality is useful in finding central words bridging formal and informal learning.

CCS CONCEPTS
- Human-centered computing → Ubiquitous and mobile computing → Ubiquitous and mobile computing systems and tools

KEYWORDS
Ubiquitous learning, seamless learning, learning analytics

1 INTRODUCTION
Seamless learning is defined as an approach “when a person experiences a continuity of learning, and consciously bridges the multifaceted learning efforts, across a combination of locations, times, technologies or social settings” [28]. Several researchers in the seamless learning field have pointed out that mobile and ubiquitous technologies have enabled students to learn continuously across different contexts [10], [11]. 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 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. In this paper, the term formal learning is defined as the learning under intentionally organized environments and the term informal learning is defined as the learning out of organized environments. For example, inside-of-class learning is one of the formal learning situations and out-of-class self-learning is one of the informal learning situations.

One of the application domains of seamless learning is language learning. For example, Wong et al. [27] 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. [25] 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 and analyzing their accumulated learning logs. So far, little attention has been paid to this aspect. The research issues of learning analytics based on seamless learning environments are as follows:

(1) How to visualize and analyze learning logs accumulated in formal and informal learning systems.

(2) How the analytics can bridge the gap between formal learning and informal learning.

(3) How the analytics can enhance and support students’ learning experiences.
To tackle these issues, this paper proposes a visualization and analysis system called VASCORLL (Visualization and Analysis System for Connecting Relationships of Learning Logs). VASCORLL is to connect logs collected by using e-book system with logs collected by using a ubiquitous learning system called SCROLL (System for Capturing and Reminding of Learning Log) [21]. The rest of this paper is constructed as follows. Section 2 discusses related works regarding e-book-based learning analytics and ubiquitous learning analytics. Section 3 introduces our proposed seamless learning design and the system that implements with SCROLL. Section 4 describes the methods of VASCORLL that works in the seamless learning environments. Section 5 and 6 describes the implementation and initial evaluation experiment on the VASCORLL. Section 7 summarizes the contributions made by the work and future works.

2 RELATED WORKS

2.1 E-book-based Learning Analytics

Nowadays, majority of textbooks are not only published in printed format, but are also created as electronic text-book (e-book) format available online or on mobile devices [2], [24]. Japanese government has announced their future policy to introduce “instead of” as their policy that they plan to introduce e-books in all K12 schools by 2020. Many countries’ e-book policies only focus on introducing the technology of e-books into K12 schools [22]. However, little attention has been paid to visualizing and analyzing important information from the e-book activity logs. Therefore, it is necessary to explore various analytics in this aspect.

This paper calls visualizing and analyzing of e-book activity logs “E-book-based Learning Analytics (ELA)”. In such analytics, some researchers at Kyushu University in Japan reported several analytics using a document viewer system called BookLooper [22], [23], [29]. The objective of their studies is 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. On the other hand, Kiyota et al. [8] proposed a seamless learning system with EPUB (Electronic PUBLICATION: one of the e-book formats). It is available on various mobile devices including general smartphones, and it is easy to obtain information, such as location, acceleration and rotation of the terminal via their integrated sensors while students read the books.

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

2.2 Ubiquitous Learning Analytics

In recent years, ubiquitous learning (u-learning) or mobile learning (m-learning) has been the focus of attention in educational research across the world [14], [19]. U-learning has been carried out using ubiquitous technologies such as RFID tags and cards, wireless communications, mobile phones, Personal Digital Assistants (PDAs), and wearable computers [20]. 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. [6] 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. [21] developed their u-learning system called SCROLL, 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. [17] 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 learnerto-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 improve knowledge of the patterns of learners’ interactions with their 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.

Mouri et al. [12], [13] tackled the issues and reported innovative visualization and analysis methods. However, the focus of their studies was to visualize and analyze learning logs accumulated in ubiquitous learning environments (informal setting). Our VASCORLL enables students to bridge the gap between formal and informal learning by visualizing and analyzing what they have learned in the classroom using a document viewer system and what they have learned outside the classroom using SCROLL. By providing the results of visualization and analysis, it is expected that students can apply what they have learned in the classroom to what they have learned outside the classroom.

3 SYSTEM DESIGN

3.1 SCROLL

As described in Section 2.2, this paper utilizes SCROLL to support international students in the real-world language learning and share their experiences with each other. In the SCROLL
project, Ubiquitous Learning Log (ULL) is defined as a digital record of what learners have learned in their daily lives. To simplify the process of capturing learners’ learning experiences, SCROLL provides an easy-to-use interface. It adopts an approach to share contents with other users based on a LORE (Log-Organize-Recall-Evaluate) model proposed by Ogata et al. [21]. How the model supports each learning process is described as below.

(1) Log: International students are likely to face some problems such as how to read, write and pronounce words in their daily life. They can save what they have learned with photo, such as location (latitude and longitude), learning place, and date and time of creation as a ULL as shown in Figure 1.

(2) Organize: When an international student adds a new ULL, SCROLL compares it with his past ULL and those of other users, categorize it and shows him related ULLs. By showing it with information on when and where they learned it, past learning and current learning can be linked and their knowledge will be reorganized and reinforced [26].

(3) Recall: Learners are likely to forget what they have learned before. It is necessary to support re-calling their past ULLs. During this learning process, the system support learners to recall what they have learned by using quiz.

(4) Evaluate: It is important to recognize what and how the learner has learned by analyzing the past ULLs, so that he or she can improve what and how to learn in the future. Mouri et al. [12] developed an innovative visualization system that implemented Time-Map [7], network graph based graph theory in order to support this learning process.

3.2 Seamless Learning System based on e-Book

The above SCROLL is instantiated as the seamless learning environment to support formal and informal language learning. Figure 2 shows the design framework of our system that integrated SCROLL with EPUB. There are two ways of supporting learning activities in our framework:

(1) E-book-based learning activity: The teachers or instructors create e-book contents using PowerPoint and Keynote before 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 smartphone and PCs. 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 EPUB viewer as shown in Figure 3. They can underline, mark unknown words in the e-books, and save it using SCROLL (Figure 1). In addition, they use the EPUB viewer to prepare before class, and to review after class. Therefore, they can read the learning materials not only during class but also outside class, such as their home or libraries. Students’ action logs such as opening a book, zooming, and page turning are collected into E-book logs and learning materials database.

(2) Authentic learning activity: In out-of-class activity, international students proactively observe things, grasp the meanings and review on their daily encounters, and apply their past experiences to other learning situations. For example, when international students learn how to read, write and create “通帳 (passbook)” in an e-book during class, then they can actually apply their experience through the e-book to their real-life experience at the bank with the tips from SCROLL.

4 METHOD

4.1 Visualization in the Seamless Learning Environment

In order to visualize and analyze learning logs accumulated in the seamless learning environment, this paper uniquely defines them as two types of three-layer structures as shown in Figure 4: 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 EPUB.

(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, it will connect the learner’ node in the upper layer in FLS to the word’ node in the intermediate layer in FLS. Then, the word’ node will connect to the node of the location where they have learned it. For example, if the learner learned “natto” (a traditional Japanese food made from fermented soybeans) 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

**Figure 3:** SCROLL with EPUB interface.

**Figure 4:** Visualization methods in the seamless learning environments: Formal Learning Structure (FLS) and Informal Learning Structure (ILS)
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 Seamless Learning System based on e-Book

Based on the network graph described above, this paper analyzes using social network analysis as shown in Table 1.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Formula (graph $G=(V,E)$ with $V$ vertices and $E$ edges)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree</td>
<td>$C_i^D = \frac{k_i}{N-1}$</td>
<td>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 $i$.</td>
</tr>
<tr>
<td>Closeness</td>
<td>$C_i^C = (L_i) = \frac{N - 1}{\sum_{j\in G, j\neq i} d_{ij}}$</td>
<td>Closeness centrality is 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.</td>
</tr>
<tr>
<td>Betweenness</td>
<td>$C_i^B = \frac{1}{(N - 1)(N - 2)} \sum_{j \in G, j \neq i} \sum_{k \neq i, k \neq j} \frac{n_{jk}(i)}{n_{jk}}$</td>
<td>Betweenness centrality is 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 $i$.</td>
</tr>
</tbody>
</table>

Degree, closeness and betweenness centrality are a fundamental measurement concept for the social network analysis [3], [9]. Especially, we hypothesize that betweenness centrality could be to bridge the gap between formal learning and informal learning. For example, if an international student learns word “natto” on e-book content in a formal setting, it might be able to be applied to various learning places such as supermarkets, shopping malls, and restaurants in an informal setting. However, it is difficult for him/her to know whether it can be learned in other learning environments nor where it can be learned. In addition, it is difficult to know which word could play the most important role to bridge over formal and informal learning to realize the seamless learning environments. By using betweenness centrality, this analysis could find most important words between FLS and ILS side.

![Visualization and analysis interface](image-url)
5 IMPLEMENTATION

5.1 Interface of VASCORLL

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 layout called “force-directed” uses the force vector algorithm proposed in the Gephi software, appreciated for its simplicity and for the readability of the network, which helps visualization [4], [18]. A network layout called “Yifan Hu multilevel” uses a very fast algorithm to reduce complexity [5]. 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 [1].

On the other hand, Mouri et al. [16] proposed Ubiquitous Learning Graph (ULG), which is divided into four areas: top-left, top-right, bottom-left, and bottom-right. In their evaluation experiment, they reported it is important to establish their nodes’ position on the network graph for readability and ease-of-use when visualizing the relationships in the real-world language learning.

With these points in mind, we developed a network layout called “Seamless Learning Graph (SLG)”, which is divided into six areas as shown in Figure 5: upper-left (Formal learners), center-left (Formal words), bottom-left (Learning materials), upper-right (Informal learners), center-right (Informal words), and bottom-right (Locations). These areas represent the layers described in the section 4.1.

As described in Section 4.2, the interface implements three centrality based on social network analysis. From the (1) to (3) buttons mean each centrality. By clicking them, VASCORLL will automatically visualize and analyze all learning logs accumulated in SCROLL with EPUB. The node size is based on the numerical value of each centrality.

Figure 6 (left) shows the enlarged graph in both formal and informal word areas. There are two learning scenarios by utilizing the results of visualization, which are called “Learning via formal words” and “Learning via informal words” as shown in Figure 6 (right).

(1) Learning via formal words: As shown in Figure 6 (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 ULLs (“natto” pages of SCROLL) learned in the informal setting. Unlike the above learning method (1), by utilizing the ULL, they can learn other learners’ learning experiences (not only words but also time, location and place information) that

![Figure 6: The enlarged graph both formal and informal words area and each hyperlink](image-url)
cannot be learned in the formal setting.

5.2 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 2.

Table 2: Color coding to distinguish the kinds of nodes

<table>
<thead>
<tr>
<th>Node</th>
<th>Layer</th>
<th>Node color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal learners</td>
<td>Upper in FLS</td>
<td>Red</td>
</tr>
<tr>
<td>Formal words</td>
<td>Intermediate in FLS</td>
<td>Yellow</td>
</tr>
<tr>
<td>Learning materials</td>
<td>Lowest in FLS</td>
<td>Blue</td>
</tr>
<tr>
<td>Informal learners</td>
<td>Upper in ILS</td>
<td>Pink</td>
</tr>
<tr>
<td>Informal words</td>
<td>Intermediate in ILS</td>
<td>Green</td>
</tr>
<tr>
<td>Locations</td>
<td>Lowest in ILS</td>
<td>Light blue</td>
</tr>
</tbody>
</table>

6 EVALUATION

6.1 Participants and Design

Twenty international students who are studying at the University of Tokushima in Japan participated in the evaluation experiments. They were from China, Malaysia, Thailand and Mongolia aged from 21 to 36. Their length of stay in Japan ranged from 1 month to 5 years.

The evaluation experiment was designed to evaluate the following three points:

1. Whether VASCORLL can increase the participants’ learning opportunities (“Learning opportunities” means that the number of ULLs that the learner uploaded to the system during the evaluation period”).

2. Whether VASCORLL would be benefit in terms of usability in finding important words in the seamless learning environment.

3. Which centrality is effective in supporting learning in the seamless learning environment?

6.2 Method

Figure 7 shows the experimental procedure.

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. Since they had never used SCROLL with EPUB before, they practiced using it for one week before using VASCORLL. In addition, based on the uploaded ULLs during the practice, the students were divided into two groups: Group A (experimental group) and Group B (control group). Group A consisted of 5 Chinese, 4 Mongolians and 1 Malaysian. Group B consisted of 3 Chinese, 5 Mongolians and 2 Thais. Group A learned words in their daily lives and words in the ebook contents using SCROLL with EPUB and VASCORLL. Group B learned words in their daily lives and words in the ebook contents using SCROLLL with EPUB.

In the next phase, both Group A and B students evaluated, during u-learning activity, each centrality based on social network analysis. Participants learned words using three centrality: degree, closeness, and betweenness. They were asked to use the prearranged one centrality (e.g. participants firstly had to use degree centrality for one day). After the evaluation experiment, the participants were asked to complete five-point-scale questionnaires to evaluate the system performance and usability, as well as the user-friendliness of understanding the contents and finding ULLs using each centrality in VASCORLL.

6.3 Result and Discussion

6.3.1 Whether VASCORLL can increase the participants’ learning opportunities

In order to examine the increase of learning opportunities by VASCORLL, we compared the number of the uploaded ULLs of Group A with that of Group B using F-test. Table 3 shows the number of ULLs that the participants uploaded during the evaluation. In total, Group A students uploaded 189 ULLs and Group B students uploaded 127 ULLs to the system. The means and standard deviations were 18.9 and 6.41 for Group A, and 12.7 and 6.75 for Group B. It was found that the learning opportunities of the two groups were significantly different with $F = 4.41$ (p
< .05), implying that VASCORLL was able to increase their learning opportunities. The adjusted mean of Group A (17.83) is statistically higher than that of Group B (12.83). That means that VASCORLL was a useful tool to increase their learning opportunities.

### 6.3.2 Whether VASCORLL would be benefit in terms of in finding important words

The results of a five-point-scale questionnaire are presented in Table 4 (Best: 5, Worst: 1).

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. Were you able to connect words inside-class to out-side-class learning by using VASCORLL?</td>
<td>3.7</td>
<td>0.82</td>
</tr>
<tr>
<td>Q2. Were you able to connect words outside-class to inside-class learning by using VASCORLL?</td>
<td>3.9</td>
<td>0.99</td>
</tr>
<tr>
<td>Q3. Were you able to learn and find the relationship between words and places by using VASCORLL?</td>
<td>3.4</td>
<td>0.96</td>
</tr>
<tr>
<td>Q4. Were you able to learn and find the relationships between words and e-book contents by using VASCORLL?</td>
<td>3.5</td>
<td>0.87</td>
</tr>
<tr>
<td>Q5. Was VASCORLL ease of use?</td>
<td>2.6</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Q1 asks about whether the participants were able to find that the words that they learned during class were connected to the words that other learners learned outside class. Similarly, Q2 asks about whether the participants were able to find that the words they have learned outside class were connected to the words that others 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 VASCORLL was able to connect the words between formal and informal learning.

Q3 asks about whether the participants were able to learn and find the relationships between words and places by using VASCORLL. For example, when a participant learned “料理 (Cuisine)” in class, he/she could find it was connected to the experiences of others at places such as schools and restaurants. By sharing the authentic experiences that are rarely able to acquire in formal setting, VASCORLL enabled them to experience indirectly what other people experienced thanks to the system, which connected their formal learning to the informal one.

Q4 asks about whether the participants were able to find their newly learned words in other e-book contents. For example, when a participant learned “使用 (Use)” in an e-book material titled “Japanese Learning Beginner Vol.1”, the system connected it to other e-book materials such as “Japanese Learning Beginner Vol.2” and “Onomatopoeia Japanese Learning Vol.1”. That way, they could learn that it is a frequently used word in the Japanese language.

Q5 asks about whether VASCORLL 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 VASCORLL was not easy to use. We asked them to give comments regarding this problem. Examples of the negative comments are as follows:

1. The speed of visualizing and analyzing logs in the system is too slow (It took about 20-30 sec.).
2. If visualizing logs using a mobile device, it is hard to read the nodes on the device because my screen is very small. However, if logs are visualized on a personal computer, they become very easy to read.
3. It was a little bit difficult to understand how to use the system.

From the comments (1) and (2), the participants would suggest that the system developers need to improve functionality in accordance with their mobile device and system’ speed in visualizing a large mount of logs. The comment (3) shows that even though we explained the usage of VASCORLL before the evaluation experiment, some participants did not understand fully how to use it. Thus, our next evaluation ought to be more carefully planned.

### 6.3.3 Which centrality is effective in supporting seamless learning

The results of five-point-scale questionnaire for evaluating each centrality (degree, closeness and betweenness) are presented in Table 5 (Best: 5, Wrong: 1). In addition, the participants were asked questions such as “Which centrality is the easiest in understanding or finding central words?” and “Which centrality is the most effective for learning” in order to evaluate each centrality in the seamless learning environment.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. Was the degree centrality easy of understanding or finding central words?</td>
<td>3.0</td>
<td>0.91</td>
</tr>
<tr>
<td>Q2. Was the closeness centrality easy of understanding or finding central words?</td>
<td>2.7</td>
<td>1.08</td>
</tr>
<tr>
<td>Q3. Was the betweenness centrality easy of understanding or finding central words?</td>
<td>3.7</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Q1-Q3 asked about whether the participants were able to understand and find central words using fundamental social network analysis: degree centrality, closeness centrality, and betweenness centrality. From the results of the questionnaire, many participants preferred to learn and find central words using betweenness centrality because the mean score of the Q3 is the most highest.

In order to find the most effective centrality for them to learn central words, we interviewed the participants to compare betweenness centrality with other centrality.

1. Degree centrality versus Betweenness centrality
Degree centrality enabled the participants to find merely nodes that have many links. Two participants selected the centrality in terms of usability and effectiveness for learning because it is simple and easy to understand the characteristics. However, some participants commented that it was difficult to find words bridging formal learning over informal learning. When comparing betweenness centrality with the degree centrality, the processing speed of betweenness centrality was little, but it was very useful in finding central words which linked formal and informal learning.

(2) Closeness centrality versus Betweenness centrality

When comparing closeness centrality with the closeness centrality, the closeness centrality was not useful to find central words in the seamless learning environment. There was no numerical value difference between formal words in FLS and informal words in ILS, so that the participants could not find central words. Therefore, this paper concluded that the closeness centrality was not a useful centrality in finding central words in the seamless learning environment if using our visualization and analysis method.

As shown in Figure 8, the majority of the participants preferred to use betweenness centrality than other centrality. We asked them “why you preferred to the betweenness centrality than other algorithms”. Their feedbacks are as follows:

- “Because it is easy to find words in my e-book content linking to informal words, the betweenness centrality is very good.”
- “It was easy to understand. And I learned some words. Then, it recommended some useful words to me (e.g. the size of green or yellow node).”

The betweenness centrality turned out a very good centrality in terms of easiness to find words bridging formal and informal learning. In addition, we compared betweenness centrality with other centrality. Fifteen answered that the betweenness centrality is helpful to find central words in the seamless learning environment. Seventeen answered it worked effectively in language learning.

7 CONCLUSION

This paper described a system called VASCORLL for visualizing and analyzing learning logs collected in the seamless learning environment in order to bridge the gap between formal and informal learning. VASCORLL works on cyber-physical setting to link learners in the real world and learning logs that are accumulated in the cyber spaces using the ubiquitous learning system called SCROLL with EPUB. SCROLL with EPUB enabled international students to learn through two learning activities: e-book-based learning activity and authentic learning activity.

Through those learning activities, we proposed visualization and analysis methods based on graph theory, social network analysis and graph drawing algorithms in order to find pivotal words in the seamless learning environment. Two types of three-layer structures called FLS and ILS were adapted as the visualization methods. That way, teachers and students could easily grasp words bridging between words in FLS and ILS. In addition, this paper evaluated whether they were able to find the most pivotal words on the network graph using each centrality based on social network analysis.

The evaluation was conducted after the implementation of VASCORLL. A questionnaire with a five-point-scale conducted after the evaluation showed that VASCORLL was a useful tool to find central words bridging formal and informal learning. The result of questionnaires for evaluating each centrality showed the most effective centrality for learning was betweenness centrality. Therefore, we concluded that the betweenness centrality is the most important centrality in the seamless learning environment.

VASCORLL will be evaluated repeatedly, with the processing speed of visualizing and analyzing learning logs improved. In addition, our future works include applying VASCORLL to other application domains such as math, physics, and science education, and long-term evaluations with an enough number of participants.

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9 REFERENCES


