Shih, J. L. et al. (Eds.) (2019). Proceedings of the 27th International Conference on Computers in Education.
Taiwan: Asia-Pacific Society for Computers in Education

E-book Learner Behaviors Difference under two Meaningful Learning Support Environments

Jingyun WANG[a*], Atsushi SHIMADA[b] & Fumiya OKUBO[c]
[a]*Research Institute for Information Technology, Kyushu University A, Japan*
[b]*Faculty of Information Science and Electrical Engineering, Kyushu University, Japan*
[c]*Department of business administration, Takachiho University, Japan*
*warmplam@gmail.com

Abstract: In this paper, we present an ontology-based visualization support system for e-book learners, which provides not only a meaningful receptive learning environment but also a meaningful discovery learning environment. Those two environments are developed to help e-book learners to effectively construct their knowledge frameworks. A series of experiments were conducted on four undergraduate classes instructed by two professors (A and B): two classes(one guided by A and the other guided by B) were assigned as control groups and studied with one e-book chapter in receptive learning environment while another two classes (one guided by A and the other guided by B) were assigned as experimental groups and studied with the same e-book chapter in discovery learning environment. For analyzing the learner behavior, K-means clustering algorithm is performed not only by considering the number of total command actions and the cumulative duration of stay on target pages as learner features, but also by considering the duration of stay on each target page (in total 15 pages) as learner features. Learners' behavior differences in e-book system are examined and discussed.

Keywords: Clustering, map, meaningful learning, discovery learning, reception learning

1. Introduction

Nowadays, many countries, especially Japan and Korea, has started to use digital textbook instead of traditional textbook due to its various advantages such as cost-saving and higher portability (Shepperd, Grace, & Koch. 2008; Shin, 2012; Yin, et al, 2018). Since the learning behavior of e-book users are recorded in logs and can be readily accessed for further analysis, when evaluating the learning effect of a learning support system, the examination of e-book logs is essential.

In the previous work (Wang, Ogata, and Yamada, 2017), an ontology-based visualization support system, is designed and developed to help e-book learners to effectively construct their knowledge frameworks. Two learning modes are provided in this system: (a) reception comparison mode, in which learners are provided directly with complete versions of relation maps; and (b) cache-cache comparison mode, where all information concerning relations is hidden at the first stage of learning, and in the second stage learners are encouraged to actively create them. In this paper, we will exploit traces of learner activities and discuss the behavior differences of e-book learners while they studied with these two modes.

2. A Visualization Support System for E-book Learners

Facilitation of the visualization support of meaningful learning (structure (Ausubel, 1963; Ausubel et al., 1978).) requires descriptions of the information about all the knowledge points and their relations. In this study, a Knowledge Point (KP) is defined as "a minimum learning item which can independently describe the information constituting one given piece of knowledge in a specific course." The learner can understand a KP via its own expression or can acquire it through practice. It is suggested that the domain knowledge needed by the learning support system should be automatically extracted from an ontology designed and developed on the basis of the content of the e-books.

To construct a demonstration unit, first we adjust the ontology design method described by Wang et al. (2014) and apply it to the development of a course-centered ontology for an existing computer science course (called COCS). The ontology consists of about 100 KPs and 20 kinds of relations, extracted and defined based on an analysis of the content of all the e-books of this computer science course. Moreover, an ontology-based visualization support system (called VSSE), which supports not only meaningful receptive learning but also meaningful discovery learning, is implemented to help e-book learners to efficiently develop their conceptual framework (Wang, Ogata, and Yamada, 2017).

2.1 Meaningful Reception Learning Environment

One of the main functions of VSSE is that the KPs appearing in any page range of any e-book, along with their upper concepts, can be displayed in a relation map. In the reception comparison mode, learners are provided directly with complete versions of relation maps (Wang, Ogata, and Yamada, 2017). As can be seen in Fig. 1, users of the e-book system can select a specific e-book and input any page range in the reception comparison interface. VSSE will display all the KPs appearing in the searched pages along with their related KPs. For example, Fig.1 displays: red nodes, which represent the KPs that appear in pages 1 to 20 of e-book A03; blue nodes, which represent related KPs that do not appear in those pages but have essential relations with the KPs represented by the red nodes; and pink nodes, which represent the upper concepts of the KPs represented by red or blue nodes. When the user places the mouse on any node in this relation map, the essential properties (such as definition and explanation, represented by the data properties of one individual in COCS) of that KP will be listed, while for every arc in the relation map, a statement of the relation will be displayed (for example, the displayed relation axiom "prescribe" from "ASCII" to "ASCII Character Set" in Fig. 1). Therefore, users can conveniently find the essential properties of every KP and all its related KPs from this visualization map. All that information is extracted automatically from COCS.

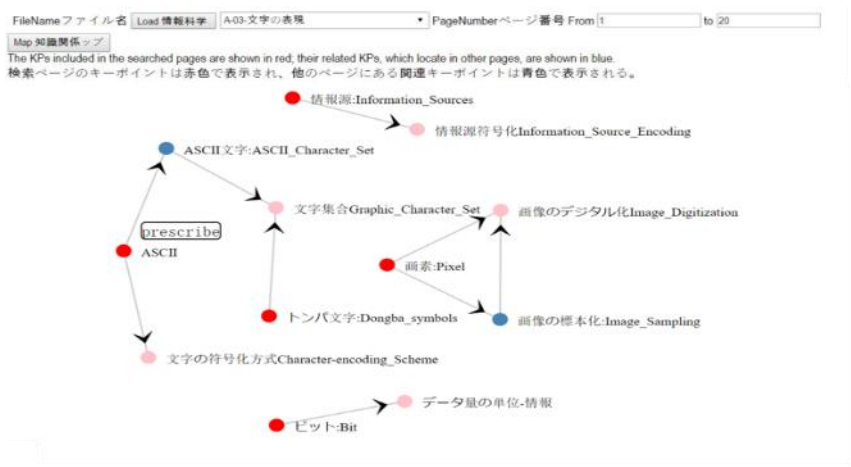

Figure 1. The relation map of the search pages

2.2 Meaningful Discovery Learning Environment

To encourage active engagement in meaningful learning, another environment (called "cache-cache comparison" mode) integration with discovery learning (Alfieri, Brooks, Aldrich, & Tenenbaum,2011; Bruner, 1961) is also presented (Wang, Ogata, and Yamada, 2017). Considering KPs and relations as the building blocks of course relation maps, "cache-cache comparison" mode in VSSE hides all the relations in expert relation maps and guides learners to seek to discover those hidden relations. The learners engage in an active learning process when they struggle to complete relation maps. Fig. 2 shows an instance of "cache-cache comparison" mode: the range of interest to the learner is pages 1 to 20 of e-book A-03. First, as shown in Fig. 2, "cache-cache comparison" mode displays all the KPs that appear in the page range of interest in red; the related KPs that do not appear in the pages of interest in ranges in blue; and their upper concepts in pink. Then firstly the learner is required to classify the KPs

by connecting them to their pink upper concepts; next, the learner is encouraged to find out the relations between KPs by connecting red nodes or connecting red nodes to blue nodes. The descriptions of the relation arcs made by the learner can be modified and saved anytime. After the learner completes the relation map, she/he can click the "Compare with experts" button. Finally, all the relations extracted from the ontology will be displayed as red lines. The learner can easily compare the red lines with the black lines that she/he has made.

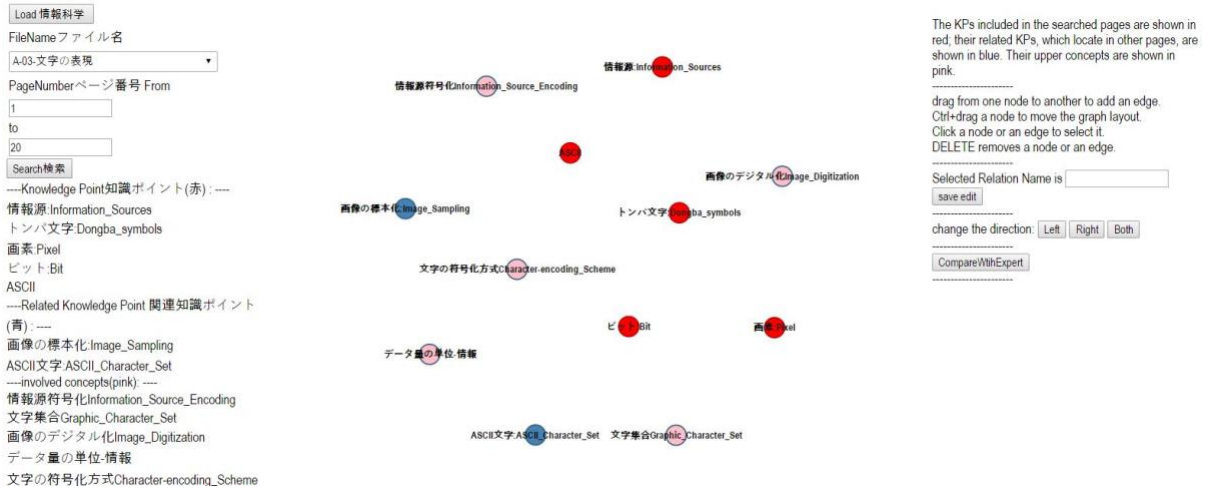

Figure 2. An instance of "cache-cache comparison" mode

3. Participants and Experimental Procedures

To explore the learning performance differences (including e-book behaviors, learning achievement and perception of learning) between participants who studied with the two environments presented in previous section, three hundred and sixty-seven first-year undergraduates from four classes belong to the same computer science curriculum at a Japanese University participated in the experiments of this study. Two of the classes instructed by Professor A, were randomly assigned as experimental group (namely E_A, 72 students) and control group (namely C_A, 103 students), respectively, while the other two classes instructed by Professor B were also randomly assigned as experimental group (namely E_B, 146 students) and control group (namely C_B, 46 students), respectively. Before the experiment, all the participants had studied this computer science course for 14 weeks within learning support systems (Moodle, e-protfolio system Mahara and an E-book system called BookLooper (Yin, et al, 2015)). And weeks before the experiment, all participants have received the instruction related to the e-book c03, entitled, "Digital Image Processing." During the experiment, the participants took pre-test at the beginning of the class and the control groups reviewed the e-book C03 with reception comparison mode support while the experimental groups reviewed with cache-cache comparison mode support. The first 15 pages of e-book C03 were chosen as target learning content for 30-minuts review activity. In those 15 pages 11 KPs appear. After the study, all of them took another post-test and a questionnaire related to this learning activity.

4. E-book Behavior Analysis using K-Means Clustering Algorithm

Whenever a user interacts with BookLooper, one data log containing user ID, the date, time, learning content ID, page number, user action (such as "OPEN", "NEXT", "PREV", "SEARCH JUMP", "PAGE JUMP" and so on), and other data, will be recorded in her/his reading history (Yin, et al, 2015). In this paper, we intend to discuss the learner e-book behavior differences under the support of the two different meaningful learning environments mentioned in Section 2. The e-book logs of all the participants who studied the target pages with the support of VSSE are analyzed by means of K-means clustering algorithm. K-means clustering is one of the data mining approaches applied to identify learners with similar features and assign them into clusters. In this paper, basic K-Means clustering by considering K=2 and K=3 was performed, respectively.

4.1 Analysis on the number of total command actions and the cumulative duration of stay

Firstly, we consider the number of total command actions and the cumulative duration of stay (the total amount of time spent on the target 15 pages) as 2 features of learners. These two features are the typical variables used to explain the individual diversity in e-learning behaviors ((Yin, et al, 2018). It is needed to mention that, in the clustering analysis of this paper, when a learner stays more than 10 minutes on one page, that page is considered left unattended after 10 minutes. During a 30-minutes learning activity, spending more than 10 minutes in a page is unusual considering the moderate difficulty of the learning content; therefore,10 minutes will be considered as the duration of stay. The 2-means clustering result is shown in Table 1. The average cumulative duration of stay of learners in Cluster 0 was significant longer than those in Cluster 1(F (1, 193)= 460, Cluster 0: Mean=787s, SD=277s, Cluster 1: Mean =200s, SD=190s); the average number of total command actions of learners in Cluster0 was significant higher than those in Cluster0 (F (1, 153)= 272; Cluster 0: Mean =105, SD=47, Cluster 1: Mean =32, SD=20). Although, lower than 20% of students in both classes guided by Professor A are found in Cluster 0, the percentage of students in Cluster 0 in E_A Class (17%) is still 3 times more than C_A Class (5%). In the other hand, 69% of students in E_B class are identified in cluster 0 while only 22% of students in C_B class are identified in cluster 0.

Table 1

The 2-means clustering result by considering the number of total command actions and the cumulative duration of stay as learner features

Cluster	Label	Average cumulative duration of stay (sec)	Average number of total command actions	N	Percentage inside label	Percentage inside cluster
0	C_A	561	74	5	0.05	0.04
	E_A	813	90	12	0.17	0.09
	C_B	718	80	10	0.22	0.08
	E_B	802	110	101	0.69	0.79
1	C_A	138	30	98	0.95	0.41
	E_A	176	31	60	0.83	0.25
	C_B	302	32	36	0.78	0.15
	E_B	286	40	45	0.31	0.19

The 3-means clustering result is consistent with 2-means clustering result. The average cumulative duration of stay of learners (F (2, 107)= 395, Cluster 0: Mean=912s, SD=318s, Cluster 1: Mean =640s, SD=208; Cluster 2: Mean =135s, SD=128s) and the average number of total command actions of learners (F (2, 112)= 261; Cluster 0: Mean =149, SD=41, Cluster 1: Mean =65, SD=25; Cluster 2: Mean =30, SD=20) in these 3 Clusters differ significantly (Cluster 0>Cluster 1>Cluster 2;) . There are 31% of E_B class student, 4% of E_A students, 4% of C_B students are found in cluster 0 and they had the longest average cumulative duration of stay and highest average number of total command actions; 50% of E_B class student, 39% of E_A student, 26% of E_A students and 9% of C_A students are found in cluster 1 and they have the medium average cumulative duration of stay and medium average number of total command actions; the rest of the students in cluster 2 had the shortest average cumulative duration of stay and lowest average number of total command actions.

The differences between classes guided by difference professors maybe caused by the learning style difference of the professors. But both 2-means and 3-means clustering results suggest that the learners in experimental groups who study with the support of meaningful discovery learning environment had longer cumulative duration of stay and higher number of total command actions than those in control groups who studied with meaningful receptive learning environment.

4.2 Analysis on the duration of stay on each target page

Secondly, to explore the reading behavior pattern of learners, we consider the duration of stay on each target page (the time spent on each target page, in total 15 variables) as 15 features of learners. The 2-means clustering results are shown in Table 2 and Figure 3. For the average cumulative duration of stay on the target 15 pages, leaners in Cluster 0 outdistanced than those in Cluster 1 in almost every page except the first page which only displays the title of the chapter (here we consider $p<0.001$ as significant standard). As shown by Figure 3, compared to learners in Cluster 1, leaners in Cluster 0 tends to stay much longer in page 2 ($F(1, 145) = 85.39$, Cluster 0: Mean =149s, SD=149s, Cluster 1: Mean =24s, SD=52s), page 3 ($F(1, 153) = 109.58$, Cluster 0: Mean =215s, SD=169s, Cluster 1: Mean =51s, SD=72s) , page 4 ($F(1, 143) = 21.14$, Cluster 0: Mean =46s, SD=89s , Cluster 1: Mean =9s, SD=30s), page 8 ($F(1, 141) = 32.28$, Mean of Cluster 0=70s, SD=114s, Cluster 1: Mean =11s, SD=34s) , page 9 ($F(1, 131) = 15.77$, Cluster 0: Mean =43s, SD=109s, Cluster 1: Mean =5s, SD=16s), page10 ($F(1, 144) = 25.88$, Cluster 1: Mean =57s, SD=94s, Cluster 1: Mean =14s, SD=32s) , and page 11($F(1, 132) = 32.90$, Cluster 0: Mean =58s, SD=100s , Cluster 1: Mean =7s, SD=17). After further examining the contents in those 7 pages, it is found that: 2 KPs and 2 relations appear on page 2; 5 KPs and 5 relations (which is one important part of the target map) appear on page 3; 2 KPs appears on page 4; 4 KPs and 3 relations (which is another important part of the target map) appears in the range between page 8 to 11. This means that these 7 pages which explain important KPs and relations are the key part of target learning content. As shown in Table 2, although lower than 20% of students in both classes guided by Professor A are found in Cluster 0, the percentage of students in E_A Class (19%) is still 3 times more than C_A Class (4%). In the other hand, 68% of students in E_B class is found in cluster 0 while only 24% of students in C_B class is found in cluster 0.

The 3-means clustering results shows learners in three clusters (114 learners in cluster 0, 18 in cluster 1, and 235 in cluster 2) differ significantly in page 2 ($F(2, 43) = 48.48$, Cluster 0: Mean =165s, SD=153s, Cluster 1: Mean =58s, SD=59s, Cluster 2: Mean =22s, SD=48s), page 3 ($F(2, 44) = 57.97$, Cluster 0: Mean =231s, SD=171s, Cluster 1: Mean =86s, SD=77s, Cluster 1: Mean =51s, SD=71s) , page 4 ($F(2, 41) = 18.22$, Cluster 0: Mean =29s, SD=38s , Cluster 1: Mean =151s, SD=199s, Cluster 2: Mean =8s, SD=26s), page 8 ($F(2, 41) = 15.29$, Mean of Cluster 0=72s, SD=117s, Cluster 1: Mean =45s, SD=83s, Cluster 2: Mean =12s, SD=35s) , page 9 ($F(2, 42) = 8.69$, Cluster 0: Mean =49s, SD=115s, Cluster 1: Mean =8s, SD=20s, Cluster 2: Mean =4s, SD=15s), page10 ($F(2, 41) = 34.80$, Cluster 1: Mean =33s, SD=30s, Cluster 1: Mean =228s, SD=175s, Cluster 2: Mean =12s, SD=21s) , and page 11($F(2, 41) = 19.05$, Cluster 0: Mean =63s, SD=105s , Cluster 1: Mean =22s, SD=25, Cluster 2: Mean =7s, SD=15s). Although students in cluster 1 in average stayed longer time on Page 4, 5 and 10 than those in the other two clusters, there is only a small number of students in cluster 1(18 in total). Except those 3 pages, the average duration of stay of leaners in Cluster 0 outdistanced those in other two cluster 2 in almost every page except the first page which only displays the title of the chapter.

For summary, the results of 3-means clustering and 2-means clustering are almost consistent. Both results suggest that the participants in experimental groups had longer average duration of stay in the pages which explain important KPs and relations than those in Control groups.

Table 2

The 2-means clustering result by considering the duration of stay on each target page as features

Cluster	Label	N	Percentage inside label	Percentage inside cluster
0	C_A	4	0.04	0.03
	E_A	14	0.19	0.11
	C_B	11	0.24	0.09
	E_B	100	0.68	0.78
1	C_A	99	0.96	0.42
	E_A	58	0.81	0.24
	C_B	35	0.76	0.15
	E_B	46	0.32	0.19

Figure 3. The duration of stay on each target page(2-means)

5. Conclusion and future work

In this paper we present an ontology-based visualization learning support system which provides not only meaningful reception learning environment but also meaningful discovery learning environment for e-book learners. A series of experiments were conducted on an undergraduate computer science course of a Japanese university. To examine the e-book learners' behavior differences under the support of these two different learning environments, the log data of all the participants was analyzed by using K-means clustering approach. The results suggest that compared to the participants who studied with meaningful reception learning environment, those who studied with meaningful discovery learning environments had longer average cumulative duration of stay and higher average number of total command actions; moreover, they also had longer average duration of stay in the pages that explain important KPs and relations. In the future work, learning achievement and learning perception differences will be analyzed and discussed for a better evaluation of these two meaningful learning environments.

Acknowledgements

The research is supported by KAKENHI Grant Number 17K17936.

References

Alfieri, L, Brooks, P. J., Aldrich, N. J. & Tenenbaum, H. R. (2011). Does Discovery-Based Instruction Enhance Learning? *Journal of Educational Psychology*, 103 (1), 1-18.

Ausubel, D. (1963). *The Psychology of Meaningful Verbal Learning*. New York: Grune & Stratton.

Ausubel, D., Novak, J., & Hanesian, H. (1978). *Educational Psychology: A Cognitive View (2nd Ed.)*. New York: Holt, Rinehart & Winston.

Bruner, J. S. (1961). *The act of discovery*. Harvard educational review.

Wang, J., Mendori, T., & Xiong, J (2014). A Language Learning Support System using Course-centered Ontology and Its Evaluation," *Computer & Education*, 78, pp 278-293.

Wang, J., Ogata H., & Shimada A. (2017). A Meaningful Discovery Learning Environment for E-book Learners. *Proceedings of IEEE Global Engineering Education Conference 2017*, 1158-1165.

Yin C-J., M. Yamada, Oi M., Shimada A., Okubo F., Kojima K., and Ogata H. (2018). Exploring the Relationships between Reading Behavior Patterns and Learning Outcomes Based on Log Data from E-Books: A Human Factor Approach, *International Journal of Human–Computer Interaction*, DOI: 10.1080/10447318.2018.1543077

Yin C-J., Okubo F., Shimada A., Oi M., Hirokawa S., and Ogata H. (2015). Identifying and Analyzing the Learning Behaviors of Students using e-Books", *Proc. International Conference of Computers on Education 2015*.