

LOD Based Semantically Enhanced Open Learning Space Raises Engagement for Historical Deep Consideration

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Abstract: The purpose of this research is to support learners in self-directed learning on the Internet using automatically generated support using the current state of the semantic web. The main issue of creating meaningful content-dependent questions automatically is that it requires the machine to understand the concepts in the learning domain. The originality of this work is that it uses Linked Open Data (LOD) to enable meaningful content-dependent support in open learning space. Learners are supported by a learning environment, the Semantically Enhanced Open Learning Space (SOLS). Learners use the system to build a concept map representing their knowledge. SOLS support learners following the principle of inquiry-based learning. Learners that request help are provided with automatically generated questions that give them learning objectives. To verify whether the current system can support learners with fully automatically generated support, we evaluated the system. The results showed that LOD based support was feasible. Learners felt that the support provided was useful and helped them learn. The question support succeeded in improving the development of learners' historical considerations and deep historical thinking skills. In addition, the engagement and interest in history of learners was improved by the questions. The results are meaningful because they show that LOD based support can be a viable tool to support learners in open learning space and that the question support has potential to support learners during a long time study.

Keywords: Linked Open Data, Question Generation, Semantic Open Learning Space, History Learning

1. Introduction

When conducting self-directed learning in an open learning space, one of the difficulties is that it requires learners to plan their learning in an unfamiliar domain. It requires learners to find and set their learning objectives while they are learning. It is difficult for learners to plan their learning effectively because they are unfamiliar with the domain and cannot decide easily which topic they should study next. This problem is increased in an open learning space because the quantity of information is much larger and the information is not organized with clear learning objectives. Thus, learners can easily become overwhelmed and discouraged during learning. One way to eliminate the difficulty is prompting question generation and answering activities (inquiry-based learning) (De Jong, 06, Roth, 96). This helps to lighten the difficulties of self-directing learning by lessening the planning activities that the learners need to perform. However, creating good inquiry questions requires an understanding of the domain, and thus learners cannot always create good questions by themselves.

Another problem of self-directed learning is that learners must stay engaged in the learning task to have fruitful learning outcomes. To raise the engagement of learners while keeping them motivated, the support given them should be adapted to their interests and orient them to information that can help them develop their knowledge without forcing them to do so.

In closed learning spaces, it is possible for experts to set clear learning objectives and to prepare meaningful content-dependent questions for learners beforehand because the quantity of information is limited. However, in an open learning space, the quantity of information is too large to be processed manually. Thus it becomes necessary to implement dynamic question generation.

For this reason, we previously proposed a question generation function to create and adapt questions to learners in open learning spaces. In a previous paper (Jouault et al., 16), we demonstrated that it is possible to generate good quality history questions automatically in open learning spaces using Linked Open Data (LOD). The method integrates data from two LOD sources, Freebase and DBpedia, to create a large source of information (around 80GB of semantic data) that satisfies the requirements to support history learning. The integrated data is combined with a history domain ontology and a history dependent question ontology to create natural language questions that can support learners. An evaluation of the automatically generated questions by a history professor showed that they could cover 84% of the human questions requiring basic knowledge to be answered. Furthermore, the evaluator judged that the quality of the automatically generated questions requiring deep historical thinking was on the same level as the ones generated by human experts. This suggests that the automatically generated questions have the potential to reinforce deep historical understanding.

The quality of the questions was assuredly high enough to support learners, but they could only be provided to learners in an adequate way to support their learning. Thus, we created a learning environment we call the “Semantically enhanced Open Learning Space” (SOLS) and installed the aforementioned question generation function into it to support learners in self-directed learning of history. In other words, we realize inquiry-based learning to support learners in open learning spaces by providing automatically generated content-dependent questions based on LOD.

The research question to be answered in this paper is whether automatic question generation support is feasible and can help learners in self-directed learning of history in an open learning space. The details of the question generation method and the quality of questions can be found in the aforementioned previous paper (Jouault et al., 16).

2. Related Work

In history learning, unskilled learners tend to only memorize basic information and do not try to integrate it to create an opinion. In learning history, an understanding of chronology is necessary (Stow, 00). Chronology is defined by Smart (Smart, 96) as “the sequencing of events/people in relation to other and existing knowledge of other, already known, events/people.” Learning history is not only remembering a series of facts; learners need to construct an image of the past in their mind. Learners need, of course, to know the events but they also need to understand their context. Thus, classroom teachers ask them questions to trigger their thinking about historical considerations, which helps the learners to integrate and assess their knowledge.

In self-directed learning, learners have to decide the direction of their learning by themselves. However, unskilled learners cannot perform good quality learning in that situation without support. Thus, to support learners in self-directed learning in an open learning space, previous research lead to the creation of systems such as the Navigation Planning Assistant (Kashihara et al., 09), which provides an environment used to describe learners’ learning plans and state of understanding to prompt their self-regulation in an open learning space. The limitation of this system is that its support is content-independent due to the difficulty of working with natural language information on the Web.

On the other hand, to provide content-dependent advice, learning materials can be prepared in advance in a specific closed domain. This is the case of Betty’s Brain (Biswas et al., 09), which uses a concept map in an environment for learning by teaching, or the Kit-Build method (Hirashima et al., 11), which provides a knowledge externalization environment for building a concept map using pre-defined kits and supporting the learner during the concept map construction. However, for both systems, the preparation requires a considerable amount of time even for constructing a closed learning space. It is not possible to use the same method in open learning spaces because there are too many learning materials.

One of the promising methods to provide support in open learning spaces is to ask meaningful questions about a specific domain. Inquiry-based learning in an open space is recognized as a useful strategy to prevent learners from losing their way and to avoid disturbing their learning processes (Hmelo-Silver et al., 07). A notable piece of research is the Web-based Inquiry Science Environment (WISE) (Slotta, 04), which provides support in self-directed learning. Learners using WISE gather information to answer an inquiry. Learners are trained in designing solutions, debating subjects, and

critiquing the resources they learn. However, preparing all the inquiries in advance requires time-consuming manual processing by specialists. This problem makes automatic question generation a meaningful approach.

The originality of our method is that the question generation function enables content-dependent support in an open learning space by using LOD. The generated questions can be used to support learners by putting them in an inquiry-based learning situation. The function can generate “shallow” questions that are designed to support basic knowledge acquisition and “deep” questions that are designed to trigger thinking about historical considerations. In history, questions make learners integrate their knowledge and are useful even if the answer is not provided (Husbands 96, Riley 00). Furthermore, previous research shows that providing handmade terms representing learning activities, even without providing their answers, has the effect of prompting internal self-conversation on the part of learners to help them understand contents that are not explicitly described in a textbook. As a matter of fact, cases have been reported in which learners were able to get higher marks for problems whose answers were not provided in a textbook (Seta et al., 11a, 11b).

3. SOLS: Semantically Enhanced Open Learning Space

The aims of embedding the question support in the system from the viewpoint of learning objectives are two-fold:

- A) Support the development of the domain understanding of the subject to be learned.
- B) Help the learners stay engaged and motivated during learning.

Regarding objective A, the questions provide support to help learners not only memorize historical events but also understand them. Learners need to not only know events, but also to understand their context. The “shallow” questions aim to support learners in developing their basic understanding whereas “deep” questions aim to trigger thinking in the learners’ minds and support them in developing their historical considerations.

Regarding objective B, the questions aim to motivate the learners by making them more aware of their progress. Every time learners answer a question, they solve a problem that they chose and can directly notice that they are developing their knowledge about the topic because they learned enough to answer a question they could not answer before. Without the questions, the learners would only have a distant goal of learning about the topic and it would be no easier for them to reach their learning objectives. In that case, it would be difficult for learners to become aware of their progress.

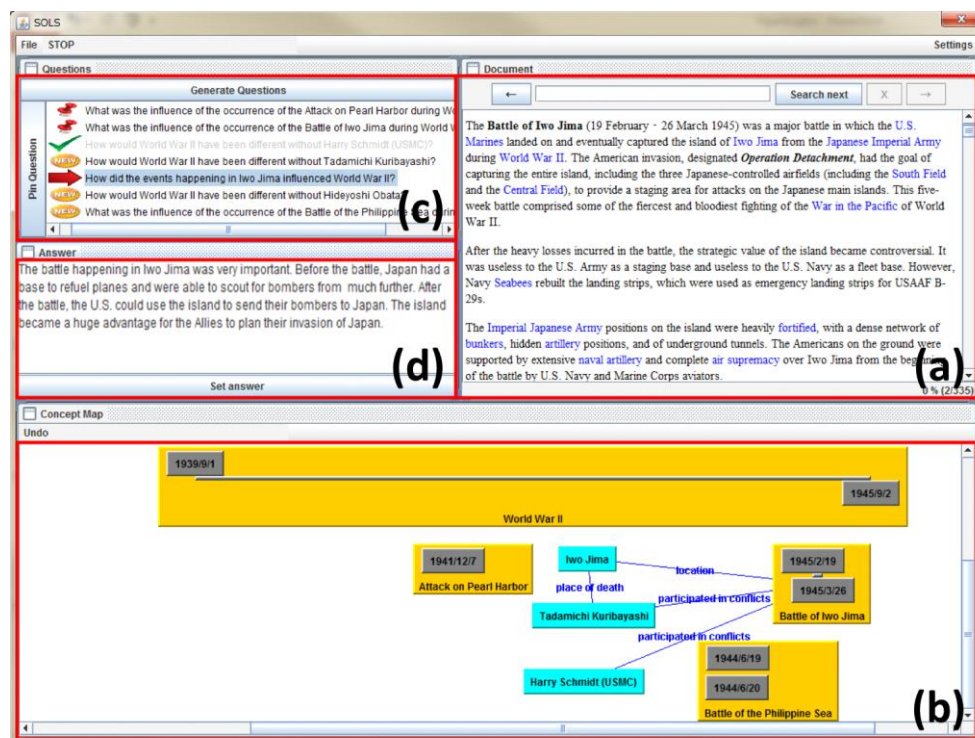


Figure 1. Interface of SOLS.

Raising engagement and motivation is an important part of self-directing learning. Since the learners do not have as much external incentive to learn as they do in classroom learning, the quality of their learning becomes dependent on their engagement and motivation as well as their previous knowledge. Learners also usually set their learning time by themselves and will stop learning if they are not motivated.

The SOLS system interface shown in Fig. 1 is designed to support learners in self-directed learning of history. It provides learning materials in natural language and a space that learners can use to build their concept map, shown in Fig. 1(b), representing their knowledge. Learners are instructed to get information from the document and build their concept map. Questions are available but only appear if the learner requests them. By letting learners request the questions as needed, we aim to let learners keep their own pace and encourage them to use their own skills when possible. Learners can request two types of questions, i.e., “shallow” and “deep” questions, which appear respectively in the concept map in Fig. 1(b) and the question window in Fig. 1(c). Shallow question has a unique answer that the system can detect, while deep does not. The function of each window is described in detail as follows.

- (a) **Document window:** It displays the learning material (Wikipedia document) the learner selected and provides usual Internet browser functions. All the links to a document about another concept appear in blue text. The learners can also use the links to add concepts to their maps.
- (b) **Concept map window:** Learners use this window to manage the concept map. The concepts in the middle are events. Events are represented on an automatically generated timeline built using data from the LOD. Other concepts are colored in blue and can be moved freely by the learner. They appear around the timeline of events, thus forming a chronology. The lines between two concepts are relations with the type of relation written at the center of the line. The concept map window also displays “shallow” questions that are designed to support basic knowledge acquisition.
- (c) **Question window:** It displays a list of “deep” questions generated by the system designed to trigger deep historical considerations.
- (d) **Answer window:** Learners use this window to answer the questions they selected in (c). Learners can write their answers to the questions in natural language.

When using SOLS, learners can request a question to support their learning whenever they want. The questions appear either in the concept map (b) or in the question window (c) depending on the learner’s request. If a learner is interested in a question, it becomes a learning objective to be reached.

The concept map represents the learners’ understanding states and reflects their interests (Nesbit et al., 06). Research has shown that building a concept map deepens the understanding of learners (Nesbit et al., 06). Building a chronology also reinforces learners’ historical understanding (Stow et al., 00). One of the advantages of our concept map is that it is machine understandable even if built in an open learning space. Each concept added to the concept map has an ID that can be used to gather information on the LOD giving additional information about the concept to the system. Thus, it plays a key role in realizing adaptive question generation that aims to deepen learners’ historical considerations and help learners set learning objectives. The machine understandable concept map makes it possible for the system to assess the learners’ knowledge and interests and adapt the generated questions accordingly.

Then, on the learner’s request, the system generates shallow questions appearing in the concept map to help the learners extend their basic knowledge. In one example, the learner requested questions about “Battle of Iwo Jima” and the system generated questions to help the learner acquire basic information about the countries involved (“Which countries were involved in the Battle of Iwo Jima?”) or its commanders (“Which commanders were in charge of the Battle of Iwo Jima?”). The learner then answered the second question about the commanders by dragging and dropping one of the valid answers: “Raymond A. Spruance.” Once the question is answered, the learner may request more questions about the concept that are more interesting for him/her, e.g. Germany, and keep studying more details about it, e.g., learn about battles involving Germany such as the “Invasion of Poland”, which is an important event of WWII. Basic knowledge is required to answer all these questions. The questions generated by this action are all relevant to the concept selected by the learner. To answer the questions, the learners need to drag and drop the concept that answers it to the empty node and the system can verify the validity of the answer by using the data from the LOD.

The question window (c) from Fig. 1 is designed to provide learners with adaptive deep questions generated on the basis of the machine understandable concept map. Learners are provided

with a list of deep questions from which they can select any that they consider interesting and try to answer them. In this situation, learners decide their learning objectives by choosing and ordering questions. The questions are generated depending on the learners' interests to respect and reinforce these interests. More detail about the algorithm to generate questions can be seen in (Jouault et al., 16).

The deep questions generated by the system were previously evaluated (Jouault et al., 16) to be of a quality high enough to trigger historical thinking. The learners have access to good quality questions to direct their learning and thus their learning should be improved.

Learners then use the Fig. 1(a) window to browse documents to find the answers to questions. Finally, they answer the chosen question in the Fig. 1(d) answer space or the Fig. 1(b) concept map. Although the system cannot grade the answer written in Fig. 1(d), for learners to answer prompts historical consideration. By repeating this process, the learners build their understanding by performing inquiry-based learning in the open learning space.

4. Experimental Setting

4.1 Objectives

In the evaluation experiment we conducted we aims to verify three points:

1. The feasibility and usefulness of LOD based support in a real learning scenario.
2. Whether the question support helps learners develop their historical considerations.
3. Whether the system can raise learners' engagement in learning history in an open learning space.

Concerning objective (1), we aim to verify whether the functions implemented in the system work smoothly so as not to disturb learning and whether the generated questions in a real learning context seem useful from the viewpoint of learners. Of particular note is that the system stores around 100 GB of LOD to enable history learning support in an open learning space. Thus, we need to confirm that the system can work smoothly without frustrating the learners. This experiment was the first evaluation involving the system and many of the functions implemented in it that use the LOD had not been proven to be effective in previous studies. For this reason, we felt we should verify the system's feasibility in a real learning scenario to prove whether the system can successfully support learners using automatically generated support created using the LOD.

Furthermore, we need to verify whether it performs meaningfully from the viewpoint of learning support.

Concerning objective (2), the hypothesis to verify is that learners using the question support should perform better in a task that requires integrated understanding to perform, such as essay writing. We expect that the deep questions prompt learners to develop their historical considerations during learning.

Concerning objective (3), the hypothesis to verify is that the question support improves the learners' engagement and interest in learning history. We expect the engagement of learners to be raised because the questions give objectives to learners to facilitate their learning, which should minimize the difficulties of self-directed learning.

4.2 Procedure

Table 1 shows the experiment procedure timetable. This evaluation involved 24 Japanese university students. They were given instructions to study about World War I (WWI) using a standard browser before the experiment (Table 1 (b1)). Why they study about WWI is to make them consider what they should learn in addition to memorizing facts before main experiment; we instructed them to "Imagine you were able to successfully enter the history department in a university where you hope to broaden your knowledge about history. You are now going to learn about WWI again using only Wikipedia as a learning resource. We will not test your knowledge about WWI after your study."

To form the control and experimental groups, the learners were then separated into two groups of 12 on the basis of the results they produced in a basic knowledge test about WWII (Table 1 (b2)).

We set a structure where both control and experimental groups can build a machine understandable concept map to support their knowledge externalization because this experiment focuses

on the validity of the question support for step-by-step clarification of the effects. Thus, even the control group (CtrlG) is supported by the concept map building situation. The only difference between the groups is the availability of the question support. The learners in the experimental group (ExpG) can request questions at any time to support their learning, while learners in the control group do not have access to questions even if they can build their own concept maps.

Learners are then introduced to inquiry-based learning and given examples of good historical considerations concerning the topic they had studied by themselves, WWI (Table 1 (e1)). We aim to prompt learners to reflect on their self-learning activities when learning about WWI and raise their readiness for performing inquiry-based learning when learning about WWII in the following experimental setting.

Learners are taught how to use the different functions of the system with a demonstration (Table 1 (e2)) and practice on the system for the WWI topic (Table 1 (e3)).

Before moving onto the main experiment (Table 1 (e4)), learners are instructed that they will have to write a report about their historical considerations on WWII after learning. Both groups are informed about the report and are instructed to study with that objective in mind.

In the main experiment (Table 1 (e4)), we set the inquiry-based learning task to learn about WWII in 90 min including learning about one topic among two in detail. The candidate topics to learn in detail are two important events from WWII: “Attack on Pearl Harbor” and “Battle of Iwo Jima.” We set a self-directed learning situation where learners can choose their learning topic according to their interests. By providing two possible topics to the learners, we can maintain this aspect in the constraints of the evaluation even if they cannot choose freely.

Furthermore, we do not set the hypothesis that we will observe large differences among the learners’ knowledge by using the effects of this experiment: we set a relatively short-term time setting to get positive feelings on the feasibility and validity of the system. We need to verify this matter by conducting a long-term study. We therefore did not set the hypothesis that we can observe large differences between the two groups regarding knowledge acquisition during this experiment, although we intend to conduct a basic knowledge test to make sure that the learning environment does not have a negative effect on learning.

At the end of the learning phase (Table 1 (e5)-(e7)), we ask learners to:

1. Fill in a questionnaire about the system to evaluate their feelings about the different functions of the system using the 5-grade Likert scale (Table 1 (e5)).
2. Answer a high-school level test about their chosen topic and WWII to evaluate their basic knowledge (Table 1 (e6)).
3. Write a report about their historical considerations to evaluate whether they performed deep historical thinking activities (Table 1 (e7)).

The knowledge tests (Table 1 (e6)) aim to test the learners’ basic knowledge and context understanding of what they had studied. Evaluating the basic knowledge of learners in self-directed learning is not easy because learners are free to learn about any concept following their interests. Effectively measuring the knowledge of each learner would require adapting the test to each learner and comparing the results for each test would be impossible. To compare the results of the learners, we have to provide all learners with the same tests even if the test questions may be about a topic the learners did not study.

The topic specific test includes 10 multiple choice questions with answers explicitly provided in the Wikipedia documents. The test about WWII takes the form of a “fill in the blank” test about general knowledge of WWII with 20 blanks to fill in. The learners do not have access to the system or to other learning materials when answering the test.

Table 1: Experiment Procedure

Time		CtlG (n=12)	ExpG (n=12)
Preparation for main experiment			
30 min	(b1)	Study of WW I on standard browser	
10 min	(b2)	Pre-Test about WWII for group formation	
Main Experiment			
5 min	(e1)	Instructions: Inquiry-based learning and good historical considerations on WWI	
35 min	(e2)	·Demonstration of system functions	
	(e3)	System without question support	System with question support
90 min	(e4)	Learning with system (Subject: WWII + Attack on Pearl Harbor or Battle of Iwo Jima)	
		System without question support	System with question support
20 min	(e5)	·Questionnaire	
	(e6)	·Basic knowledge test (Subject: WWII and chosen topic)	
30 min	(e7)	·Report writing (Subject: Describe your historical considerations about WWII)	

Table 2: Usability of Question Generation Function (Experimental Group Only)

		Questionnaire item	ExpG	
			Avg.	SD
(A) Quality of the questions	(a1)	Do you think the questions seemed unnatural?*	2.67	1.44
	(a2)	Do you think the questions were nonsensical?*	2.42	1.51
(B) Shallow questions usefulness	(b1)	Do you think the questions in the concept map made you realize what knowledge you needed to develop?	4.08	0.67
	(b2)	Do you think the empty node that appears with each question in the concept map made you want to answer the questions?	4	0.74
	(b3)	Do you think the shallow questions were easy?	3.5	0.8
	(b4)	Do you think the shallow questions were useful?	3.75	0.75
(C) Deep questions usefulness	(c1)	Do you think the questions the system provided were about the topic you were focusing on at the time?	3.42	0.79
	(c2)	Do you think the deep questions were easy?	2.42	0.9
	(c3)	Do you think the deep questions were useful?	4.33	0.65

* represents a reverse grade item.

The essay report (Table 1 (e7)) aims to evaluate whether the question support gives positive effects to learners to prompt their deep historical considerations. The subject of the report is kept simple: “Describe your historical considerations about World War II.” By giving an abstract subject, the differences between the learners’ levels of thinking becomes more visible.

During essay writing, after the basic knowledge test, learners from both groups have access to the system in read-only mode, because we do not aim to test their knowledge in their short-term memory in this phase. They cannot see any documents but can only look at their concept map and their questions and answers. They cannot modify either the questions or the concept map.

5. Results and Discussions

5.1 Feasibility and Usefulness of the System

During the use of the system, all learners were able to study for 90 minutes with no critical problems on standard computers (Processor Intel 2 Duo 3GHz, 4GB RAM). Even though the clients of the system were running simultaneously for the learners participating in the experiment, the server could handle all the data requests. The performance of the system was satisfying and it confirms that LOD based support is feasible in a real learning situation.

Moreover, Table 2 shows the results of the questionnaire items concerning the generated questions with the average scores on the 5 grade Likert scale as well as the standard deviation.

Regarding both shallow and deep questions, category (A) of Table 2 shows the questionnaire results for the questions only for the experimental group using question support. The answers to the questions (a1) and (a2) confirm that learners judged that the questions did not appear unnatural or nonsensical.

Regarding the results of both the average test scores about general knowledge of WWII (CtrlG: 7.58, ExpG: 7.42) and the test about the topic chosen (CtrlG: 5.17, ExpG: 5.58), as we expected, neither showed any significant difference between the groups for short term use. On the other hand, category (B) of Table 2 shows questionnaire results concerning whether learners felt the shallow questions were useful. The answers to questions (b1) and (b2) show that the shallow questions work to motivate learners in developing their basic knowledge. In addition, the answers to question (b4) show that learners judged that the shallow questions were useful. Thus, even if significant improvement does not appear in the test results after using the system for 90 minutes, the question support did not have a negative effect on knowledge acquisition. Moreover, it is notable that the ExpG learners were not forced to use the question support; they requested questions on their own spontaneous will. Although they did not get large benefits in terms of test scores, the fact that they requested an average of 14.3 shallow questions in the concept map, as well as their subjective feelings mentioned above, are meaningful.

Category (C) of Table 2 shows the questionnaire results for the questions relevant to the deep questions. The learners felt that the questions were adapted to their interests and knowledge since they were related to what they were studying (c1). An interesting result about deep questions is that the answer to question (c3) shows that the learners judged that the deep questions were useful, even though they felt that the questions were difficult (c2).

Table 3: Report Quality Comparison.

	(1) Personal feeling	(2) Fact only	(3) Lesson learned	(4) Historical considerations	(5) Irrelevant
Control (3 reports in 2 categories)	2	8	3	1	1
Experimental (2 reports in 2 categories)	0	3	2	6	3
Average number of questions answered (ExpG only)	-	3.33	5	5.17	2.33

By comparing the results for (b3) and (c2), it became apparent that they felt deep questions were more difficult than shallow questions, which is what we had designed. Furthermore, by comparing the results for (b4) and (c3), it became apparent that they felt deep questions were more useful. These results suggest that learners might have felt that deep questions were difficult but that they help to deepen their historical consideration. Consequently, we took this into consideration in the next section.

5.2 Effects on Historical Considerations

A history professor categorized the reports into 5 categories. Table 3 shows the number of reports categorized into each respective category. Each category represents:

1. **Personal feeling:** the report describes the learners' personal feelings about the events.
2. **Fact enumeration:** the report is mostly a list of facts described with little historical considerations made by the learner.
3. **Lesson learned:** the report describes the lessons that should be learned from the events and makes the connection between the events and the current situation.
4. **Historical considerations:** the report describes the learner's historical considerations about the topic. It contains the results of deep historical thinking from the learners.
5. **Irrelevant:** the report's contents cannot be categorized in another category or are confusing.

Some reports had contents that could be categorized in two different categories (3 for the control group, 2 for the experimental group). These reports are included in the count for both categories of Table 3 in these cases. From 1 to 4 (excluding irrelevant content in 5), the history professor judged that the quality became higher from the viewpoint of historical considerations.

Moreover, the reports were graded by a history professor with scores from 1 to 5. Even though the grades of the reports from both groups have no significant difference (CtrlG average: 2.08, ExpG average: 2.33), the results clarify the question support has meaningful effects on the content of the reports even with short term use of the system.

The results show that learners that used the question support (i.e., those in the ExpG) wrote reports including deeper considerations. Most learners in the CtrlG (who did not use the question support) wrote reports that were mostly enumerations of facts with little historical considerations.

On the other hand, many of the learners in the ExpG wrote reports containing deep historical considerations. The results also show that the more the learners in the ExpG answered deep questions, the more their reports were categorized into higher quality.

This suggests that the deep questions prompt their historical considerations as intended. It is notable that learners in the ExpG were able to write higher quality essay reports, which suggests the question generation function prompts their internal self-conversation on historical consideration, even though limited to 90 minutes. As we pointed out in Section 1, in general it is difficult to make good questions in an unfamiliar domain. Thus, it suggests quite meaningful effects to eliminate this problem.

5.3 Effects on Engagement

Although the results had already suggested that the question generation function prompts internal self-conversation in the context of inquiry-based self-directed learning, which helps to raise the learners' engagement in their learning, we conducted a questionnaire to verify that they themselves were aware of such effects.

Table 4 shows the results of the questionnaire items for both groups. Category (D) of Table 4 shows the questionnaire results about the usefulness of the system. The learners from both groups gave good average scores on the 5 grade Likert scale to the answer to the questions concerning the usability and usefulness of the system. Answers to the questions in Table 4 (d1) show that learners in both the

Table 4: Comparison between two groups about common function.

		Questionnaire item	CtrlG (n=12)		ExpG (n=12)	
			Avg.	SD	Avg.	SD
(D) System usability and usefulness	(d1)	Do you think the system was easy to use?	3.33	1.15	3.25	0.97
	(d2)	Do you feel that the system made it easier to learn?	3.5	1.09	3.92	0.79
	(d3)	Do you think using the system helped you understand the topic?	3.92	0.67	4.25	0.62
	(d4)	Do you want to use the system again?	3.25	1.48	3.83	0.72
(E) Concept map usefulness	(e1)	Do you think the concept map was easy to build?	4	1.15	3	0.97
	(e2)	Do you think the timeline part of the concept map helped you understand the events?	4.25	0.75	4.5	0.67
	(e3)	Do you think building a timeline including the context is a good way of learning history?	4.33	0.65	4.5	0.67
	(e4)	Do you think building a concept map is interesting?	3.42	1.44	3.58	0.79
	(e5)	Do you think building the concept map helped you learn history?	3.83	0.94	4.08	0.51
(F) Effects on learning motivation	(f1)	Are you interested in learning history?	3	1.28	3.58	0.9
	(f2)	Do you want to learn more about history?	3.08	1.24	3.5	1
	(f3)	Do you think using the system made you want to learn more?	3.08	1.24	3.67	0.65
	(f4)	Do you feel using the system made you more interested in learning about history?	3.17	1.19	4	0.74
(G) Usefulness of inquiry-based learning	(g1)	Do you think it is easier to perform inquiry-based learning using the system?	3.33	0.78	4.25	0.62
	(g2)	Do you think being aware of the questions is helpful to learn history?	3.67	0.78	4.58	0.51

CtrlG and ExpG did not have much difficulty in using the system. Table 4 (d2) and (d3) show that the learners in both the CtrlG and ExpG felt benefited from using the system while learners in the ExpG using the question support felt they could get relatively higher benefits than the learners in the CtrlG. Moreover, Table 4 (d4) shows that the learners in the ExpG felt more positive about using the system again than those in the CtrlG, which supports the notion that learners in the ExpG have much greater feelings about the usefulness of the system. The results of Table 4 (d3) and (d4) are consistent with each other.

Another interesting result is the answer to the question in Table 4 (e1). Learners in the ExpG felt that the concept map was harder to build than the learners in the CtrlG group. This suggests that the shallow question support appearing in the concept map on their demand made it harder to build the map. Even though the map building task was made harder by the question support, as we described, learners in the ExpG got a higher feeling that they had benefitted by using the system.

Moreover, regarding the timeline of the concept map used by both groups as shown in Table 4 (e2) and (e3), learners in both the CtrlG and ExpG felt it was highly useful. This suggests that using machine understandable LOD worked quite well as we intended.

Table 4 (e4) and (e5) also show that they felt the building concept map helped them to learn about history, while at the same time feeling it was not easy to build.

Even though both groups judged that the system was helpful, some differences appeared between them from the viewpoint of learning motivation.

Category (F) of Table 4 shows that learners in the ExpG had more interest in learning history after using the system. The learners in the ExpG gave higher marks for the Table 4 questionnaire items (f1), (f2), (f3), and particularly (f4). This shows that the question support has the potential to raise the engagement of the learners in learning history as the average mark for learners in the ExpG is higher. Taking this result into account and referring to the results shown in Table 3 suggests that the question generation support prompts learners' internal self-conversation activities. Since the learners in self-directed learning can choose to stop learning at any time and tend to feel bored if they lose their learning objectives, it is important to keep them engaged in the learning task by prompting their thoughts. This will enable engaged learners to spend more time for learning and develop their knowledge further.

Finally, category (G) of Table 4 shows their awareness of the usefulness of inquiry-based learning. Table 4 (g1) shows that learners in the ExpG felt that performing inquiry-based learning using the system was easier than the learners in the CtrlG. Because the only difference between the CtrlG and ExpG learners was that the latter used the question generation function, it can be concluded that this function makes them feel it is easy to perform their inquiry-based learning. Furthermore, Table 4 (g2) shows that the QG function makes learners become aware of the importance of questions in conducting their inquiry-based learning.

The results of Table 4 (g1) and (g2) suggest that the QG function makes learners aware that the inquiry-based learning strategy means learning about learning methods (meta-learning effects).

6. Conclusion

The evaluation results showed that supporting learners in an open learning space using support automatically generated using the LOD is feasible and can be useful for learners. Most learners judged that using the system was useful and that it helped them learn about history.

Even though the use time was short (90 min), the question support still had an effect on the development of historical considerations of learners and motivated them to perform deep historical thinking to develop their opinions.

The question support also had an effect on the engagement of learners. Engagement has strong effects in self-directed learning because being engaged and interested in the topic leads learners to study for a longer time and learn about more topics.

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