An Adaptive Navigation Support with Reorganized Learning Resources for Web-based Learning

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On the Web, there are diverse learning resources with the same learning topic, each of which is designed by different authors. Properly using these web-based resources, learners can study the topic from diverse points of view. This is one of the prominent merits of web-based learning. However, learners would have difficulty in finding a learning resource suitable to their learning contexts because there are currently an enormous number of learning resources on the Web and because most web-based learning resources do not have a clear description of their characteristics such as what kind of learners should use, what kind of learning goal can be achieved. Our approach to this issue is to reorganize web-based learning resources with indexes called resource indexes representing their characteristics, and to provide learners with an adaptive navigation support, which recommends them some learning resources to be learned next in accordance with their needs and knowledge states. We also report a preliminary experiment to evaluate the validity of the adaptive navigation support with a demonstration system. From the results of this experiment, we have made sure that it is valid.

Keywords: Learning Resource, Web-based Learning, Resource Index, Resource Navigation

1 Introduction

Over the past several years, an increasing number of hypermedia/hyperdocuments based resources on the Web have been available, which are designed from an educational point of view, or which are worth learning. Learning with such existing web-based resources has accordingly become more important, particularly as the realization of lifelong and distance learning [1].

On the Web, there are many learning resources with the same topic, each of which is designed by different authors. Some of them are suitable for augmenting domain concepts/knowledge in the topic. Some are also suitable for having a deeper understanding of the topic with examples/simulation/illustration, or applying knowledge with exercises. Properly using these kinds of learning resources, learners can study the topic from diverse points of view. This is a prominent merit of learning a topic on the Web.

This paper describes a web-based learning environment that makes use of diverse learning resources involving a certain topic to promote learning. The main issue addressed here is how to help learners select some instructive learning resources according to their learning contexts. There are currently an enormous number of learning resources on the Web. In addition, most web-based learning resources do not have a clear description of what kind of learners should use, what kind of learning goal can be achieved and so on [7]. Learners consequently have difficulty in finding an instructive learning resource [4].

The approach presented in this paper is to reorganize web-based learning resources with indexes called resource indexes representing their characteristics, and to build a learning resource database. At present, there exist a number of Web sites collecting URLs of web-based learning resources. These sites use resource indexes, which mainly represent learning topics/subjects, to classify the learning resources. The resource indexes allow learners to know what they can learn beforehand. In other words, they can select learning resources from a "what to learn" point of view. However, the indexes are not enough for them to find a learning resource suitable to their

learning contexts since they would usually think of not only "what to learn" but also "how to learn". They would particularly think of in which learning phase they try to learn. There are generally several phases of learning a topic such as augmenting new knowledge/information about the topic, deepening understanding of knowledge, applying/stabilizing knowledge, etc [5]. Which learning resource to select depends on in which phase learners try to learn. Learning phases should be accordingly represented as resource indexes.

In this paper, we propose a way to reorganize web-based learning resources with "how to learn" indexes (HTL indexes for short) including learning phases in addition to conventional "what to learn" indexes (WTL indexes for short), building a learning resource database. We also demonstrate an adaptive navigation support with the database, which recommends learners some resources to be learned next in accordance with their learning contexts such as needs and knowledge states. This aims to promote their learning from knowledge accretion phase to knowledge stabilization phase.

In the following sections, we first describe the way to build a learning resource database with WTL and HTL indexes. Next, we demonstrate the adaptive navigation support with the database. Furthermore, we report a preliminary experiment to evaluate the validity of the adaptive navigation support. From the results of this experiment, we have made sure that it is useful.

2 Reorganizing Web-based Learning Resources

2.1 Learning with Existing Resources on the Web

Before discussing the way to reorganize learning resources on the Web, let us first consider learning with them. In this paper, a learning resource means a hyperdocument, which describes a learning topic within a Web site. It provides learners with a hyperspace that consists of a number of Web pages. Learners can explore the hyperspace to learn domain concepts/knowledge [2], [6]. On the Web, in addition, there are diverse learning resources with the same topic, which could facilitate diverse learning phases such as augmenting and applying domain concepts/knowledge. Properly using these learning resources, learners can study the topic from diverse points of view.

As shown in Figure 1, we view web-based learning as learning a topic in three phases and as the transition between learning phases. The learning phases are as follows: accretion, understanding, and stabilization [3]. Each phase is also explained as follows:

- Accretion phase is the one in which domain concepts/knowledge are augmented;
- Understanding phase is the one in which known concepts/knowledge are understood with examples, simulations, illustrations, etc.;
- Stabilization phase is the one in which known concepts/knowledge are stabilized by means of problem-solving with exercises.

The transition between learning phases is expected to occur according to completion or impasse of learning in a phase. It is also expected to take place from knowledge accretion phase to knowledge stabilization phase or in the opposite direction. Learners' knowledge is finally expected to stabilize. However, learners need not always start learning from the accretion phase. They can start learning from any learning phase according to their knowledge states.

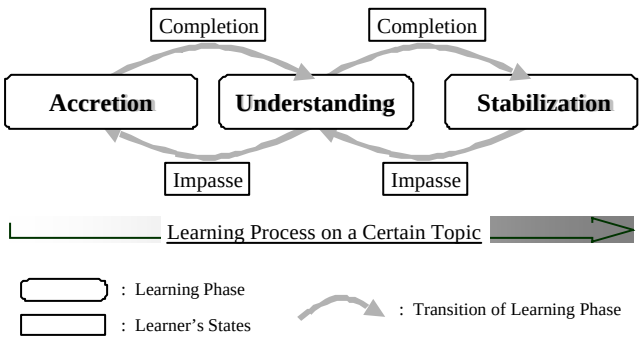


Figure 1 Web-based Learning

Table 1 Resource Index

WTL Index	Academic Year Subject Learning Topic	
HTL Index	Learning Phase	Accretion Understanding Stabilization
	Media	Texts only Graphics Animations Sounds Simulations E-Mail BBS, Chat Others
	Communication Channel	High Immediacy High Interactivity Questions and Answers

2.2 Resource Index

In learning a topic, learners would select a learning resource according to their knowledge states. However, most existing learning resources on the Web do not usually have a clear description about which learning phase could be facilitated. Therefore, the proper selection of learning resource is not so easy for them. One way to resolve this problem is to provide learners with a learning resource database.

There currently exist many Web sites, which collect URLs of web-based learning resources. In these sites, they are classified with resource indexes that mainly represent learning subjects/topics. These indexes allow learners to select learning resources from a "what to learn" point of view. However, such indexes are not enough for them to find a learning resource according to their learning contexts. When a learner wants to stabilize his/her knowledge of a topic, for example, he/she could select a learning resource suitable for augmenting knowledge about the topic. Learners would usually think of not only "what to learn" but also "how to learn" especially in which learning phase they should learn.

We have consequently provided resource indexes that consist of "How To Learn (HTL)" indexes in addition to conventional "What To Learn (WTL)" indexes, and have proposed a way to reorganize learning resources. In helping learners select learning resources proper for the transition between learning phases as shown in Figure 1, "learning phase" is first most important as HTL indexes. In helping learners continue learning in a phase, second, some HTL indexes are necessary for differentiating learning resources that could facilitate the phase. In fact, some learners may try to resolve an impasse, which occurs in one resource, with other resources that could facilitate the same learning phase. Considering web-based learning resources with the same topic, we can see various media for representing the contents such as text, diagram, chart, illustration, etc. We can also see various interactive/real time environments such as simulation, chat, BBS, etc. Such media and communication channels would have an influence on how to learn. In addition to learning phase, we accordingly regard them as HTL indexes as shown in Table 1.

2.3 Reorganization

Figure 2 shows how to reorganize learning resources with WTL and HTL indexes. First, the learning resources are classified with WTL indexes so that learners can see from a "what to learn" point of view. Next, the resources are classified with learning phases so that learners can select from a number of learning resources with one topic. Some learning resources may have two or three indexes of learning phase. Finally, indexes of media and communication channels are attached to each learning resource as its attributes so that learners can select from a number of resources that could facilitate the same learning phase.

Following the above way, we have implemented a learning resource database where many existing resources have been indexed. We have also addressed the issue of how to support indexing (See [5] for more detail).

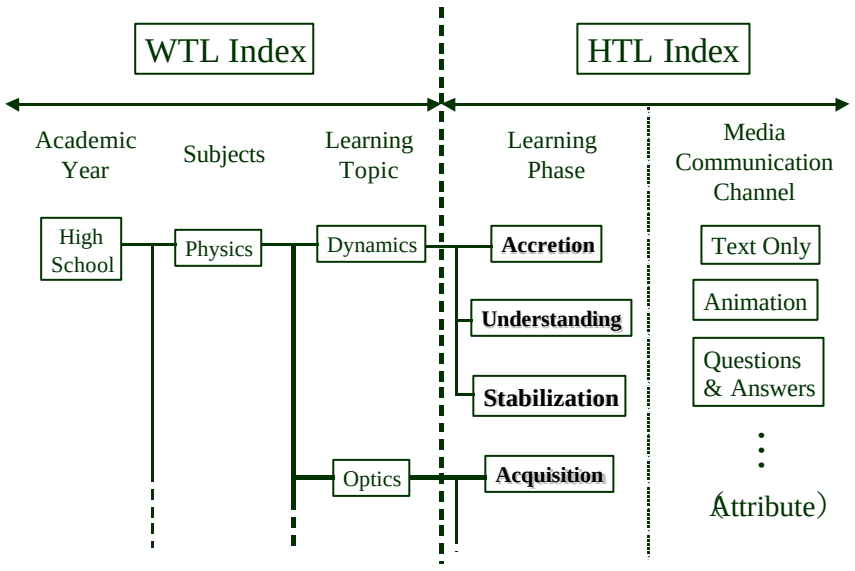


Figure 2 Hierarchy of Indexes

3 Adaptive Navigation Support

3.1 Learning Resource Navigation

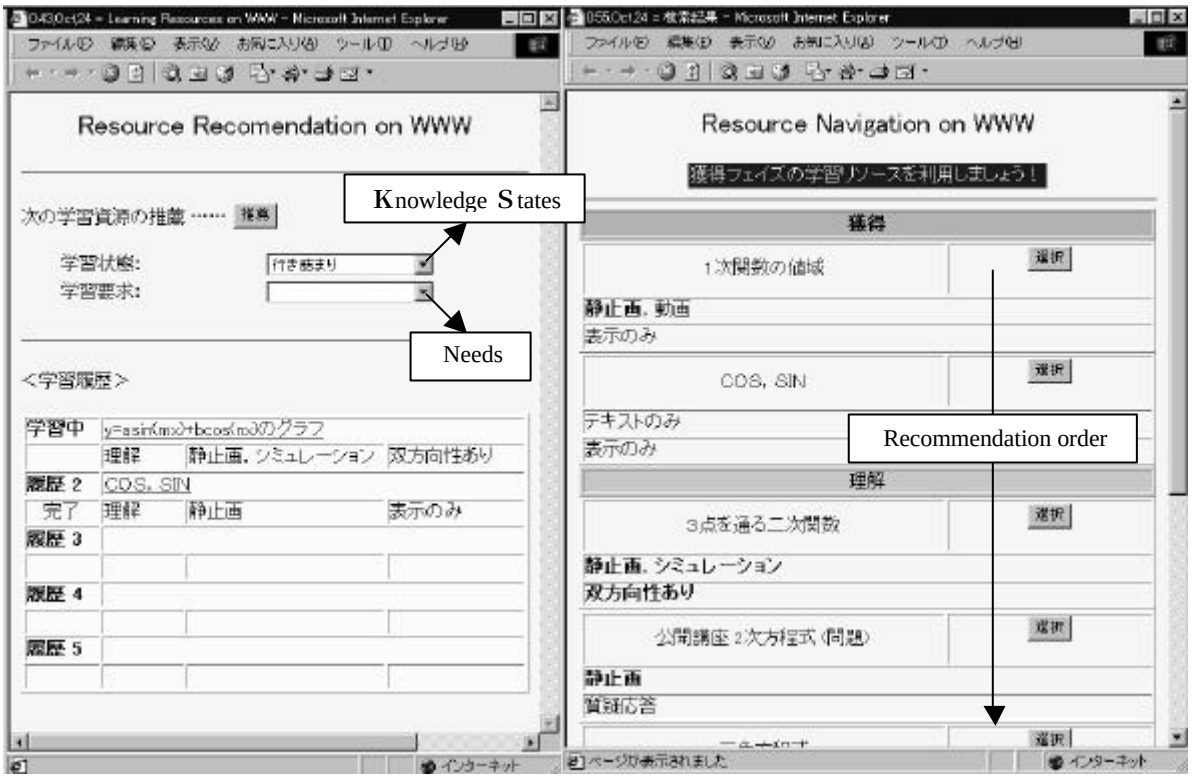
Let us now introduce an adaptive navigation support with the learning resource database. Although the resource indexes allow learners to search learning resources they want to learn, it is still difficult for them to select a learning resource in accordance with their learning contexts to promote learning from knowledge accretion to knowledge stabilization. We have accordingly proposed a navigation support, which recommends learning resources to be learned next according to learners' knowledge states and needs.

The main aim of this support is to promote learning of a specific topic with diverse learning resources so that learners' knowledge can be stabilized. For this aim, in particular, it attempts to facilitate the transition between learning phases and to change media/communication channels for promoting learning in one phase. If a learner reaches an impasse in the understanding phase, for example, he/she is encouraged to return to the accretion phase to resolve it. If he/she completes the understanding phase, on the other hand, he/she is encouraged to move to the next phase that is stabilization phase. He/she is alternatively encouraged to continue learning in the same phase with different resources that have different media/communication channels.

Figure 3 shows the interface of the prototype system for adaptive navigation support. This system, implemented with Common Gateway Interface (CGI), consists of two windows. The left window enables learners to input their needs and knowledge states in learning the current resource. It also shows a history of learning resources used, and encourages the learners to reflect on their learning processes. The right window displays a list that puts learning resources in order of priority for recommendation.

3.2 Recommendation

Let us next explain how to execute the learning resource recommendation in accordance with learners' knowledge states and needs. In the navigation support, we consider two knowledge states: impasses and completion of learning a resource. Learners are asked which state they reach after learning the resource. If necessary, they can also demand change of media/communication channels for a learning resource to be learned next as their needs.



< Learner's Input Window> <Resource Recommendation Window>

Figure 3 Resource Navigation System Interface

The learning resource recommendation uses the information given by the learners to make a list of learning resources to be learned next. The learning resources are put in the order of priority. The aim of the recommendation is not to give the learners the most instructive resource from the database. The list provides them with a guide in selecting instructive learning resources.

3.3 Procedure

Let us next explain how to decide the order of priority for recommending learning resources to be learned next. It corresponds to deciding which resource indexes should be given priority.

3.3.1 Ordering with Knowledge States

(1) Case of Impasse
When learners reach an impasse in a learning phase, learning resources, which could facilitate the previous learning phase, are first recommended so that they can resolve the impasse. The previous phase as index is accordingly given priority. On the other hand, the next phases are not given priority. Learning resources that have the same media/communication channels are also recommended since the learners may get confused with a change of media/communication channels in addition to the change of learning phase. The same media/communication channels as indexes are accordingly given priority. In case learners' knowledge state is in an impasse, therefore, learning resources that have the previous phase and the same media/communication channels as resource indexes are recommended as resources that are more instructive.

(2) Case of Completion
When learners complete learning in a learning phase, learning resources that have the next phase as index are first recommended so that they can further their knowledge. The next phase as index is accordingly given priority. The previous phases, on the other hand, are not given priority. The media/communication channels as indexes are given in the same way as the case of impasse. In case learners' knowledge state is in completion of learning, therefore, learning resources that have the next phase and the same media/communication channels as resource indexes are recommended as resources that are more instructive.

3.3.2 Ordering with Learners' Needs

In learning a resource, some learners may demand change of media/communication channels for the learning resource to be learned next. Regardless of learners' knowledge states, in this case, the same learning phase and different media/communication channels as indexes are given priority. The same media/communication channels are not given priority. Second, the different learning phases as indexes are not given priority according to learners' knowledge states. In case of impasse, the next phases are not given priority. In case of completion, the previous phases are not given priority. Learning resources that have the same phase and different media/communication channels as resource indexes are consequently recommended as resources that are more instructive. However, the way of ordering discussed in 3.3.1 is executed if learners reiterate learning in the same phase.

3.3.3 Calculation for Recommendation

Let us explain the way of calculation for ordering learning resources with an example. Learning resources are ordered with recommendation score, which is calculated every resource. Each learning resource has a number of HTL indexes. The recommendation score is calculated as follows. It is first scored ten points per learning phase index that is given priority, and is scored minus ten points per learning phase index that is not given priority. Next, it is scored one point per media/communication channel index that is given priority, and is scored minus one point per media/communication channel index that is not given priority. The larger the recommendation score is, the higher the priority of recommendation is.

Figure 4 shows an example of ordering five leaming resources. In this example, a learner inputs "impasse" as his/her knowledge states in learning a resource. The learning resource has the "understanding" phase, "text only" media as HTL indexes. In this case, the accretion phase as index is given priority. The stabilization phase is not given priority. In addition, the "text only" media as indexes is given priority, while the other media/communication channels are not given priority. Therefore, the recommendation scores for the five learning resources calculated as shown in the right side of Figure 4. The learning resource that has the accretion phase and "text only" media as HTL indexes is recommended in the highest priority.

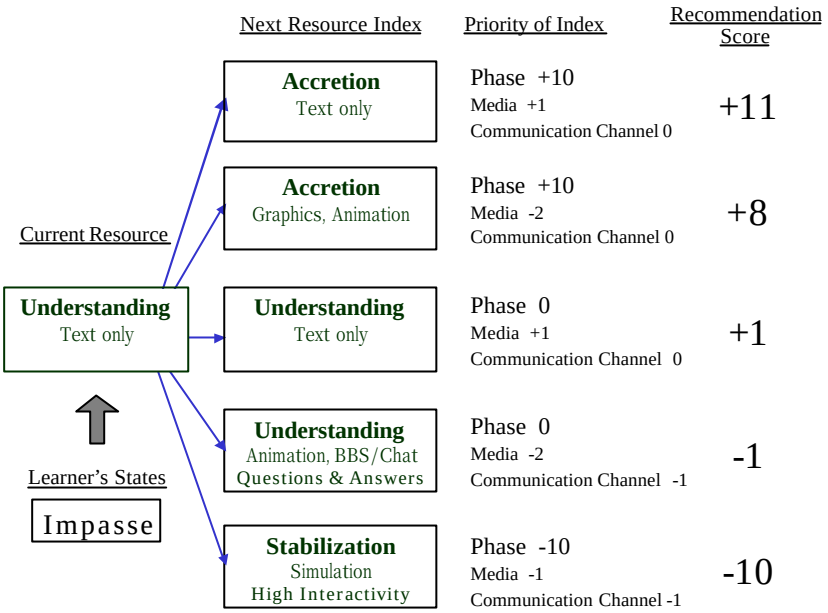


Fig. 4 Example for Recommendation

4 Preliminary Evaluation

4.1 Experiment

In order to evaluate the adaptive navigation support with the resource indexes and the learning contexts, we have had a preliminary experiment. The main purpose of this experiment was to ascertain the validity of the way of calculation for the recommendation order.

In this experiment, we compared the order of priority for recommendation generated with the adaptive navigation support to the order in which subjects placed learning resources by reading them carefully. Table 2 shows learning resources used in the experiment, which are described about a learning topic of "Global Warming Issue". Subjects were 12 graduate and undergraduate students in department of engineering. In spite of a well-known topic, the results of pretest indicated that they did not necessarily have sufficient domain knowledge.

The procedure of the experiment with each subject was as follows:

(1) He/she was asked to learn the resource A and then to input his/her knowledge state after learning. If he/she wanted to change media/communication channels, he/she could also input it as his/her need.

(2) He/she was asked to read the remaining resources carefully and place them in the order where he/she felt them more proper for his/her knowledge state and need.

Table 3 shows the order of priority for recommendation in each learning context considered. The order is calculated by the way discussed in section 3.3. For example, the recommendation is done in order of resource C, B, D and E, when a subject's knowledge state is in completion. Comparing the order of priority for recommendation to the order that subjects decided, we evaluated the validity of the learning resource recommendation.

4.2 Result

Table 4 shows the results of this experiment. The vertical axis is the order in which the system placed the learning resources (System-decided Order for short) and the horizontal axis is the order in which subjects placed them (Subjects-decided Order for short). The smaller the number of the order is the higher the priority for recommendation is. Each value in the table means the number of cases that fulfilled the System-decided order and the Subjects-decided order. For example, there were six cases where both System-decided and Subjects-decided orders were the first place.

In order to look into an approximate tendency in Table 4, we divided the order of priority into High and Low. As shown in Table 5, the High order including the first and second places of both System-decided and Subjects-decided orders, and the Low order also including the third and fourth places. We then performed Fisher's exact probability test in Table 5. As a result, there was a significant relevancy between System-decided order and

Subjects-decided order(p=0.00867), and these orders were positively related with a correlation (f =0.42). It indicates that System-decided order agreed with Subjects-decided order approximately.

Table 2 The Learning Resource for Experiment

	Resource	HTL Index
A	Think about global warming http://www.nature-n.com/g_wrm/index-j.htm	Phase : Accretion Media : Graphics
B	Eco-Life Guide · The Issue of Global Warming http://www.eic.or.jp/ecolife/t001.html	Phase : Understanding, Stabilization Media : Graphics, Others Communication Channel : Questions and Answers
C	Kyoto-Earth's Homepage · Environment/ Global Warming http://www.pref.kyoto.jp/intro/21cent/kankyo/h3.html	Phase : Accretion, Understanding Media : Graphics, E-Mail
D	Global Warming http://www.wnn.or.jp/wnn-eco/cop3/index.html	Phase : Accretion, Understanding, Stabilization Media : Graphics, Others Communication Channel : Questions and Answers, High Interactivity
E	Tackling to the global environmental problems · Global Warming http://www.epcc.pref.osaka.jp/apec/jpn/earth/index.htm	Phase : Accretion Media : Graphics

Table 3 Order of Priority that the System Ordered

Case of Completion

Resource	Priority			Order
	Phase	Media	CC	
B	+1	+1,-1	-1	2
C	+1	+1,-1	0	1
D	+1	+1,-1	-1,-1	3
E	0	+1	0	4

Case of Impasse

Resource	Priority			Order
	Phase	Media	CC	
B	-1,-1	+1,-1	-1	3
C	-1	+1,-1	0	2
D	-1,-1	+1,-1	-1,-1	4
E	0	+1	0	1

Case of Change (State : Completion)

Resource	Priority			Order
	Phase	Media	CC	
B	0	+1,-1	+1	4
C	+1	+1,-1	0	2
D	+1	+1,-1	+1,+1	1
E	+1	-1	0	3

Case of Change (State : Impasse)

Resource	Priority			Order
	Phase	Media	CC	
B	-1,-1	+1,-1	+1	4
C	+1,-1	+1,-1	0	2
D	+1,-1,-1	+1,-1	+1.+1	3
E	+1	-1	0	1

(CC : Communication Channel)

Table 4 Result of Experiment

System-decided Order	Subjects-decided Order			
	1	2	3	4
4	2	1	4	5
3	1	3	3	5
2	3	3	4	2
1	6	5	1	0

Table 5 Result of Experiment

	Subjects-decided HighOrder	Subjects-decided LowOrder
System-decided LowOrder	7	17
System-decided HighOrder	17	7

5 Discussion

From the results of the experiment, we have made sure that the adaptive navigation support is useful for learners to learn a certain topic with diverse learning resources. However, it does not work well for learners who cannot input their knowledge states and needs by themselves because these are important information for the adaptation.

One way to resolve this is that teachers/instructors help such learners input. In addition, some learners may input their wrong knowledge states. However, this is not a serious problem from a whole learning process point of view since inputting "completion" as knowledge state despite his/her incompleteness of leaming would cause a serious impasse in the next learning phase, for example. Alternatively, inputting "impasse" despite his/her completeness of learning as knowledge state would cause a complete learning in the previous phase without difficulty.

Lets us next discuss the adaptive navigation support compared with related work on courseware generation on the Web [8]. Courseware is generally generated in order to facilitate learning of a series of topics and relationships between these topics. Each topic included in a courseware accordingly needs to be designed as learning resource from a specific point of view. In related work on courseware generation, the same designer prepares each learning resource for each topic on the Web. However, it is hard to make a courseware from existing web-base resources since they are usually designed from different points of view. On the other hand, we focus on properly using diverse resources with the same topic, not with related topics, to promote learning of it from diverse points of view.

6 Conclusions

This paper has proposed a learning resource database that reorganizes learning resources on the Web with resource indexes. This paper has also presented the adaptive navigation with the database, which recommends learners some resources to be learned next according to their needs and knowledge states. This allows learners to use existing learning resources with a certain topic to promote their learning. In addition, the paper preliminarily evaluated the adaptive navigation support. In this experiment, we compared the order of priority for recommendation generated with the adaptive navigation support to the order in which subjects placed learning resources. As a results, we have made sure that it is valid.

In the future, it is necessary to evaluate the adaptive navigation support in more detail. We would also like to develop a more practical system and open to the public.

Acknowledgments

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