

Creating a Topic Maps Based e-Learning System on Introductory Physics

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Abstract. Construction of an introductory physics e-learning system based on Topic Maps is discussed in view of subject-centric design of web-based learning. A pilot system with a visualized Topic Maps portal was created and utilized for students' self-study of university lectures. The aim of this system is to provide a platform where learners can design their study by themselves, and extend their study into information resources on the Internet. The students' response to an inquiry on their impressions of the pilot system suggested that the Topic Maps portal is useful for figuring out the relationships of knowledge, and that navigation for the order of learning materials was required for beginners. Further, an e-Learning Topic Maps system that consists of three main domains, i.e., physics subjects, learning resource types, and learning record types, was created to improve the system extensible in physics related knowledge and in the types of associations between subjects.

Keywords: Topic Maps, e-Learning, introductory physics education

1 Introduction

Web-based e-Learning has gained popularity as a type of learning facilities in many fields. E-Learning can provide learners with an interactive and flexible interface to knowledge resources, and it can be adopted with individual requirements of learners. One of the authors is creating an original e-Learning

system of introductory physics “Everyday Physics e-Learning (EPEL in abbreviation)” [1], which is made open also for public use, and utilizing it as a learning environment for students’ self-study in the university, in addition to the ordinary face-to-face lectures.

The system had been used with the schedule type portal, as shown in fig. 1, in which learning materials were arranged linearly with time, i.e., the dates of lectures, for 4 kinds of courses of dynamics, heat, wave, and electromagnetism. In order to enhance learners’ spaced repetitive learning [2], the system was equipped with an original time-dependent weighted accumulation function to evaluate learners’ drill scores [3]. This learning support system had been mainly used for preparation and review for the face-to-face lectures.

Topic Maps technology has already been applied to the construction of e-Learning system [4, 5]. In the 2006 autumn semester, we introduced a Topic Maps visualization style portal as shown in fig. 2 into the previous schedule type system, in order to represent overall knowledge structures of learning resource the system consisted of, and to stimulate spontaneous self-study over a wider range than that covered by the lectures the students followed. In the maps, button labels showed the names of subjects, and the emphasized arrows pointed base subject of a selected one.

In the renewed system, the equivalent maps of contents were displayed for texts and 4 kinds of drills, i.e., essay drills, multiple-choice drills, calculation drills, and free-style drills. In the drill maps, the colors of button labels were determined by the evaluation values that were calculated by the above weighted accumulation function of drill scores.

From the 2007 spring semester, the system was changed to use completely the Topic Maps visualization style, and the previous schedule type portal was removed. The aim of this change is to make the system be a platform where learners are able to design their way of study by themselves, even independent upon lecture schedules, and the teacher can evaluate students’ individual study.

From the 2007 autumn semester, the authors are reconsidering the construction of the system from the viewpoint of subject-centricity, and are trying to make it to be a platform where students start their study and extend into broad knowledge resource of the Internet.

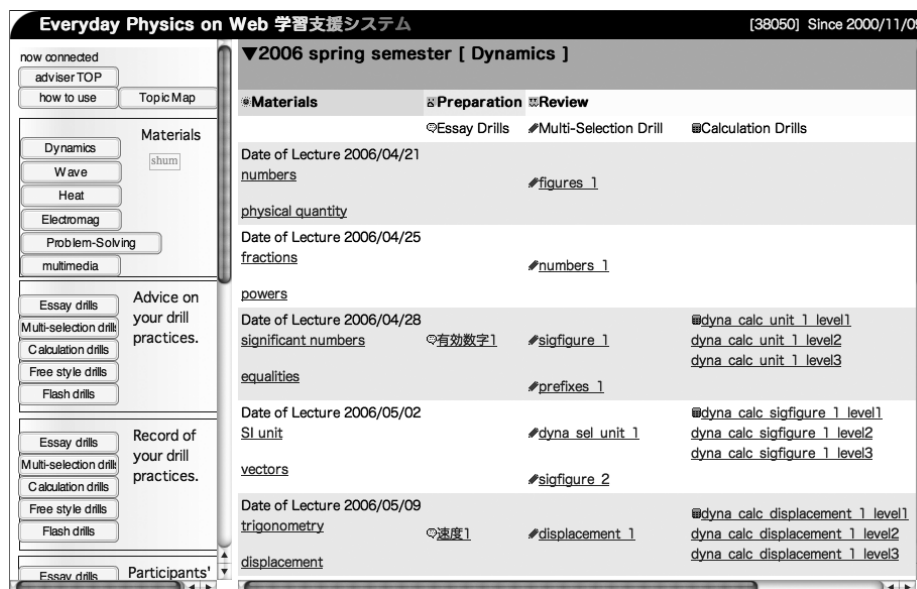


Fig. 1. An example of schedule type portal. Links for texts and drills were arrayed linearly along with the lecture schedule, from the top to the bottom of the portal page.

2 Towards a Subject-centric learning system

2.1 Change from “Course-Centric” to “Subject-Centric”

In the traditional course styled e-Learning systems, learning resources are arrayed sequentially along with the lecture time schedules. The way of arrangement defines the context of information that the course provides. Following the sequence of learning materials, learners acquire necessary base knowledge to proceed to higher steps in the course. However, less motivated students often loose enthusiasm in the middle of the course, feeling difficulties in understanding or in skills. Further, in order that the learners are able to explore the learning resources according to their own particular interest, another mechanism is required in the learning system.

On the other hand, students often study at home by using learning resources that exist on the web. The manner of online information retrieval was modeled as “berrypicking”, where the motivation of retrieval is often stimulated and is changed in the repetition of retrieval, browsing, and thinking [6]. This

berrypicking manner is also expected to be a typical style of learning on the web. The topic maps will enhance this berrypicking learning manner, and is expected to be effective to keep the learners motivated in learning.

Thus, in order that the learners can design their study manner on e-Learning system, we designed a Topic Maps-based system. Subjects and their associations in the knowledge layer of introductory physics were visualized in the portal of learning as shown in fig. 2. By clicking the subject buttons, related learning resources in the information layer are retrieved. Learners are able to choose and study the learning materials freely, viewing the whole conceptual structure. Further, the record of learning for each subject was made also visible in the Topic Maps portal. In this way, the system was changed from course-centric to subject-centric by introducing Topic Maps.

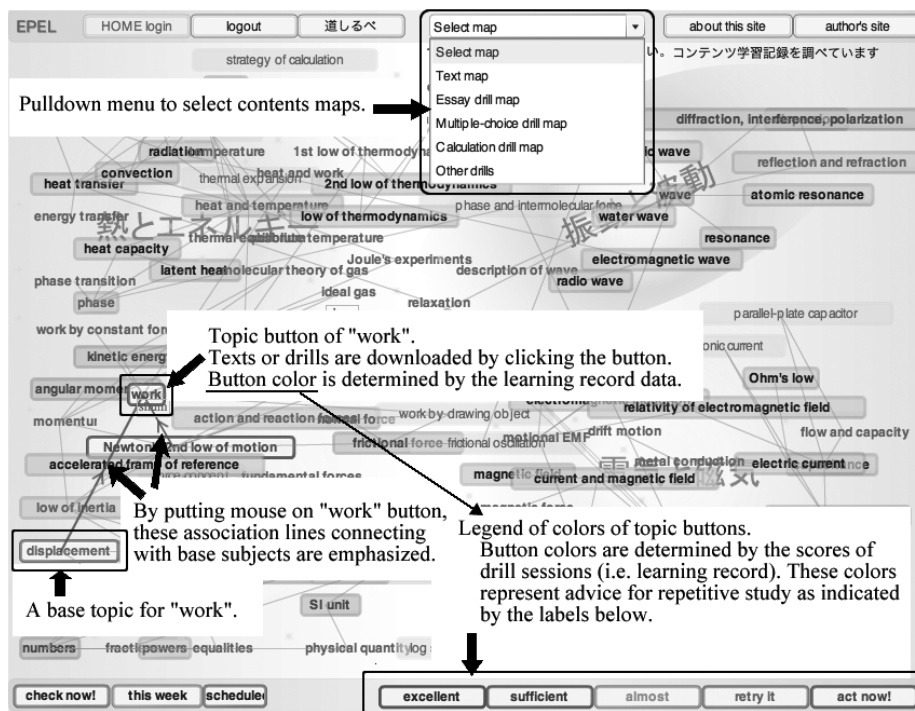


Fig. 2. A primitive portal that consists of the buttons to download/access texts and drills/most of the learning objects in the e-Learning site. By putting mouse over on the a button, its association lines that connect the selected button with to the buttons of its base concepts are emphasized. Portals that provide Pull down menu changes the type of learning objects such as texts and 4 types of drills are selected

2.2 Creating a Primitive Topic Maps Portal and Students' Response

In autumn 2006, a primitive Topic Maps portal as shown in fig. 2 was created and introduced in our e-Learning system, EPEL. Contents of the system ranges over the fields of “basic mathematics”, “dynamics”, “heat”, “wave”, and “electromagnetism”, in the form of texts, multiple selection drills, calculation drills, essay drills, and other free-style drills.

The web server used was Windows IIS, and the data base server was Windows SQL Server 2000. Connection of web application and the data base server was implemented using Macromedia ColdFusion MX7. The client application was developed using Macromedia Flash 8 Professional. The flash remoting technology was used for the communication between client Flash pages and the ColdFusion components implemented in the web server. In addition, Macromedia Flash Communication Server MX was used for several real time communication functions implemented in EPEL system.

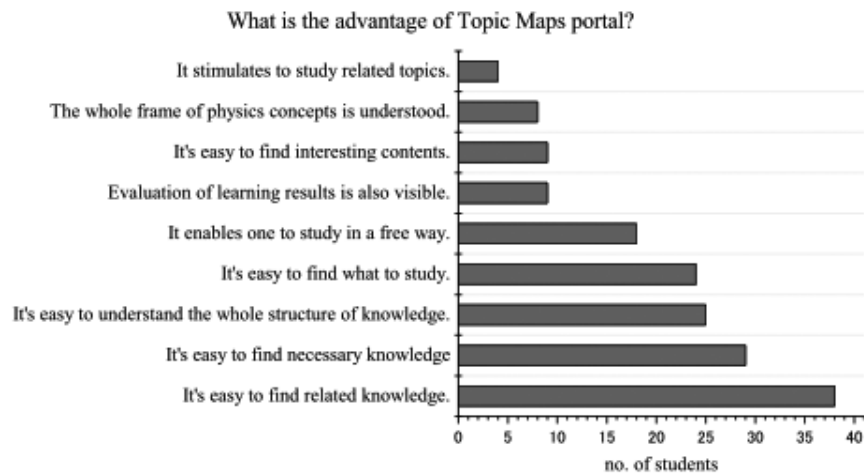


Fig. 3. Results of an inquiry for students, asking to choose useful pointsmerits of topic Topic map Maps portal, shown in fig. 2, from thea multiple selection list shown in the figure. Choice of more than one selection was allowed.

The primitive portal of EPEL consists of buttons with the labels of subject names, and association lines, which are emphasised with mouse rollover events, pointing from base subjects to applied subjects as also shown in fig. 2. The association role types are simply “base” and “application”, correspondingly. In most cases, the grain fineness of subjects is similar to the sub section of ordinary textbooks, such as “work”, “work and kinetic energy”. The way of association is based on ordinary traditional instruction method. Visually equivalent topic maps

were displayed for the above 5 types of contents. Maps were switched by a pull down menu, which was shown in the upper middle position of fig. 2.

To stimulate repetitive learning with an appropriate interval of time, 6 levels of advises were provided and visualized by the label colours of topic buttons. The levels of advise, from “Study again right now” to “You understood well, Try it after a while” were determined by the values of time-dependent weighted accumulation function of individual drill scores. These advise levels represent priority levels of reviewing.

Our e-Learning system, EPEL, was utilized in the introductory section of the curriculum of School of High-Technology for Human Welfare, which consists of Dept. of Perceptual Human Interface Design, Dept. of Information and Communication Engineering, Dept. of Materials Chemistry, Dept. of Biological Science and Technology, and Dept of Bio-Medical Engineering, in Tokai University. “Classical dynamics” courses (2 sessions every week) were opened in the spring semesters, and “heat and energy”, “oscillation and wave”, and “electromagnetism” courses (one session every week for each class) were opened in the autumn semesters. In 2006 and 2007, each class had approximately 30 students. Most of the students utilized e-Learning system during semesters.

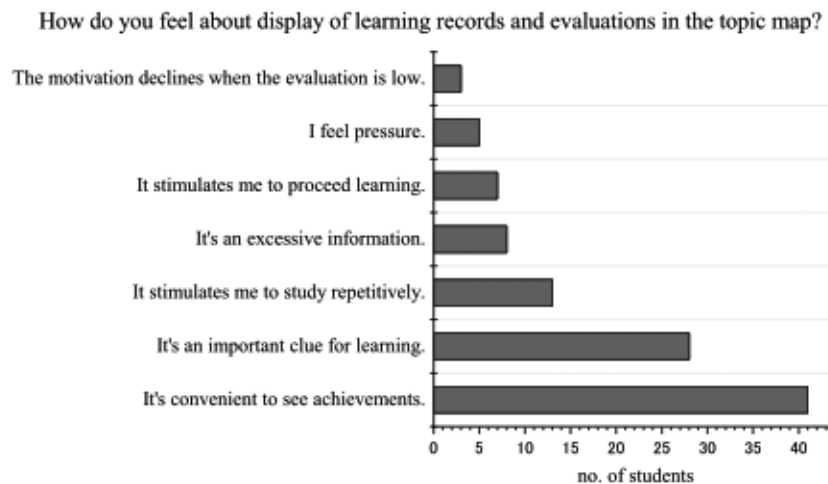


Fig. 4. Results of an inquiry about on impression of impression display of drill score evaluations displayed in the topic maps portal. Choice of more than one selection was allowed.

From autumn 2006 to spring 2007 semesters, the number of students who studied a wider range of fields in the e-Learning than in face-to-face class increased. Particularly, those who studied many times had a tendency to explore uniformly

on the map. This suggested that the topic map was effective for inducing self-study of non-lectured field. In addition, a positive feedback appeared in studying behavior from base knowledge to applied one [7].

Now we turn to the results of inquiry that was done for students in the middle of the autumn 2007 semester on their impression of the Topic Maps portal. Figure 3 shows the result for a question on the positive factors of the Topic Maps portal. Total number of students who answered was 71. Many students regarded the Topic Maps visualization had advantages in the recognition of relationships of knowledge. Not many students thought the maps were effective to grasp whole structure of physical knowledge. This might be due to the complexity of the visualization with too many items.

Figure 4 shows the result of the inquiry on displaying evaluation of drill scores on the Topic Maps buttons. Many of the students seemed to feel convenience in finding achievement and items to review. However, a number of students claimed complexity with excess information.

Figure 5 shows the results on the negative points of map representation. Many students claimed it was hard to see the order of study on the map. One of the student even claimed that the former scheduled type portal was better for preparation and review for the face-to-face class. Another student suggested that a fairly simple view was necessary at first to find the way to study easily, and, as the learning proceeded, the detailed presentation should appear gradually.

Balance between “Push” and “Pull”. Considering these results, one solution that should be made is the introduction of sequential navigation that corresponds to the traditional course structure. However, many of the students in our department are likely to make less effort to get through the course. Sufficient care should be taken to introduce simple navigation in the topic maps.

This problem concerns the balance of “push” and “pull” for the findability. If the direct navigation that works as “push” dominates in the system, learners might not become active in exploring the knowledge. This, in turn, might cause a decline of motivation. On contrary, if functions of “pushing” are removed, learners will not feel any stimuli to commence or keep learning activity.

Obviously, use of simple navigation will not solve this problem. The state of balance between “push” and “pull” will evaluate the learning system. “Push” and “pull” properties characterize every interactive function. Advise for repetitive study, as well as representation of drill scores, will act as “push” function in our system. Also, Topic Maps portal as a whole is characterized by its “pull” property. Considering the results of inquiry, our present system can be evaluated to be still insufficient in its “push” property.

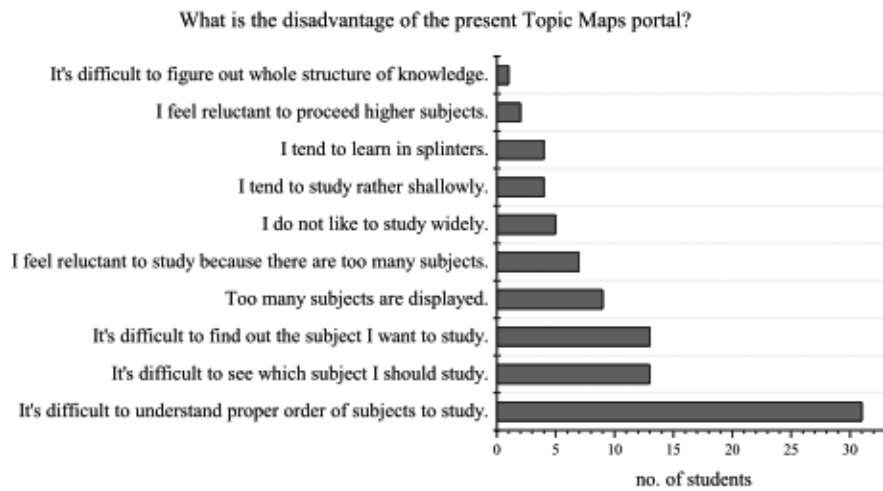


Fig. 5. Results of an inquiry about weaknegative points in the topic Topic maps portal. Choice of more than one selection was allowed.

3 Construction of Topic Maps for Subject Centric Extensible e-Learning

Our primitive EPEL system until 2007 did not fully make use of the potential of topic maps. Here we try to create a multi-layered topic maps to enable the system more extensible. We consider the following requirements.

1. Topic Maps ontology of physics knowledge can be created and extended independent upon the actual learning resources and learning record data.
2. It should be easy to add new types of contents, independent upon the physics knowledge structure.
3. Learning Records are divided into assessable and non-assessable type, and assessable type is divided into self-assessment and automatic-assessment type.

3.1 Topic Maps Ontology of EPEL

Table 1. Topic types and occurrence types of EPEL.

Topic Types (broader <-> narrower)		Occurrences
Physics Subject	Basic Mathematics	(empty)
	Common Concepts	
	Dynamics	
	Heat	
	Wave	
	Electromagnetics	
Learning Resource	Text	(SQL queries for learning resources)
	Essay Drill	
	Multiple-Choice Drill	
	Calculation Drill	
	Free Drill	
Learning Record	Text Learning Record	(SQL queries for users' learning records)
	Essay Drill Learning Record	
	Multiple-Choice Drill Learning Record	
	Calculation Drill Learning Record	
	Free Drill Learning Record	

Table 1 shows the taxonomy of topic types and occurrences for EPEL 2008 spring semester. Knowledge structures are considered in “Physics Subject” type. The structure of learning materials is considered in “Learning Resource” type. The recorded data of individual learning, such as the date and time of sessions, scores of drills, the values of time-dependent weighted accumulation function of drill scores, students’ comment and questions, etc., are considered in “Learning Record” type. Sub types of “Physics Subject” are divided into 6 individual field types, and each field has its own characteristic network of associations among its instance topics.

No occurrence is defined for “Physics Subject” type. One can concentrate on the concept of physics and construct ontology of physics subjects, even without thinking of any actual materials.

“Learning Resource” type has, at present, 5 types of materials. These types are distinguished by the format of learning materials. Thus, the ways of formatting are considered as topics in this e-Learning ontology. Since the ways of contents formatting are independent upon the subject of physics, “Physics Subject” type is independent upon “Learning Resource” type. Occurrences of “Learning Resource” and “Learning Record” are embodied in a variety of SQL queries.

“Learning Record” is the topic type for organizing individual records of activities in EPEL system, and is also based on the ways of assessments. In EPEL, text reading has no assessment. For essay drills, learners write texts, and then

compare with the example of answer. In this case, learners themselves assess their understanding, i.e., self-assessment. For other drills, learners' answers are automatically checked and analyzed by the evaluation function, i.e., interactive-assessment.

Table 2. Association types and association role types of EPEL.

category	Association Type	Association Role Type	
Physics Association	is_based_on	base	application
	Transfield_is_based_on		
	Advanced_is_based_on		
	Applied_is_based_on		
	is_analogous_to	(symmetric)	
Learning Resource Association	is_subject_of_Resource	Subject	Text
			Essay Drill
Learning Record Association	is_subject_of_Record	Subject	Multiple-Choice Drill
			Calculation Drill
			Free Drill
			Text Learning Record
			Essay Drill Learning Record
Learning Record Association	is_subject_of_Record	Subject	Multiple-Choice Drill Learning Record
			Calculation Drill Learning Record
			Free Drill Learning Record
			Free Drill Learning Record

Table 2 shows the association types and association role types for corresponding topic types. "Physics Association" category defines various types of associations among "Physics Subject" topic instances. "is_based_on" type and "Transfield_is_based_on" type define a hierarchical structure of physics knowledge system. "Advanced_is_based_on" association and "Applied_is_based_on" association connect the basic concepts with the advanced subjects or with the applied subjects. These associations are particularly useful for learners to explore the knowledge from the basic concept.

The navigation association “Preceding_Following” is used to simulate ordinary course learning system. It provides traditional order of learning materials to learn introductory physics. Many of the basic subjects within each field are connected sequentially by this association. As it was mentioned in section 2.2, many of those students who used EPEL claimed to make clear a standard order of subjects to learn.

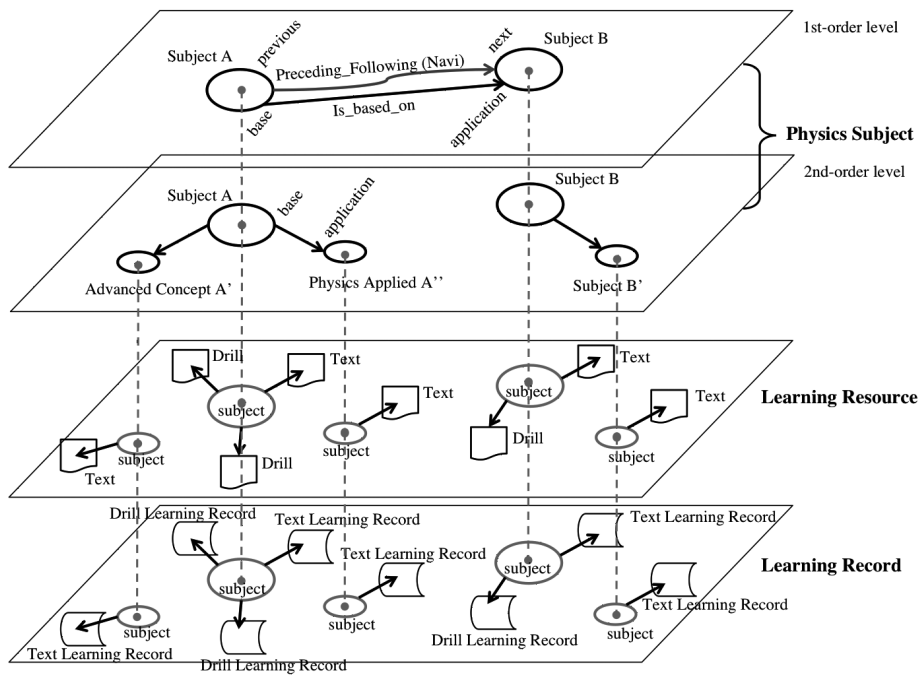


Fig. 6. Structure of topic maps. Physics subject types forms the knowledge structure of physics, without having occurrences to specific materials. Learning resource types and learning record types are related to the physics subject types, and have occurrences to real learning materials and records of learners’ activities and scores.

The topic map of instances of “Physics Subject” in the knowledge layer constructs the fundamental structure of EPEL. Instances of subtypes of “Learning Resource” type and “Learning Record” type are associated to the networked “Physics Subject” topics. Thus, the architecture is centered in physics subject in the knowledge layer.

3.2 Multi-Layered Structure of Topic Types

Figure 6 shows a schematic illustration of the structure of EPEL topic types, by a multi-layered modeling. The backbone of EPEL is the 1st-order level where the instances of basic subjects are connected by “is_based_on” associations. Also, many of basic subjects are aligned with “Preceding_Following” navigation associations. Advanced subjects and applied subjects are connected with the corresponding basic subjects in the 2nd-order level. The layers of physics subjects can be added by introducing another types of associations.

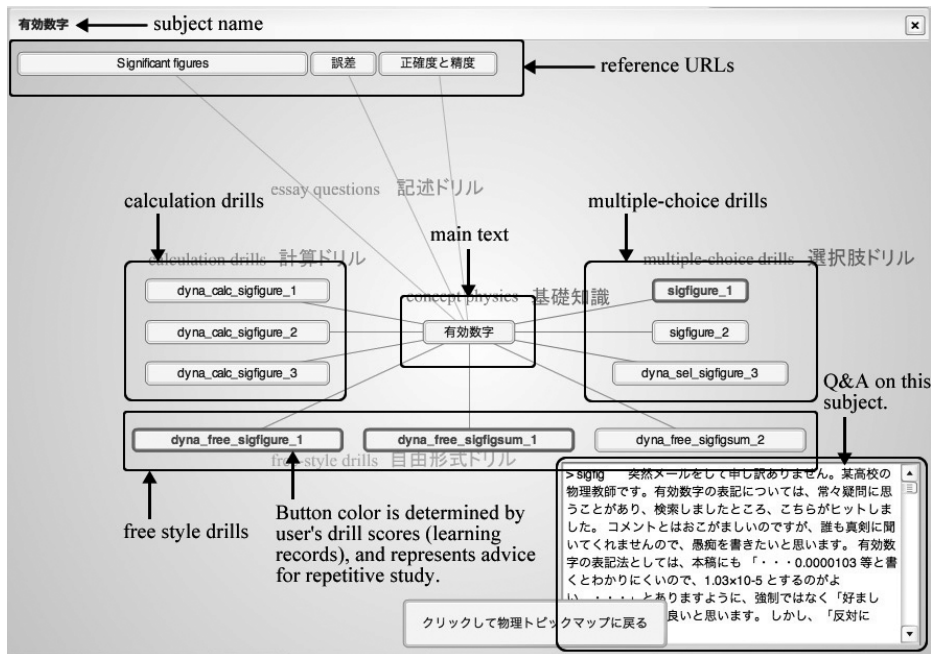


Fig. 7. An example of representation of 2nd-order level topic maps portal. A button for basic subject is located in the center, and those for drills are around. Buttons at the top are for related subjects.

Learning resource and learning record type instances are located on the corresponding layers, and associated with the physics subjects by “is_subject_of_Resource” and “is_subject_of_Record”, correspondingly. In the figure, resource type instances, as well as record type instances, are connected with subject images projected onto the corresponding layer. Learning resource layer and learning record layer have the occurrence links to the real materials and recorded learning data.

Figure 7 shows an example of real image of 2nd-order map layer, with the learning resource layer and learning record layer superimposed on it. Particularly, information of the learning record layer, i.e., the values of time-dependent weighted accumulation function, is represented by the button colors. Physics subjects at 2nd-order level themselves have no occurrences. Only the subject names appear as labels of buttons. The association between physics subjects are visualized by line. The main text instance button of basic subject is located at the center, and its text is downloadable by clicking the button. Text instances of related subjects are located at the top of window. Buttons for drill resources surround the main subject. Label colors of material buttons represent the data of learning records.

4 Concluding Remarks

This paper discussed the change of e-Learning system from traditional sequential course type to a primitive Topic Maps portal type. Students' responses to this change suggested that the Topic Maps portal was useful for recognizing relationships of knowledge, and that the balance between push and pull in the functions of e-Learning system should be improved. In the next step, we proposed a new topic map system that is physics subject centric as backbone ontology. One can concentrate on extending the physics subjects and the associations.

Learning introductory physics as efficiently as possible is really important for beginners who have a variety of majors. However, it is also important to bridge between basic physics knowledge to real natural phenomena and technological applications in students' self-study on web. The subject-centric nature of Topic maps technology will play an essential role for this purpose.

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