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ONTOLOGY TECHNIQUE AND MEANINGFUL LEARNING SUPPORT ENVIRONMENTS

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Abstract: In this chapter, we present two ontology-driven learning support systems, which intend to provide meaningful learning environment: a customizable language learning support system (CLLSS) and a visualization learning support system for e-book users (VSSE). CLLSS was built to provide an interface for the learning objects arrangement which displays the visual representation of knowledge points and their relations. The intention underlying the development of CLLSS is to encourage instructors to orient their teaching materials to specific knowledge points and even directly to relations between knowledge points. With these orientations, CLLSS is able to provide an environment in which learners can readily distinguish between related knowledge points. In the other hand, VSSE is designed and developed to help e-book learners to effectively construct their knowledge frameworks. Making use of e-book logs, VSSE supports not only meaningful receptive learning but also meaningful discovery learning. In other words, two learning modes are provided in VSSE: (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.

Key words: meaningful learning; ontology; digital textbooks; discovery learning; visualization

1. INTRODUCTION

Evidence from diverse studies suggests that in the human brain knowledge is incorporated more effectively when it is organized in hierarchical frameworks. Learning approaches that facilitate this kind of organization significantly increase the learning capability of learners (Bransford et al, 1999; Tsien, 2007). Ausubel's learning psychology theory (Ausubel, 1963; Ausubel, 1968; Ausubel, Novak, & Hanesian. 1978) defines this effective assimilation of new knowledge into existing knowledge frameworks as the achievement of “meaningful learning.” Therefore, means of helping learners to efficiently develop their conceptual framework emerge as a main issue for fostering meaningful learning in e-learning.

In this chapter, we will present two learning support systems which intend to provide meaningful learning environments. Although these two systems are designed for different usages, they both make use of the ontology technique for the domain modelling.

2. MAPPING AND ONTOLOGY TECHNIQUE

In the interest of encouraging meaningful learning, maps consisting of nodes (key concepts) and links (relationships) can provide scaffolding to help learners to organize knowledge and structure their own knowledge frameworks (Novak & Cañas, 2006). In this study, we will introduce two meaningful learning environments which provide topic maps to enable the learner to associate the knowledge structure with corresponding learning materials, including definitions and explanations of knowledge and the e-book contents. Different from “concept maps” (Novak & Cañas, 2006; Chu, Lee, & Tsai, 2011) and “knowledge maps” (Lee, & Segev, 2012; Donnell, Dansereau, & Hall, 2002), which are used as learning materials in knowledge representation, topic maps are mainly used as metadata of learning materials (Wang, Mendori, & Xiong, 2014).

Some researches study the effectiveness of maps in pencil-and-paper format, for example, Lim, Lee and Grabowski (2009) examine the effectiveness of concept-mapping strategies with different generativity levels (expert-generated, partially learner-generated and full learner-generated concept maps) between high and low level of self-regulated learning skills. However, using pencil-and-paper format requires the instructor to fully control and guide the whole study procedure, and also the assessment of the maps generated by learners is time-consuming. Therefore, in this chapter we only focus on e-learning environments which provide interaction with maps (no matter partially or fully generated by experts) and automatic assessment of learner’s completion of the map.

Owing to the flexibility of ontology in describing map structure and allowing the merging of different sources, ontology is a viable means of modelling a hierarchical knowledge network in which nodes represent concepts and arcs or arrows represent the relations between concepts. Several knowledge-based systems have utilized ontology techniques to support knowledge mapping. For instance, the concept map learning system of Chu et al. (Chu, Lee, & Tsai, 2011), intended to help reduce the user's cognitive load, and TM4L (Dicheva & Dichev, 2006), a specialized environment for creating, maintaining and using “TM-based” learning repositories, both depend on ontology-based engines.

“An ontology is a formal explicit specification of a shared conceptualization” (Gruber, 1993). Common vocabularies are defined by ontology for the users (such as instructors, learners and researchers) who need to share information in a domain (Noy & McGuinness, 2001). A number of reusable ontologies have been constructed to support the modelling of efficient learning or teaching solutions. A knowledge management ontology characterized in terms of formal definitions and axioms was presented by Holsapple et al. (2004); this ontology enables the development of intelligent tools for knowledge sharing and reuse. An ontology of programming concepts (Gomez-Albarran & Jimenez-Diaz, 2009), developed based on existing educational ontology (Sosnovsky & Gavrilova, 2006) for procedural and object-oriented programming, is used to provide unique vocabulary for query retrieval in a case-based recommendation strategy for personalized access to earning objects (LOs) in educational repositories. The recommendation strategy considers the student ranking scores of LOs and the taxonomical information provided by the ontology to calculate similarity between concepts and decide the ranking of LOs. OMNIBUS (Hayashi, Bourdeau, & Mizoguchi, 2009), a task ontology which covers different learning/instructional theories and paradigms, was built to support an authoring system called SMARTIES. This system is a theory-aware authoring system using a top-down approach to the support of learning/instructional scenario design by teachers. A disciplinary ontology, whose concepts contain declarative knowledge (such as definitions, theorems, propositions, skills, the method it employs and specific examples it related to), is constructed to assess how well learners master knowledge structure in a geometric intelligent assessment system (Zhong, Fu, Xia, Yang, & Shang, 2015). To access a learner's mastery of knowledge, this system employs a hybrid cognitive assessment method which considers not only the declarative knowledge described in the disciplinary ontology but also procedural knowledge described in a problem solving process.

From the knowledge-based system point of view, ontology is considered as a hierarchical network, where nodes represent concepts and arches or arrows represent the relations which exist between related concepts. Using ontology to describe domain knowledge promotes the reuse of the ontology in other ontologies and applications owing to its flexibility of the map structure. However, most of the domain ontologies (Gomez-Albarran & Jimenez-Diaz, 2009; Oltramari, Gangemi, Guarino, & Masolo, 2002; Sosnovsky & Gavrilova, 2006) just focus on "is-a" or "part-of" relation, which describe only the inclusion relation between concepts and just can provide taxonomical information in a domain. The promising feature of ontology that it can enrich the meaning of relationships (Mansur & Yusof, 2013) has not been taken full advantage of.

3. COURSE-CENTERED ONTOLOGY AND AN “INDIVIDUAL-CLASS-INDIVIDUAL” ONTOLOGY DESIGN APPROACH

Actually, as an extension of taxonomies, ontologies which provide a hierarchy network rather than hierarchy tree structure as taxonomies, further allow any relation exist between any two concepts; this facilitates the embodiments of relevance among KPs and also among their related learning materials, which are indispensable in education fields. Therefore, in our research (Wang, Mendori, & Juan, 2014), a “course-centered ontology”, which involves the construction of domain knowledge network especially the natural relations (such as similarities, contrasts and so on) between knowledge points inside a specific course, is presented for learning support systems which intend to provide meaningful learning environment. In this research, 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.

For each individual of a course-centered ontology, which represents each KP of the target course, consists of two types of attributes: the data attribute (DA) which describes the datatype properties of the KP and the object attribute (OA) which describes its relations with other KPs. However, the construction and maintenance of this kind of course-centered ontology is quite time consuming. Therefore, to effectively design and develop a course-centered ontology, we suggest the following three steps which all need the participation of instructor and ontology builder.

(1) Individual creation and its DA design: For each KP in the target course, create a corresponding individual (also called “instance”) and use its DAs to describe the properties of the KP.

(2) The design of inclusion relations: use the classes of ontology to reflect the knowledge classification in the target course. Individuals assigned to the same class, which represent corresponding KPs, should share some common data properties. Furthermore, these common data properties should be created as the data attributes of the class they belong to. Similarly, the sub-classes in a class share some common data properties which also need to be created as the data attributes of that class.

(3) The OA design: the meaning of relationships between individuals should be enriched to represent those essential natural relations between KP in the target course (for example, to a grammar course, it refers to grammatical relations) and placed between the corresponding KPs those individuals represent. In other words, the OAs of individuals should cover all the object properties that describe the relations which originate in the course characteristics.

This three steps approach begins with details about individual creation and DA design of each individual; then works up to the highest conceptual level by deciding the knowledge classification (classes design); and finally go back again to the design of natural relationships just between individuals (individual's OA design). The last step, which is our innovative contribution, makes our ontology design an “individual-class-individual” model while the former ontologies normally were built by individual-class (bottom-up) or class-individual (top-down) methods.

In our previous work (Wang, Mendori, & Juan, 2014), we focused on course-centered ontologies addressing various languages courses for assisting learning support systems to embody the relations among knowledge points and also among the learning materials for those knowledge points, which can be built to create the metadata of LOs and identify learners' knowledge structures of target language courses. Hence, "a Course-centered Ontology of Japanese grammar" (COJG) has been developed as a sample domain model for the learning support system by Wang and Mendori (2012). COJG includes 23 top level classes, 23 second level classes, 25 third level classes (54 of these classes have only individuals), and 205 individuals. Among all the 205 GPs in COJG, totally 630 OAs are designed. The elaborated examples of OA designs are described by Wang et al. (2012). Besides the inclusion relation, other twenty-four types of relations were concluded in COJG.

As shown in Table 1, these relations include the concept dependences, similarities and contrasts, and even grammatical equivalence phenomena. Except for "isPriorOf" and "isNextOf" relations, which can also exist between two classes, all these relations are only exist between two individuals. It needs to be noticed that, except for the unidirectional relation "hasNecessaryPrior", other 23 bidirectional relation in COJG are either inverse relation or symmetric relation. It is essential to prepare inverse relations (such as "hasHonorific" and "isHonorificOf") and symmetric relations (such as "isSimilarWith") when there is a bidirectional semantic relation between two GPs. For example, assumed that GP X1 has honorific X2 and COJG just indicates the relation "hasHonorific" from X1 to X2, it is time-consuming to discover this relation from X2 direction when a learner is studying X2. However, preparing inverse relation or symmetric relation just needs one-time setting on the"description" of a relation. This setting enables the bidirectional relation location.

The frequency of each relation's occurrence in COJG is also described in Table 1. For a symmetric relation, their frequency is shown as "times (times)" while for a pair of inverse relations its frequency is described as "times/times." For instance, "41(41)" shown in Table 1 as the frequency of "isSimilarWith" means this relation is placed 41 times to imply a bidirectional relationship; another example is "13/13" as the frequency of the pair of relations "hasHonorific/isHonorificOf", which represents the relations "hasHonorific" and "isHonorificOf" are placed as inverse relations 13 times, respectively.

The frequency information of those relations depicted in Table 1 also reflects the advantages of ontology. As shown in Table 1, this symmetric relation “isSimilarWith” was placed 41 times to indicate similarity between two GPs which can be used in the same language context. However, in the old LMS/CMSs such as Moodle, to build the same content of the same course, an instructor needs to describe this similarity relation 82 times and create 82 hyperlinks for the bidirectional search. Even worse, the consistency maintenance of the old LMS/CMSs is much more difficult than that of ontology-driven systems which perform consistency checking and even other knowledge reasoning.

In our recently work (Wang, Ogata, and Shimada, 2017), to facilitate the visualization support of meaningful learning for e-book users, we adjust the three steps ontology design method (Author of Wang , Mendori, & Juan, 2014) and apply it to the development of a course-centered ontology for an existing computer science course (called COCS). COCS 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, we developed a tool which can automatically identify the location (including the file IDs and the page numbers) of the KPs in the E-Book system. This tool was used to add the location information details into COCS automatically.

As shown in Table 2, COCS relations include e-book location indications, concept dependences, and concept similarities and contrasts. Except for the “is_Located_After” and “is_Located_Before” relations, which exist between two upper concepts (defined as classes in ontology), all these relations only exist between two KPs (defined as individuals in ontology). Similar to the construction of COJG, it is also essential to prepare inverse relations (such as “prescribe” and “is_prescribed_by”) and symmetric relations (such as “is_Compatible_with”) when there is a bidirectional semantic relation between two GPs. Therefore, except for the unidirectional relations “has_Necessary_Prior” and “Comprise”, the 18 other relations in COCS are either inverse or symmetric relations.

Besides the difference in the domain knowledge, the essential difference between COCS and COJG is that COCS includes the location information of KPs in e-book system. That e-book location information is designed for supporting the service of the provision of personalized topic maps based on the learners’ e-book logs. In summary, depending on the specific purpose of the ontology-driven system, the design of its course-centered ontology may require adjustment.

Table 1 Frequency and usage of all the relations of COJG.

Function of Relation	Relation name	Frequency	Type	Usage

indicate concept dependences	*hasNecessaryPrior*	242		When the pattern of concept A involves another prior concept B, this relation exists from A to B.
	isRelatedTo	17(17)	symmetric	When two concepts are normally used together in a Japanese sentence, this symmetric relation exists between them.
	isPriorOf / isNextOf	54/54	inverse	This pair of inverse relations is used to give a suggestion of the teaching steps. (This pair of relation can exist between two classes or between two individuals.)
indicate equivalence of grammatical phenomena	*hasHonorific/ isHonorificOf*	13/13	inverse	This pair of inverse relations is used to show the honorific of a common form and the common form of an honorific.
	hasHumbleEquivalent / isHumbleEquivalentOf	7/7	inverse	This pair of inverse relations is used to show the humble equivalent of a common form and the common equivalent of a humble form.
	hasColloquialEquivalent/ isColloquialEquivalentOf	1/1	inverse	This pair of inverse relations is used to show the oral equivalent of a written expression and the written equivalent of an oral expression.
indicate concept similarities	*isSimilarWith*	41(41)	symmetric	When two concepts have similar meaning and both can be used

or contrasts				in the same context, this symmetric relation exists between them.
	isOppositeOf	3(3)	symmetric	When two concepts with the same usage pattern have the opposite meaning, this symmetric relation exists between them.
	isMoreColloquialThan/ isLessColloquialThan	7/7	inverse	This pair of inverse relations is used to compare two concepts for the colloquialism degree.
	isMoreFormalThan/ isLessFormalThan	1/1	inverse	This pair of inverse relations is used to compare two concepts for the formality degree.
	isMoreRespectfulThan/ isLessRespectfulThan	6/6	inverse	This pair of inverse relations is used to compare two concepts for the respect level.
	isMoreImpoliteThan/ isLessImpoliteThan	3/3	inverse	This pair of inverse relations is used to compare two concepts for the degree of impoliteness.
	hasMoreCertaintyThan/ hasLessCertaintyThan	30/30	inverse	This pair of inverse relations is used to compare two concepts for the degree of certainty.
	isMoreSubjectiveThan/ isLessSubjectiveThan	11/11	inverse	This pair of inverse relations is used to compare two concepts for the degree of subjectivity.

Table 2 Frequency and usage of all the relations of COCS.

Function of relation	**Relation name**	**Frequency**	**Type**	**Usage**
Indicate the location information	is_Located_After / is_Located_Before	28/28	Inverse	This pair of inverse relations is used to show the relative e-book location of the two upper concepts.
	include /located-in	531/531	inverse	This pair of inverse relations is used to record the KPs appearing in one e-book page or the location information of one KP.
Indicate concept dependences	has_Necessary_Prior	20		When concept A involves another prior concept B, this relation exists from A to B.
	Is_Related_to	4	symmetric	When two concepts are normally used together, this symmetric relation exists between them.
	Comprise	6		When the representation of a KP consists of several parts represented by other KPs, this relation exists.
	is_a_type_of / has_type	7/7	inverse	This pair of inverse relations is used to group several KPs by linking it with one basic KP.
	is_an_instance_of / has_instance	7/7	inverse	This pair of inverse relations is used to indicate a specific case of the representation of a KP.

	encode/ can be encoded by	5/5	inverse	When the representation of one KP defines the standardized code of the representation of another KP.
	is_Prescribed_by/ prescribe	3/3	inverse	This pair of inverse relations is used to indicate a definition described by an approach or a standard or a schema.
	can_be_calculated_from/ can_be_used_to_calculate	1/1	inverse	This pair of inverse relations is used to indicate the input and output of a calculation.
Indicate concept similarities and contrasts	is_Compatible_with	3	symmetric	This pair of inverse relations is used to show the compatibility between two approaches or schema.
	Extend /has extension	2/2	inverse	This pair of inverse relations exists between two KP of the same type when one representation of one KP is modified based on the representation of another KP.

4. ONTOLOGY-DRIVEN LEARNING SUPPORT SYSTEMS

Facilitation of the visualization support of meaningful learning requires descriptions of the information about all the knowledge points and their relations. It is suggested that the domain knowledge needed by the system be automatically extracted from an ontology designed and developed on the basis of the target learning content. In this section, we will discuss two ontology-driven learning support systems which both intend to support meaningful learning environments.

4.1 An ontology-based language learning support system

For effective second language learning, it is essential that the learners are able to make connections between related KPs and distinguish between similar ones. However, those older systems (such as Moodle) utilizing tree structures usually do not support the development of those skills because they cannot characterize essential relations between KPs. In order to support the development of learner ability to compare related KPs, an ontology-based language learning support system (called CLLSS) with a meaningful receptive learning environment is developed (Wang, Mendori, & Xiong, 2013).

The course-centered ontology COJG discussed in previous section is incorporated in CLLSS for the construction of domain knowledge network and also for the metadata creation of LOs. The system framework of CLLSS and the way that the system was programmed to automatically use the knowledge information in ontology, are both described in our previous paper (Wang et al., 2013). After uploading the course-centered ontology of an existing language course (here we refer to COJG), which is stored in OWL file, an instructor of CLLSS can arrange the learning materials based on the domain model provided by the ontology. This kind of arrangement enables the learners to compare related knowledge points and conveniently study relevant LOs according to their knowledge structure.

Fig. 1 shows the common view of CLLSS 2.0 for both instructors and learners. On the left part of this view, all the concepts of COJG including the classes (directly named by grammar concepts in natural Japanese) and the individuals (directly named by GPs in natural Japanese) are shown by a tree structure. The system automatically extracts all the “isPriorOf” and “isNextOf” relations, from the OWL file of COJG to interpret the recommended teaching steps; this means all the grammar concepts (represented by classes) and GPs (represented by individuals) shown in the tree structure are arranged in the teaching steps defined by COJG.

In CLLSS, if an instructor wants to change the teaching steps, she/he only needs to modify the objects of “isPriorOf” and “isNextOf” relations on the “restriction filler” of any class (or on the “value” of any individual) in COJG and then update the new OWL file. However, in old LMS/CMSs such as Moodle, if an instructor wants to change the order of topics or chapters in a course, she/he needs to modify the destination URLs of all those hyperlinks which are used to indicate the related KPs among topics or chapters. Obviously, compare to older LMS/CMSs, the advantage of CLLSS that the teaching steps of a course can be flexibly modified, attributes to the use of the course-centered ontology.

Search function is provided right above the tree structure. After putting key searching words, items which contain the key words in tree structure will be highlighted to enable further check for users. Besides, users also can open all the concepts level by level until reach the GP they are seeking.

As shown in Fig. 1, when a user (instructor or learner) selects one grammar point "~te ku da sa i ma sen ka" represented by one individual in COJG, the relation panel on the right part will provide the user a visual representation of this grammar point and its related grammar points in the course. If the user puts the mouse on any node shown in the relation panel, the essential properties of its representing grammar point, represented by data properties of the individual in COJG, will be listed. On the other hand, putting the mouse on any arc in the relation panel will caused the display of the name and the direction of a relation which are represented by a relation axiom in COJG.

In other words, all the information in this common view, which includes the tree structure on the left and relation panel on the right, is automatically extracted from the OWL file of COJG by the web-based CLLSS. Consequently, after selecting one GP from the tree structure, in the relation panel the user can get essential properties of this GP and all its related GPs conveniently. Moreover, if there are too many relations shown in the relation panel, the user can select her/his interested relations by using Arc-Types panel.

Further, at every node or arc on the relation panel, instructors can open a teaching material management panel to upload and manage teaching materials for the chosen grammar point or relation between grammar points. This guarantees the metadata description of every new learning object cover the information about one individual or one relation of COJG. Since the course-centered ontology are developed by the expert teachers, ontology driven CLLSS makes using the relation panel to encourage instructors (especially novice instructors) to follow teaching procedures and teaching strategy of expert teachers. Instructors can produce and arrange teaching materials directly addressing specific grammar points and even directly addressing relations between them. Based on this kind of learning materials' organization, CLLSS assisted by COJG which includes special relations (as shown in Table 1) is able to support the learner to compare an unlearned grammar point with all its related grammar points, especially with those acquired ones. This pedagogical approach is enabled by the consideration of the learners' dynamic knowledge structure.

In our previous work (Wang, Mendori, & Juan, 2014), it is found that the subjects who learned in this environment achieved significantly better learning outcomes than those who did only self-study with textbooks after studying the same target Japanese grammar contents. This suggests that new knowledge can easily be understood and remembered with this visualization support. However, students reported that they felt pressure and were disturbed when more than four related KPs were shown at one time. In other words, from the cognitive load point of view, the e-learning environment should avoid giving too much information at one time.

From the perspectives of learning attitude and motivation, the learner data from before and after CLLSS supported study of target grammar content were also analyzed (Wang, &Mendori, 2015). The results of that analysis suggest that not only learners' attitude towards Japanese grammar learning, but also their motivation to learn Japanese language improved after studying with CLLSS. Considering learning attitude and motivation before the learning activity as individual difference variables, further ANOVA tests were performed using mean value with dichotomization of attitude and motivation before the learning activity by mean value so as to form Low and High categorical variables. We found that learners with High attitude and motivation levels perceived a greater development of the habit of "learning by comparing related knowledge" and felt more satisfied with the CLLSS environment learning mode. Moreover, compared to learners with a Low level of attitude towards Japanese grammar before the activity, learners with High level of attitude reported significantly less mental effort in study with CLLSS and performed better on the grammar post-test. These results confirm that learning attitude and motivation are factors that must be considered in the promotion of meaningful learning.

However, in interviews after the experiment, 19 out of 60 participants reported that since the system already provides numerous bits of related knowledge, they didn't have the inclination to proactively search for more knowledge. Furthermore, several students reported that their curiosity and willingness to seek more related knowledge decreased. This phenomenon likely reflects the fact that CLLSS directly displays the information about related concepts and relations, and the participants made comparisons between concepts in a passive receptive manner. This kind of passive learning is known to lower learners' willingness to explore. This reminds us that CLLSS needs to be modified so as to encourage learners to actively engage in the construction of their relation maps.

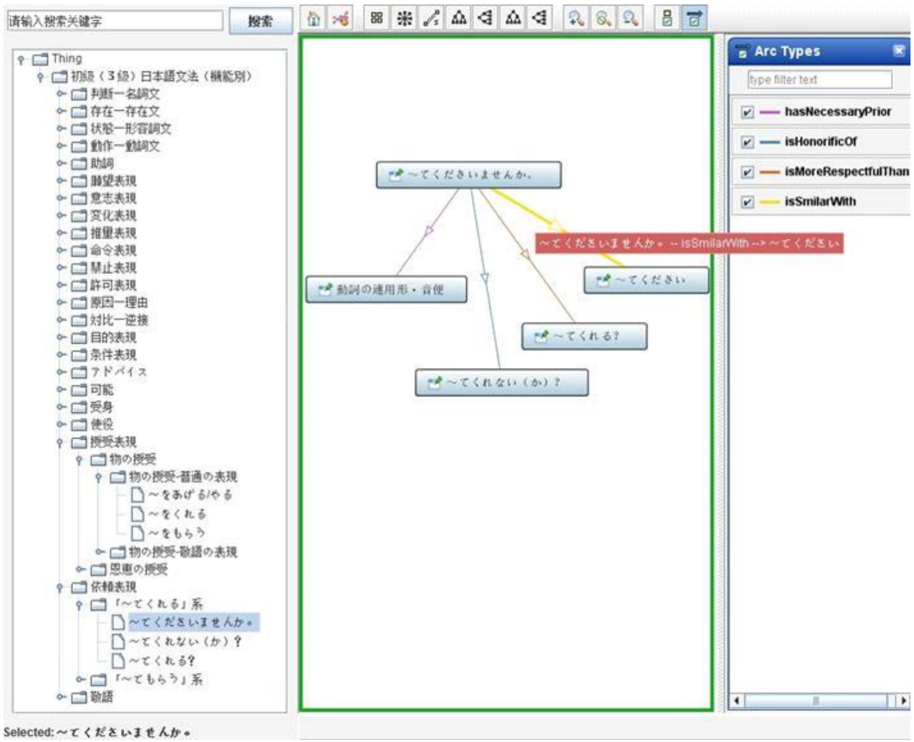


Fig.1. The main interface of CLLSS

4.2 Visualization Support System for E-book Users

Nowadays, e-book systems are widely used in education. In Japan, an education ministry panel is urging schools (K-12 and higher education) to use digital textbooks to support daily classroom teaching from 2020 onward. Kyushu University started to use e-book systems in 2014, in tandem with the Moodle learning management system and the Mahara e-profile system, to support daily classroom teaching. E-book systems provide a platform where instructors can easily upload teaching materials which learners can conveniently view and annotate or comment. Those systems can also record learning behaviour and report the results to the instructors. However, in e-book systems it is difficult for the learners to identify the knowledge they possess before and after a learning activity. Furthermore, existing e-book systems (even other e-learning systems) do not encourage learners to compare new knowledge with the relevant previously acquired knowledge and thus cannot effectively support the construction of the learners' knowledge structures.

Therefore, a visualization support system for e-book users (VSSE) was implemented to support e-book users' effective construction of their knowledge structures. The three main functions provided by this system are described below.

4.2.1 Visualization of knowledge in any page range of any e-book

First, the information about each KP included in the e-books can be searched via a catalogue. As shown in the left part of Fig 2, all the learning contents included in the e-books are organized in a tree structure. Users can open all the concepts level by level until they reach the KP they are seeking. When the user double clicks one leaf (which represents one KP) the right relation panel will display that KP and all its related KPs linked by relations defined in COCS.

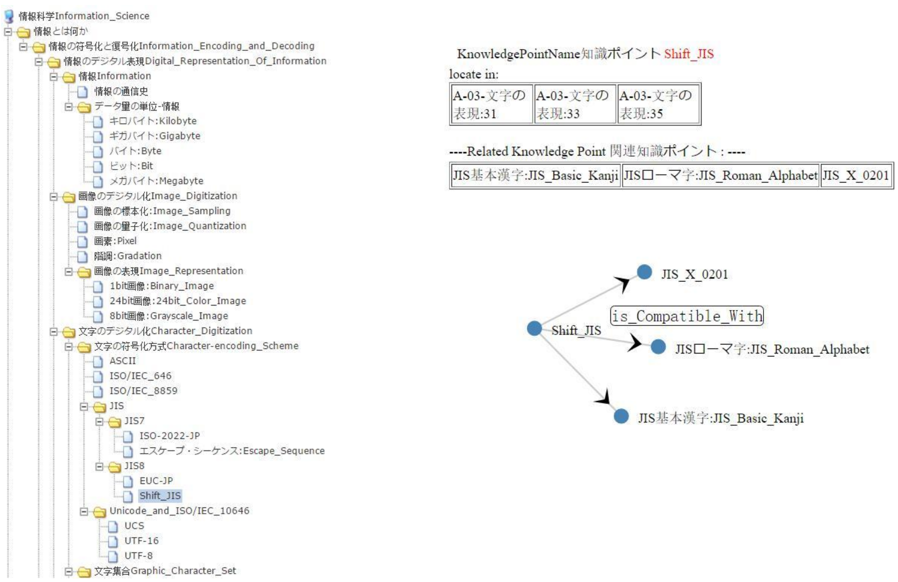


Fig.2. Search KP from a catalogue

For example, in Fig. 2, after the item representing the KP "shift_JIS" is clicked, the right panel shows that there is reference to KP "shift_JIS" on pages 31, 33 and 35 of E-book A03 and that KP "shift_JIS" has 3 related KPs. Also, a visual representation of information about related KPs is provided. 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 "is compatible with" from "shift_JIS" to "JIS_X_0201" in Fig. 2). 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.

This VSSE function shown in Fig. 2, is similar to the interface of CLLSS, but with the e-book location information. The difference between this VSSE function and CLLSS is that in CLLSS the learners can further access learning materials via the relation map while in VSSE the learners can further just to the e-book pages from the location table.

4.2.2 Visualization of Knowledge Learned During Any Period

Second, VSSE can display the relation map, including the KPs appearing in any page range of any e-book, along with their upper concepts. As can be seen in Fig. 3, users of the e-book system can select a specific e-book and input any page range in the VSSE interface. VSSE will display all the KPs appearing in the searched pages along with their related KPs. For example, Fig. 3 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. The pink nodes and the lines that come from the pink nodes can be hidden if the learner wishes to decrease the amount of the information displayed. As in the previous function, with this visualization map users can conveniently get the essential properties of every KP and all of its related KPs.

On the other hand, it is desirable that instructors be able to visually check all of a learner’s knowledge structures. For example, for each KP in any e-book range, the percentage of learners who have already acquired that KP should be available to instructors. This information will encourage instructors to give further explanation or show more learning material addressing KPs which have only been acquired by a small percentage of learners. This function is still under development.

4.2.3 Visualization of Knowledge Learned During Any Period

Using the e-book system log data, VSSE can provide an interface where e-book users can search the knowledge they have accessed during any learning period. VSSE will display all the KPs included in the e-book pages which have been read during any given period along with their related KPs. For instance, Fig. 4 shows the KPs (the red nodes) contained in the e-book pages the learner accessed between 2016/9/9 and 2016/9/10, along with the related KPs (the blue nodes) which are not presented in those pages. In Fig. 4, the upper concepts and the lines emanating from them were chosen to be hidden. As in the previous two functions, users can conveniently get the essential properties of every KP and all of its related KPs from this visualization map.

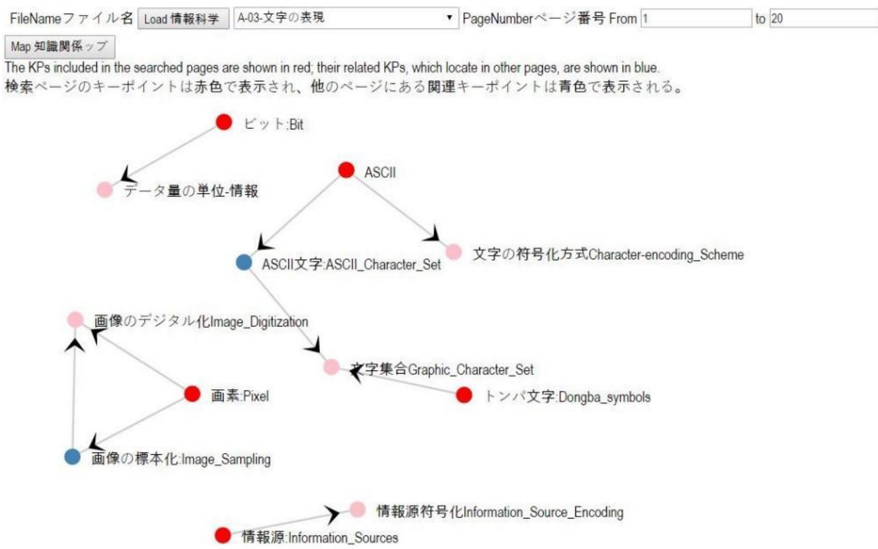


Fig.3. The relation map of the search pages

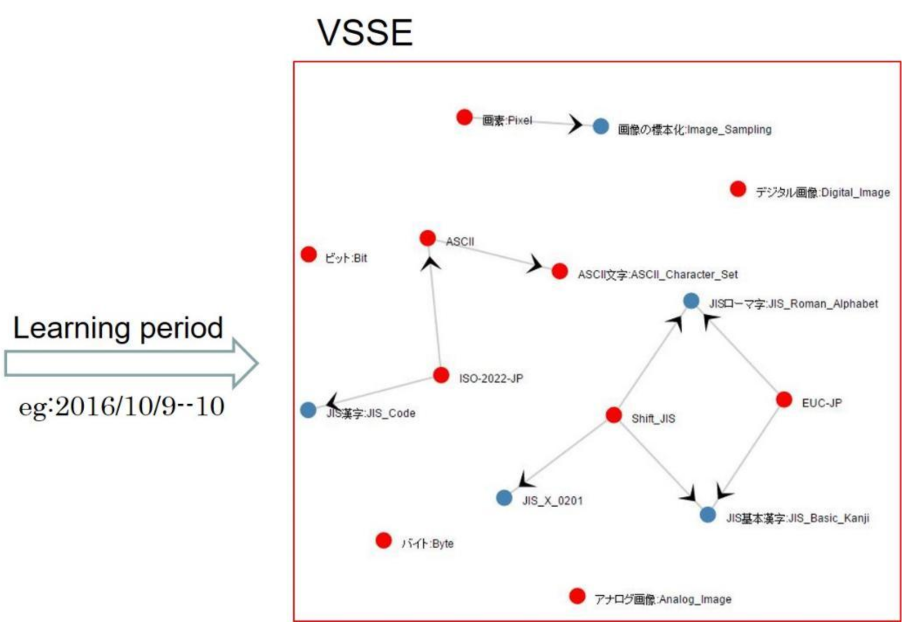


Fig.4. Visualization of the learning log

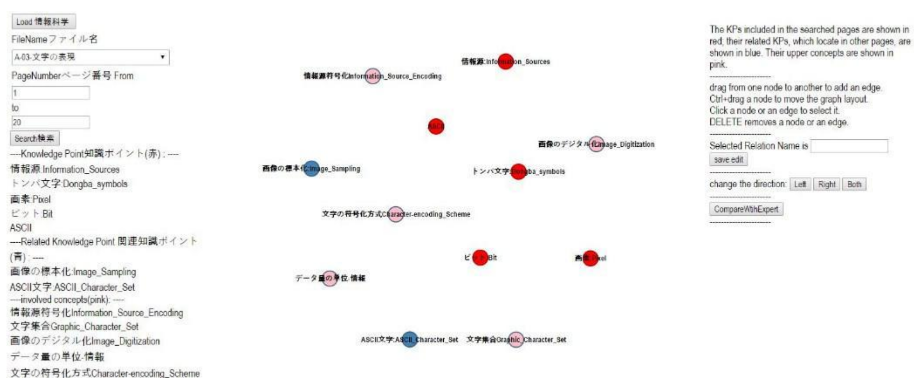
4.2.4 A Meaningful Discovery Learning Environment

In an attempt to avoid inducing high cognitive load and low attitude/motivation as occurred in CLLSS, we present "cache-cache comparison" mode, an integration of discovery learning for the three main functions mentioned in the previous section. The word "cache," which originally comes from the French for "to hide" or "a hidden place." The French word "cache-cache" means "hide and seek" in English. It is a popular children's game in which one or more players, the seekers, try to find several hidden players. We propose to apply the familiar concept of "cache-cache" to represent the process of "hiding and seeking" in the children's game. From the learning support perspective, directly presenting too many pieces of information related to a new knowledge item will create a high level of cognitive load. As mentioned before, this overload phenomenon was also observed in one of our previous studies (Author of this paper, 2014). Therefore, we suggest hiding some parts of the information at the first stage of learning, and encouraging the learners to actively discover them in the second stage. This process, involving discovery learning, is termed "cache-cache comparison" here.

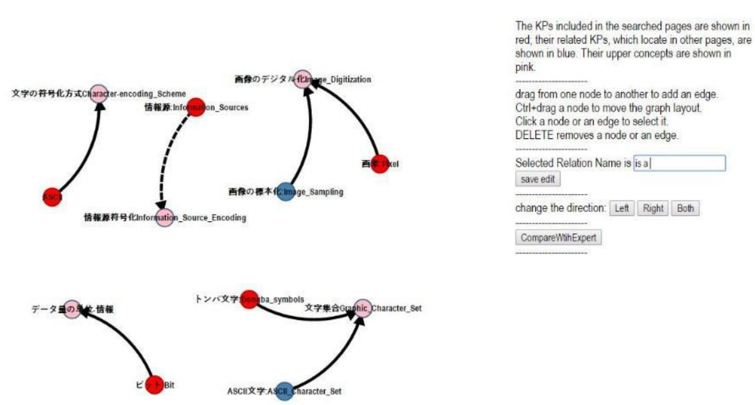
"Discovery learning" is an inquiry-based, constructivist learning theory process that takes place in problem solving situations where the learner draws on his or her own past experience and acquired knowledge to discover facts and relations and new truths to be learned (Bruner, 1961). Bruner (1961; 2009) states that students are more likely to remember knowledge that they discover on their own than that which is presented directly in receptive instruction. The learner experiences individual discovery when he/she solves problems using existing knowledge. This process, which encourages active engagement, can foster the development of creativity and problem solving skills, and promote learning motivation. However, many researchers (Mayer, 2004; Alfieri, et al, 2011) have cautioned that unassisted discovery learning without sufficient prior knowledge and guidance may easily lead to misconceptions and cause additional cognitive overload. Timely guidance is needed in discovery learning to avoid learner confusion and frustration (Kirschner, Sweller, & Clark, 2006). Learners need to gain confidence in their ability to complete tasks given the requisite knowledge; on the other hand, when confronted with failure they also need to be motivated to learn from mistakes and thus be better prepared to continue learning. The "cache-cache comparison" visualization interface, which can support the learners in actively constructing their knowledge framework, was developed. Considering KPs and relations as the building blocks of course relation maps, "cache-cache comparison" mode in VSSE hides several blocks in an expert relation map and guides learners to seek to discover those hidden blocks. The learners engage in an active learning process when they struggle to complete the relation map.

Fig. 5 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. 5(a), “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 the learner is required to classify the KPs by connecting them to their pink upper concepts, as shown in Fig. 5(b). 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.

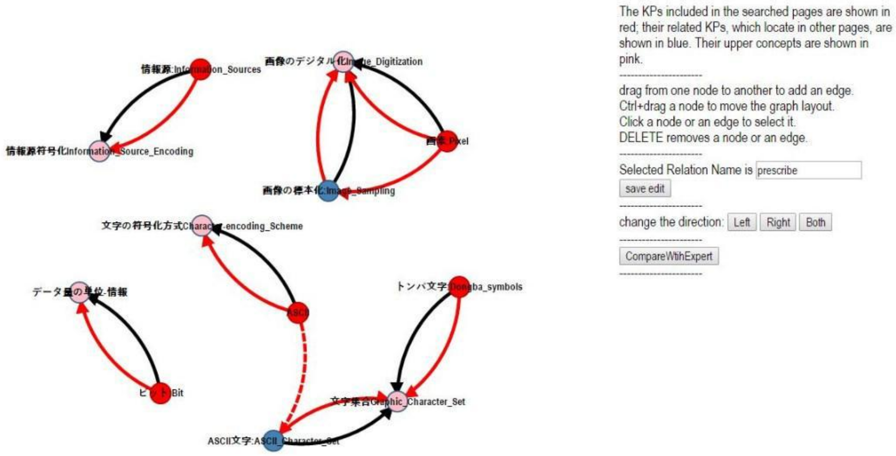
Finally, all the relations extracted from the ontology will be displayed as red lines, as shown in Fig. 5(c). The learner can easily compare the red lines with the black lines that she/he has made. This active engagement is expected to improve or at least maintain learners’ willingness to explore.



(a)



(b)



(c)

Fig. 5. An instance of “cache-cache comparison” mode

5. CONCLUSION

In this chapter, we discuss the ontology technique and its application in knowledge-based systems, especially in learning support systems. Two ontology driven learning support systems which provide meaningful learning environments are introduced: a customizable language learning support system (CLLSS) and a visualization learning support system for e-book users (VSSE). Both systems provide meaningful receptive learning environment. Furthermore, in VSSE, to encourage active engagement in meaningful learning, the “cache-cache comparison” environment is also presented by Wang et al. (2017). This environment, which hides some relations and guides the learners to actively recall their prior knowledge as they design their own relation maps before comparison with the relations maps of experts, is intended to lower cognitive load and encourage active engagement.

However, for both systems, the construction and maintenance of ontology are quiet time-consuming. Therefore, the automatic method for creating and updating ontology information should be discussed in the future work.

EFERENCES

Ausubel, D. P. (1963). The psychology of meaningful verbal learning. New York: Grune and Stratton.

Ausubel, D. P. (1968). Educational psychology: A cognitive view. New York: Holt.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). Educational psychology: A cognitive view (2nd ed.). New York: Holt, Rinehart and Winston.

Bransford, J., Brown, A. L., & Cocking, R. R. (Eds.). (1999). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy

Bruner, J. S.(1961). The act of discovery. *Harvard Educational Review,* 31 (1), 21–32.

Bruner, J. S. (2009). The process of education. Harvard University Press.

Chu, K. K., Lee, C. I., & Tsai, R. S. (2011). Ontology technology to assist learners' navigation in the concept map learning system. Expert Systems with Applications, 38, 11293-11299.

Gomez-Albarran, M., & Jimenez-Diaz, G. (2009). Recommendation and students' authoring in repositories of learning objects: a case-based reasoning approach. International Journal of Emerging Technologies in Learning (IJET), 4, 35-40.

Gruber, T. R. (1993). A translation approach to portable ontologies. Knowledge Acquisition, 5(2), 199-220.

Hayashi, Y., Bourdeau, J., & Mizoguchi, R. (2009). Using ontological engineering to organize learning/instructional theories and build a theory-aware authoring system. International Journal of Artificial Intelligence in Education, 19(2), 211-252.

Holsapple, C.W., & Joshi, K. D. (2004). A formal knowledge management ontology: conduct, activities, resources and influences. Journal of the American Society for Information Science and Technology, 55(7), 593-612.

Kirschner, P. A. et al (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41 (2), 75–86.

Lee, J. H., & Segev, A. (2012). Knowledge maps for e-learning. Computers & Education, 59(2), 353-364.

Lim, K. Y., Lee, H. W., Grabowski, B. (2009). Does Concept-Mapping Strategy Work for Everyone? The Levels of Generativity and Learners' Self-Regulated Learning Skills. British Journal of Educational Technology, 40 (4), 606-618.

Novak, J. D., & Ca~nas, A. J. (2008). The theory underlying concept maps and how to construct them. Technical report IHMC CmapTools 2006-01 Rev 01-2008.

Mayer, R., (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59 (1), 14–19.

Machine Cognition. Available at http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf.

Mansur, A. B. F., & Yusof, N. (2013). Social learning network analysis model to identify learning patterns using ontology clustering techniques and meaningful learning. Computers & Education, 63, 73-86.

Noy, N. F., & McGuinness, D. L. (2001). Ontology development 101: a guide to creating your first ontology. Development, 32(1), 1-25.

O'Donnell, A. M., Dansereau, D. F., & Hall, R. H. (2002). Knowledge maps as scaffolds for cognitive processing. Educational Psychology Review, 14(1), 71-86.

Oltramari, A., Gangemi, A., Guarino, N., & Masolo, C. (2002, May). Restructuring WordNet's top-level: the OntoClean approach. In Workshop Proceedings of OntoLex'2, Ontologies and Lexical Knowledge Bases (LREC2002), Spain (pp. 17-26).

Sosnovsky, S., & Gavrilova, T. (2006). Development of educational ontology for C-programming. International Journal Information, Theories & Applications, 13(4), 303-307.

Tsien, J. Z. (2007). The Memory. Scientific American, (July), 52-59.

Wang, J., & Mendori, T. (2012). A course-centered ontology of japanese grammar for a language learning support system. Frontiers in Artificial Intelligence and Applications (KES2012), 243, 654-663.

Wang, J., Mendori, T., & Xiong, J. (2013). A customizable language learning support system using ontology-driven engine. International Journal of Distance Education Technologies, 11(4), 81-96.

Wang J. Y., 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. Y., and Mendori T. (2015). An evaluation of the learning attitude and motivation in a language learning support system," Proceedings of Advanced Learning Technologies and Technology-enhanced Learning (ICALT 2015), Hualien, Taiwan.

Wang J. Y., Ogata H., & Shimada A. (2017). A Meaningful Discovery Learning Environment for E-book Learners. IEEE Global Engineering Education Conference 2017, Apr. 25-28.

Zhong X., Fu H., Xia H., Yang L., & Shang M. (2015). A hybrid cognitive assessment based on ontology knowledge map and skills. Knowledge-Based Systems, 73, 52-60.

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