A language learning support system using course-centered ontology and its evaluation

Jingyun Wang a,b,*, Takahiko Mendori a, Juan Xiong b

a Kochi University of Technology, Japan
b Xiamen University of Technology, China

ARTICLE INFO

Article history:
Received 6 December 2013
Received in revised form 6 May 2014
Accepted 17 June 2014
Available online 25 June 2014

Keywords:
Course-centered ontology
Language learning support
Knowledge comparison
Learning style
Learning habit

ABSTRACT

This paper presents a course-centered ontology for assisting learning support systems to embody the relations among knowledge points and also among the learning materials for those knowledge points. An “individual-class-individual” ontology design (first an individual-class design, then an innovative design about relations among bottom individuals), was applied to the construction of a course-centered ontology for an existing Japanese grammar course. Furthermore, a customizable language learning support system was built to manipulate the course-centered ontology 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 the system is to encourage instructors to orient their teaching materials to specific knowledge points and even directly to relations between knowledge points. With these orientations, the learning support system is able to provide an environment in which learners can readily distinguish between related knowledge points. The results of the study suggest three main points: (a) the experimental students who learned with our system achieved significantly better learning achievement than those who just did self-study with textbooks after studying the same target contents for 60 mins; (b) the learning achievement of experimental group was not related to either their learning style in Sequential/Global dimension or their habit of “learning from comparison”; and (c) in terms of the learning perception of experimental group, compared to “Sequential learners”, most “Global learners” had a stronger feeling that the comparison function is useful in improving their learning performance, and the learners who don’t habitually “learning from comparison” were more likely to suffer from lack of the attention and feel more pressure than those who do habitually “learning from comparison”.

© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

1. Introduction

Nowadays, learning/content management systems (LMS/CMSs) such as Moodle (Dougiamas & Taylor, 2003) are widely used in language teaching. In such systems, the instructor can organize a course by topic or by schedule. In one topic or one lesson, the course content description is followed by the related learning materials. In other words, the course content is normally organized in a tree structure (as shown in Fig. 1, in which the yellow circles (in the web version) represent the learning contents while the blue rectangles (in the web version) represent learning objects), the branches of which represent either topics or class schedule elements.

For effective second language learning, it is essential that the learners are able to make connections between related knowledge points (KPs) and distinguish between similar ones. However, those older systems utilizing tree structures usually do not support the development of those skills because they cannot characterize essential relations between KPs.

* Corresponding author. Kochi University of Technology, Japan.
E-mail addresses: warmplam@gmail.com (J. Wang), mendori.takahiko@kochi-tech.ac.jp (T. Mendori), xiongjuanxmut@126.com (J. Xiong).

http://dx.doi.org/10.1016/j.compedu.2014.06.009
0360-1315/© 2014 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).
For example, in Fig. 1 there are two KPs, “d” and “t”, which are located in Lesson 1 and Lesson 10 respectively. In Lesson 10, to compare the KP “t” with the prior KP “d”, the instructor has to indicate the location “d” (this can be done by hyperlink) and explain the relation between “d” and “t”. Even so, it is still difficult for the learners to locate the learning materials, which directly address the relation between these two KPs, unless they look through all the learning material in lessons 1 and 10. The searching will be even more time-consuming if the learner is comparing three or more KPs (for example, comparing “t” with “d” and “s”) in the course at one time.

In order to support the development of learner ability to compare related KPs, this research presents a “course-centered ontology” (i.e. ontology based on a specific course) with a map structure that could assist e-learning systems to encourage the instructor to produce and arrange teaching materials that directly address specific KPs and even directly address relations between KPs. The construction of a course-centered ontology for an existing Japanese grammar course is discussed in this paper as an instance of “course-centered ontology”. Furthermore, this course-centered ontology was incorporated in the development of an ontology-based language learning support system which provides learning content in response to the learner’s learning knowledge structure. Also, a series of experiments was conducted to evaluate the effectiveness of this ontology-based system.

The remainder of this paper is structured as follows: Section 2 introduces some former studies related to our work; Section 3 discusses the construction of the course-centered ontology of an existing Japanese grammar course and also introduces an effective “individual-class-individual” technique for the ontology design of general courses; Section 4 presents the personalized learning support system based on the course-centered ontology and also compare our systems with the authoring environment TM4L (Dicheva & Dichev, 2006); Section 5 describes a study which is designed based on the result of a preliminary evaluation to further explore the impact of learning styles and learning habits on learning performance and demonstrates the analysis of the results in details; finally, the conclusion and the direction of the further work are provided in Section 6.

2. Related work

2.1. Maps and meaningful learning

To encourage meaningful learning patterns, using maps, which have nodes as key concepts and links as relationships between key concepts (Lee & Segev, 2012), can solve the problem caused by tree structure. According to Ausubel’s learning psychology theories (Ausubel, 1963; 1968; Ausubel, Novak, & Hanesian, 1978), meaningful learning is achieved when new knowledge is assimilated into existing frameworks of the learner. However, individuals vary not only in the quantity and quality of the relevant knowledge they possess, but also in the strength of their motivation to seek ways to incorporate new knowledge into relevant knowledge they already possess.

Human memory is a complex set of interrelated memory systems which interact with affective and psychomotor inputs. After reaching short-term memory, all incoming information will be organized and processed in the working memory which could incorporate knowledge into long-term memory. However, the working memory’s processing capacity limits the transformation of unrelated concepts into long-term memory (Miller, 1956).

Although the retention of information learned by rote still takes place in long term memory, that knowledge tends to be quickly forgotten unless repeat rehearsed and cannot contribute to enhance learner’s knowledge framework. In further problem solving, there is little or no potential that the persisting knowledge learned by rote will be used (Novak, 2002). (A full discussion of memory mechanisms is beyond the scope of this research.) Evidence from diverse sources of research suggests that knowledge finally gets incorporated into human brain when organized in hierarchical frameworks and that learning approaches that facilitate this kind of organization significantly enhance the learning capability of all learners (Bransford, Brown, & Cocking, 1999; Tsien, 2007). From this point of view, maps can serves as a kind of scaffold to help learners to organize knowledge and structure their own knowledge framework (Novak & Cañas, 2008); this facilitate the meaningful learning.

Organizing knowledge concepts in map structure, e-learning systems can present/provide progressively more explicit knowledge to help learners to slowly develop conceptual frameworks; learners also can clearly understand large general concepts before learning more specific concepts and incorporate new knowledge into their prior knowledge frameworks to foster meaningful learning. In addition, when learners have different levels of prior domain knowledge, using maps they can jump directly to a specific chapter interested. Although a search

![Fig. 1. An example of the tree structure in Moodle system.](image)
engine in the LMS can also be used to look for the information on a certain concept, the inquiry results without relation information between KPs limit its usage.

In knowledge presentation field, “Concept Map”, “Knowledge map” and “Topic Map” are three main types currently used (Lee & Segev, 2012). Concept maps are constructed with reference to a focus question. The word “Concept” is defined as “a perceived regularity in events or objects, or records of events or objects, designated by a label” (Novak & Cañas, 2008). One characteristic of concept maps is that the concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. The designer of a concept map normally attempts to organize the knowledge, which pertains to some situation or event, in a map form to ease the understanding of the knowledge. “Knowledge map” differs from “Concept maps” or other graphic organizers in the deliberate use of a common set of labeled links that connect ideas (O’Donnell, Dansereau, & Hall, 2002). In a word, “Concept Map” and “Knowledge map” are often used as learning materials instead of the metadata of learning material.

Unlike the previous two types of maps, topic maps (TM) are used to associate the knowledge structures it represents with corresponding resources. In other words, one of the main functions of topic map is to work as metadata of learning materials or objects. This is exactly what our research is interested in. The differences between our system and the authoring environment TM4L (Dicheva & Dichev, 2006) based on TM standard will be described in Section 4.3.

2.2. Ontologies

Ontology is one of the main techniques which are adopted in maps for knowledge representation. E-learning systems using maps to support learning activities, such as the concept map learning system of Chu et al. (Chu, Lee, & Tsai, 2011), intended to help reduce the user’s cognitive load, or TM4L (Dicheva & Dichev, 2006), a specialized environment for creating, maintaining and using “TM-based” learning repositories, mostly 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 modeling 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 learning 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.

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.

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. This advantage is one of the main reasons ontology technique is chosen for the learning support system in our research.

“Protégé”, which is an open source ontology editor and knowledge-base framework, was used to develop the course-centered ontology in this research and formalized it in OWL 2.0 (W3C OWL Working Group, 2012). OWL allows the meaning of Object properties to be enriched through the use of property characteristics and restrictions (Horridge, 2011); this enables the described ontology can be processed by a “reasoner” to automatic compute class hierarchy and perform consistency checking, which ensures that the ontology remains in a maintainable and logically correct state. Consequently, ontology-driven e-learning systems also can benefit from this advantage by manipulating the ontology to automatic reason the relationships between knowledge concepts.

As mentioned in the previous section, the discussion about similarity or contrast relations between KPs in language teaching can help the learner to assimilate new KPs into her/his prior knowledge framework so as to foster meaningful learning. However, only inclusion relation in an ontology is insufficient for supporting this pedagogic procedure. Therefore, “course-centered ontology”, which involves the construction of domain knowledge network especially the natural relations (such as similarities, contrasts and so on) between KPs inside a specific language course, is presented for language learning support systems in this paper.

3. Course-centered ontology

The literal meaning of “course-centered ontology” is an ontology based on a specific course. The flexible hierarchical map structure represented by ontology, allows not only the containment relation as tree structure but also any kind of relations between any two nodes. This facilitates the embodiment of relevance among KPs and also among their learning materials in learning support systems.

Consequently, the definition of course-centered ontology is: a course-centered ontology not only formalizes all the KPs of a course, but also describes all kinds of natural relations (include the concept dependences, similarities, contrasts, and so on) between those KPs. Accordingly, for
A group of expert Japanese teachers, who work in the foreign language department of a Chinese university, participated in the construction of COJG for an existing Japanese grammar course. The learning objective of this course is the grammar contents of Japanese proficiency Test Level 3 (shorten by N3). The reference of this course-centered ontology is a Japanese grammar book (Shigeno, Seki, & Nishikimi, 2009) which has been extensively used by Chinese learners of Japanese for years. This book is functional or situational based, in which every chapter includes a dialog introducing target structures and vocabulary, a formal explanation of the grammar points covered, practice exercises ranging from controlled to free production, and perhaps a meaning-focused task or reading that elicits the use of target structures during the performance.

### 3.1. Step 1: individual creation and DA design

For the target N3 grammar course, a KP means a grammar point (GP). According to the definition of course-centered ontology, each individual of COJG, which represents each GP of N3 course, should be designed to consist of the DA, which describes the datatype properties of the GP, and the OA, which describes its relations with other GPs. Therefore, after creating the 205 individuals (directly named by GPs in natural Japanese) to represent all 205 corresponding GPs of the N3 course, the value of their datatype properties, which defined “what they are”, can be determined by referring to the book (Shigeno et al., 2009) and the lesson plan of expert teachers. In COJG, there are fifteen kinds of DAs which includes “pattern”, “example”, “subject”, “object”, “content”, “judgmentBasis”, “variationCharacteristic”, “negativeForm”, “respectForm”, “normalForm”, “limitedToMale/Female”, “languageStyle”, “passive/negative”, “objective/subjective” and “partOfSpeech”. These DAs are designed to describe the essential properties of GPs according to the characteristics of Japanese grammar. Among them, “pattern” and “example” are the default DAs of every individual.

Fig. 2 below shows an example of all the properties of the individual that represent GP “-te mo i i” (means “can/may do ~” in English). This individual has four data properties (“pattern”, “example”, “respectForm” and “negativeForm”) and three related GPs described by three object properties.

### 3.2. Step 2: the design of inclusion relations

Assume the course-centered ontology as O, all the classes (directly named by knowledge topics in target second language) and individuals (directly named by the knowledge points in target second language) which represent the knowledge concepts of the target course...
as $G$, all the data attributes of the classes and individuals as $A$, and all the relations (which actually are described by “object attributes” in ontology) among $G$ as $R$, then

$$O = (G, A, R).$$

According to the course design, the GPs of N3 can be generalized into 23 top-level concepts: $G = \{\text{Nominal Predicate Sentences, Existential Sentences, Adjectival Predicate Sentences, Verbal Predicate Sentences, Particle, the Expressions of Desire, the Expressions of Will, the Expressions of Change, Conjectural Expressions, Imperative Expressions, the Expressions of Permission, the Expressions of Prohibition, the Expressions of Request, Honorific}\}.$

These 23 top-level concepts, which reflect the topics of N3 grammar course, are designed as top-level classes in COJG. Every topic represented by class has only sub-topics represented by sub-class or only GPs represented by individuals. These classes and individuals are linked by the “is-a” or “instance-of” relation to show the inclusion relation between them. This means that all the inclusion relationships of the course-centered ontology depict the knowledge classification information.

After this step, the construction of domain knowledge taxonomy is finished. In other words, all the inclusion relationship between all the concepts of the target course is already decided.

3.3. Step 3: OA design

The development work of a number of the former ontology, such as WordNet (Oltramari et al., 2002), actually only cover the first two steps mentioned above, which complete the construction of domain knowledge taxonomy. In addition to these two steps, the contribution of our research is integrating the advantage of ontology relations with traditional education methodologies to support e-learning systems to provide pedagogical intervention to help learners to find their personalized learning process; this is exactly what is done in the third step.

Assume a learner’s present knowledge framework of a course as Set $A$, then all the KPs of Set $B$ still need to be learned to achieve the objective of this course. From the educator’s perspective, knowledge comparisons could significantly support learner comprehension of the new KP and the construction of her/his own knowledge framework (Amadieu, Tricot, & Marine, 2010; Fisher, 2004; Rittle-Johnson, Star-Jon, & Durkin, 2009), which foster the meaningful learning. Hence, when a learner need to learn one KP of Set $B$, which has related KPs in set $A$, the pedagogic teaching approach is to encourage the learner review the acquired KPs in set $A$ first; then explain the relations between the acquired KPs and the new KP of Set $B$; finally expose and explain the new KP.

To provide such pedagogic procedures based on knowledge structures of learners, the ontology-based system requires the ontology of the target course not only to formalize all the KPs of the course, but also describe all kinds of relations between these KPs (this requirement is exactly in accord with the definition of the course-centered ontology). Therefore, besides the comparison and analysis of related GPs

<table>
<thead>
<tr>
<th>Function of relation</th>
<th>Relation name</th>
<th>Frequency</th>
<th>Type</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicate concept</td>
<td>hasNecessaryPrior</td>
<td>242</td>
<td></td>
<td>When the pattern of concept A involves another prior concept B, this relation exists from A to B.</td>
</tr>
<tr>
<td></td>
<td>isRelatedTo</td>
<td>17(17)</td>
<td>Symmetric</td>
<td>When two concepts are normally used together in a Japanese sentence, this symmetric relation exists between them.</td>
</tr>
<tr>
<td></td>
<td>isPriorOf/isNextOf</td>
<td>54/54</td>
<td>Inverse</td>
<td>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.)</td>
</tr>
<tr>
<td>Indicate equivalence</td>
<td>hasHonorific/isHonorificOf</td>
<td>13/13</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to show the honorific of a common form and the common form of an honorific.</td>
</tr>
<tr>
<td>of grammatical</td>
<td>hasHumbleEquivalent/isHumbleEquivalentOf</td>
<td>7/7</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to show the humble equivalent of a common form and the common equivalent of a humble form.</td>
</tr>
<tr>
<td>phenomena</td>
<td>hasColloquialEquivalent/isColloquialEquivalentOf</td>
<td>1/1</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to show the oral equivalent of a written expression and the written equivalent of an oral expression.</td>
</tr>
<tr>
<td>Indicate concept</td>
<td>isSimilarWith</td>
<td>41(41)</td>
<td>Symmetric</td>
<td>When two concepts have similar meaning and both can be used in the same context, this symmetric relation exists between them.</td>
</tr>
<tr>
<td>similarities or</td>
<td>isOppositeOf</td>
<td>3(3)</td>
<td>Symmetric</td>
<td>When two concepts with the same usage pattern have the opposite meaning, this symmetric relation exists between them.</td>
</tr>
<tr>
<td>contrasts</td>
<td>isMoreColloquialThan/isLessColloquialThan</td>
<td>7/7</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the colloquialism degree.</td>
</tr>
<tr>
<td></td>
<td>isMoreFormalThan/isLessFormalThan</td>
<td>1/1</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the formality degree.</td>
</tr>
<tr>
<td></td>
<td>isMoreRespectfulThan/isLessRespectfulThan</td>
<td>6/6</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the respect level.</td>
</tr>
<tr>
<td></td>
<td>isMoreImpoliteThan/isLessImpoliteThan</td>
<td>3/3</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the degree of impoliteness.</td>
</tr>
<tr>
<td></td>
<td>hasMoreCertainyThan/hasLessCertainyThan</td>
<td>30/30</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the degree of certainty.</td>
</tr>
<tr>
<td></td>
<td>isMoreSubjectiveThan/isLessSubjectiveThan</td>
<td>11/11</td>
<td>Inverse</td>
<td>This pair of inverse relations is used to compare two concepts for the degree of subjectivity.</td>
</tr>
</tbody>
</table>

Table 1
Frequency and usage of all the relations of COJG.
which already exist in the reference book (Shigeno et al., 2009), the expert teachers who participated in the construction of COJG were asked to provide a document which listed in natural language all the rest of grammatical relations among all the 205 GPs in this N3 grammar course.

Afterward, for each GP, one of its grammatical related GP determines one OA of its represented individual. Consequently, totally 630 OAs of all the 205 GPs are designed in COJG. The elaborated examples of OA designs are described by Wang et al. (2012). Besides the inclusion relation already decided by the previous step, 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 “hasHonoriC” and “isHonoriC”) 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 “hasHonoriC” 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. These data are automatically recorded by “Protege”. For a symmetric relation, their frequency is shown as “times(timess)” 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 “hasHonoriC/isHonoriC”, which represents the relations “hasHonoriC” and “isHonoriC” are placed as inverse relations 13 times, respectively.

The frequency information of those relations depicted in Table 1 also reflects the advantages of ontology. For example, among the OAs shown in Fig. 2, “isSimilarWith” relation is used to indicate the similar GP of “–te mo i i”. 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.

3.4. The matters worthy of attention

The following matters about the design of the course-centered ontology are worthy of note.

1. The three steps approach presented in this section begins with details about individual creation and OA 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.

2. In step 2, the depth of the ontology and the number of individuals in one class both should be carefully designed to not be too large without compromising the accuracy of the ontology (in fact, the experimental result on optimum branching in the evaluation Section 5.5 further suggests the optimum number). When one concept involved too many sub-concepts, those sub-concepts might be better to be divided in to groups according to their common features (described by DAs) to avoid a large number of individuals in one class. However, no only for the quantity of individuals in one class, but also for the number of classes-layers, anyone of these two parameters reaches a limit might cause the difficulty of the maintenance of the ontology. Therefore, the tradeoff between these two parameters need deliberate consideration. In COJG, the depth of the ontology, which includes 23 top level classes, 23 second level classes and 25 third level classes (54 of these classes have only individuals), is 4. Of all the 205 individuals in COJG, the average number of individuals in one class is 3.7 and the largest number of individuals in one class is 9.

3. This “individual-class-individual” approach for building course-centered ontology described above in detail is not only restricted to the Japanese courses or other language courses, but also can be generalized to engineering courses. Actually, right now we are building another two instances of course-centered ontology targeting at existing English and Physics courses. When this method is adapted to other courses, the part which needs careful adjustment is the OA design in step 3. For example, when an existing English grammar course is chosen as target, the OA of individuals in the ontology should be adjusted to enable the description of all the essential relations that originate in characteristics of the English grammar, since the grammatical relations between English GPs are different from the Japanese language. The comparison of ontologies design between Japanese grammar course and other language courses, and between language courses and engineering courses, will also be explored in further work.

4. A personalized learning support system based on COJG

4.1. System overview

A customizable language learning support system (CLLSS) intended to provide LOs according to the learner's knowledge structure, learning style and habits has been developed and the first version of the system (CLLSS 1.0) is presented by Wang, Mendori, and Xiong (2013). The course-centered ontology 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 (in this paper we refer to COJG), which is stored in OWL 2.0 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. 3 shows the common view of the newest version of our system (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.

Although similar function also can be provided by other sequencing techniques, such as activity tree in SCORM (Advanced Distributed Learning Initiative, 2009), those methods normally required a predefined set of activities to describe the branching and flow of learning contents; instead, the meaning of relation of an ontology can be enriched according to the purpose of the sequencing; this advantage enables the ontology-based systems to calculate the personalized learning order of KPs by considering both information from the data properties and object properties, which describe the essential features of KPs and the essential relationship between KPs, respectively.

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. 3, when a user (instructor or learner) selects one GP “~te mo i i” represented by one individual in COJG, the relation panel on the right part will provide the user a visual representation of this GP and its related GPs 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. For example, the relation panel in Fig. 3 displays the properties “respectForm”, “pattern”, “negativeForm” and “example” of the GP “~te mo i i” (all the properties of the individual in COJG which represents this GP is shown in Fig. 2.). 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.

4.2. The teaching materials organization for teacher and the pedagogical approach for learner

In older LMSs/CMSs, for deciding the metadata of LOs, the users tend to create some vocabulary for they own end use and purpose; this makes the sharing and retrieval of learning materials very difficult. Although Learning Object Metadata (LOM) (IEEE Standards Association,
is a well-designed specification for learning object metadata, it involves more than 80 elements which is a very big burden for users (IMS Global Learning Consortium Inc., 2004). Even those element are optional, the understanding of their meaning is still a burden for users. Therefore, COJG which defines common vocabularies that both instructors and learners are familiar with, are used as one of the foundations of the learning object metadata in CLLSS (another one is the teaching method ontology described in our previous paper (Wang et al., 2013). To automatically record the information defined by COJG as metadata for every new LO, the organization of the LOs is designed underlying the relation panel (shown in Fig. 3). 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 GP or relation between GPs. This guarantees the metadata description of every new LO cover the information about one individual or one relation of COJG.

The relation panel of CLLSS encourages instructors (especially novice instructors) to follow teaching procedures and teaching strategy of expert teachers. Instructors can produce and arrange teaching materials directly addressing specific GPs 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 GP with all its related GPs, especially with those acquired GPs. This pedagogical approach is enabled by the consideration of the learners’ dynamic knowledge structure.

For example, when the GP “~te mo i i” is identified as the present learning content according to a learner’s present knowledge structure, the learner can get a visual representation of relevant information as shown in Fig. 3: the pattern of “~te mo i i” involves the prior concept represented by Node 1; the expression “~te mo i i” and the GP represented by Node 2 have similar meaning and both can be used in the same context; the expression “~te mo i i” and the GP represented by Node 3 have the same usage pattern but the opposite meaning. COJG enable the learner of CLLSS to compare “~te mo i i” with all its three related knowledge points through three kinds of different relations. This learning process including knowledge comparison is intended to support the learner comprehension of the new grammar point.

In addition to LOs directly addressing certain GP, LOs directly addressing those relations between GPs also are provided by CLLSS. Learners can open LOs panel not only at every node but also every arc on the relation panel. Fig. 4 displays the LOs panel opened on the arc which represents the “isOppositeOf” relation between “~te mo i i” and the GP represented by Node 3 of Fig. 3.

In this research, two stages of grammar teaching are considered for LO organization. The first stage is “exposure with explanation” which presents new target language data to learners to facilitate the noticing of grammatical phenomena and then explains the grammar rules (may involving more examples) to the learners to better understand the grammar points. The next stage is “practice” which expects learners to apply grammar rules to all forms of exercises until they reach competence expansion. Apparently, the concrete contents of these two stages should be also decided by the knowledge features of the course. Also, while uploading a new LO on the teaching material management panel, the instructor need to choose which stage it belongs to.

Compared to CLLSS 1.0, the learning objects addressing these two stages in CLLSS 2.0, not only on the “learning objects panel” (such as example shown in Fig. 4) for learners but also on the “teaching material management panel” for instructors, are separately displayed to highlight the order of the stages. In additional, in the new version of CLLSS, when learners open a file from “practice stage”, they will be required to submit their exercises to the system before checking the reference file; on the other hand, the instructor also can review those answers through the system.

4.3 The comparison with TM4L

CLLSS enables the organization of ontology-aware LOs through the use of a “course-centered ontology” for sematic annotation of learning resources in a specific course. Using the practical ontology as a standard structure for the exploration of LOs, facilitate not only the explanation of what a KP is but also how to use the KP. Furthermore, since the ontology is abstracted above any particular implementation platforms and independent of any programming language used for implementation, the same ontology could also drive other LMS platforms automatically, which achieves a high level of portability.

The previous research similar to our work is “the only general education topic maps editor and viewer” TM4L system (Dicheva & Dichev, 2006), which makes use of a developed subject ontology with courses on the same subject to increase the reusability of available educational resources. TM4L supports an efficient context-based retrieval of learning content tailored to the needs of a learner working on a specific task.

The similarities of TM4L and our system CLLSS are:

1. they are both based on a general framework for ontology-ware digital course libraries although some differences exist between frameworks they were built on;

<table>
<thead>
<tr>
<th>Exposure With Explanation</th>
<th>File Name</th>
<th>Average Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal explanation</td>
<td>temoiiTewaikenaiEW.pdf</td>
<td>0.0 open</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Practice</th>
<th>Style</th>
<th>File Name</th>
<th>Reference File</th>
<th>Average Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>Fill-in-blanks with pictures</td>
<td>temoiiTewaikenaiPT.pdf</td>
<td>temoiiTewaikenaiPTd.pdf</td>
<td>0.0 open</td>
</tr>
<tr>
<td>Visual</td>
<td>Transformation</td>
<td>temoiiTewaikenaiPZ.pdf</td>
<td>temoiiTewaikenaiPZd.pdf</td>
<td>0.0 open</td>
</tr>
<tr>
<td>Visual</td>
<td>Translation</td>
<td>temoiiTewaikenaiPF.pdf</td>
<td>temoiiTewaikenaiPFd.pdf</td>
<td>0.0 open</td>
</tr>
</tbody>
</table>

Fig. 4. The LOs panel addressing the similarity “~te mo i i” and the GP represented by Node 3 of Fig. 3.
286

they both focus on specifying concepts and relations on a particular domain to provide ground for knowledge sharing and provide the function to use ontolog to link concepts to learning resources;

(3) they both propose concept-driven access to learning repositories and use browsable maps to make the understanding more easily.

The differences between these two systems are listed as follow:

(1) although TM4L enables the learner to understand the relationships between the resources, it does not provide organization of LOs directly addressing relations between concepts or KPs. Therefore, the biggest difference between TM4L and CLLSS is that, CLLSS not only displays the concept relations like Protégé or CmapTool (Novak & Canas, 2008), but also encourages the instructors to create and orient their teaching materials to those relations. Owe to this kind of organization, the users of CLLSS can get LOs not only under a specific KP but also under a specific relation in the browsable maps provided in relation panel of CLLSS.

(2) the TM4L Editor is an ontology editor allowing the user to build ontology-driven learning repositories using Topic Maps. The learning content created by the Editor is fully compliant with the XML Topic Maps (XTM) standard and thus interchangeable and interoperable with any standard XTM tools. However, until the latest version of CLLSS (version 2.0), the system itself do not support the edit of ontology. Our system only provides a plug-in for users to upload their course-centered ontologies which are stored in OWL files to create a map structure for their courses.

(3) the LOs organization of these two systems is towards opposite direction. The LOs organization of TM4L is bottom-up. In TM4L, LOs are classified based on topics/concepts; and then those topics/concepts are clustered in contexts/themes; finally those contexts/themes can be got by multiple viewpoints. However, the LOs organization in CLLSS is top-down based on uploaded course-centered ontologies. In a chosen course, the users (instructors and learners) can firstly browse the knowledge concepts classified from top to the bottom and read their properties; then go to the KPs or relations between KPs located in the bottom, which finally are linked to corresponding LOs.

(4) last but not the least, until now, no only evaluation of TM4L under a practical course has been presented while a series of experiments has been conducted to examine the learning performance of the learners while using CLLSS in our research.

5. Experiment and results

5.1. The purpose of the experiment

To evaluate the prototype system of CLLSS, a preliminary experiment was conducted in the International Language department of a Chinese university (the detail of this experiment is described by Wang et al., 2013). A class of 29 first grade students, who major in Japanese and already studied Japanese for five months before the experiment, were assigned to be the experimental group and the control group based on their achievement on the pre-test, so as to minimize the group composition differences.

In the following 3 weeks, fifteen grammar contents are taught in classroom which mainly involved in Expressions of Will, Conjectural Expressions and Conditional Expressions. In addition to taking the same classroom teaching (8 classes/week), after classes the experimental group with 15 students used the CLLSS 1.0 while the control group with 14 students studied with the older LMS the university already had. After 3 weeks of learning activity (each student of experimental group at least used the system for 10 h, the average using time is 16.13 h), all the students took the post-test and a questionnaire. The experimental results suggest that the average learning achievement of the students in the experimental group, who studied with CLLSS 1.0, was significantly better than that of the control group, who studied with the traditional learning management system while taking the same Japanese course as the experimental group.

However, in the interview section of the preliminary experiment, some students in experiment group reported that they felt pressure while using the knowledge comparison function especially when confronted with numerous related GPs in the relation panel at one time. To determine the factors underlying this pressure, the experiment in the study of this paper was conducted to further evaluate the knowledge comparison function provide by CLLSS (the 2.0 version are used in this study). The following research questions are intended to investigate:

(1) What is the optimum number of related GPs to be shown in the relation panel at one time?
(2) Is there correlation between learning styles and learning performance (including learning achievements, perception, cognitive load, and so on) while the learners study with CLLSS?
(3) Is there correlation between learning habit (in this paper refer to the habit of learning from the comparison of related KPs) and learning performance while the learners study with CLLSS?

Besides the differences in the version of CLLSS, the number of participants, and the target learning contents, the biggest distinctions between this two experiments are:

(1) to minimize the group composition differences, the preliminary evaluation simply assigned the experimental and the control group based on their achievement on the pre-test, while the experiment in this study even grouped participants by considering the their learning style in Sequential/Global dimension and their learning habit of "learning from the comparison of related KPs";
(2) in the preliminary evaluation, since the participants used CLLSS 1.0 or older LMS after the regular classroom teaching, their learning environment and time is difficult to control; however, in the experiment in this study, the experimental group learned with CLLSS 2.0 in a computer-assisted language learning lab while the control group just did self-study with textbooks, both of which studied the same target contents for the same time.

From the experimental results of this study, we aim to evaluate the effectiveness of the learning support function of CLLSS 2.0 and also search for a better solution to the design of the relation panel of CLLSS.
5.2. The experiment design from learning style perspective

“The ways in which an individual characteristically acquires, retains, and retrieves information are collectively termed the individual’s learning style” (Felder & Henriques, 1995, p.21). Among the learner’s characteristics, learning style has been considered as one of the key elements that affect the learning effectiveness in many studies (Filippidis & Tsoukalas, 2009; Hwang, Sung, Hung, & Huang, 2012).

In this paper, the widely adopted learning style model, which was presented by Felder and Silverman in 1988 and revised by Felder in 2002, is used to model the learner’s learning styles. This model defined four dimensions of learning style: Active/Reflective, Sensing/Intuiting, Visual/Verbal, and Sequential/Global dimensions. Learners of active scale tend to understand the knowledge through active trial, discussion or by explaining it to others while learners of reflective scale tend to observe reflectively; learners of sensing scale prefer to perceive data by the senses while learners of intuiting scale prefer by accessing memories or insights; visual learners prefer that information is presented by diagrams, flow charts, pictures or films rather than in written words, which is preferred by verbal learners; sequential learners gain understanding in logically linear steps while global learners need the big picture of a subject before mastering details.

As shown in Fig. 3, the relation panel of CLLSS provides a visual representation of every KP and makes use of diagram to highlight the relations between KPs. Therefore, from the learning style perspective, the global learners, who like to relate the new knowledge to their prior knowledge and experience, may feel less pressure than sequential learners while using the comparison function provided by this relation panel of CLLSS; on the other hand, the visual learners, who prefer the knowledge presented by diagrams than in written words, may feel more comfortable than verbal learner while using CLLSS. Based on this hypothesis, the experiment in this study was conducted to further analyze learner performance while using CLLSS.

5.3. Participants

Ninety undergraduate of the Japanese language major participated in the experiment in this study. These first grade students from 3 different classes of a Chinese university were taught by the 3 different instructors who had taught Japanese grammar course for more than seven years. Before the experiment, all the students already studied Japanese for 8 months and used the same reference books for the Japanese grammar course.

In the preparatory phase, a questionnaire was conducted to collect learning style distribution data. The measuring tool adopted in this phase was a questionnaire written in Chinese, translated from the Index of Learning Styles (ILS) questionnaire of 44 questions (Felder & Silverman, 1988). The ILS questionnaire was designed based on the Felder-Silverman learning style model (1988, 2002) and its current version was suggested to be reliable, valid and suitable for capturing learners' behavioral tendencies (Felder & Spurlin, 2005). All the participants including 38 male and 52 female students were required to fill in this questionnaire. The learning style profiles suggested by the results of the learning style questionnaire are shown in Table 2.

As shown in Table 2 (Dimension 3: Visual/Verbal), 24.4% of participants are strong visual learners, who strongly prefer that information is presented visually, and 28.9% are moderate visual learners, while only 2.2% are strong verbal learner who strongly prefer spoken or written explanations to visual presentations, and 2.2% are moderate verbal learner. Meanwhile, 42.2% of participants with mild preference for visual or verbal are fairly well balanced in the dimension of Visual/Verbal. Since there are too few verbal learners (19.9%) comparing to verbal learners (81.1%) among the 90 participants, it is very difficult to analyze the learning performance differences between visual learners and verbal learners.

Therefore, the analysis of the learner data in this paper only focuses on the Sequential/Global dimension of learning style model. As shown in Table 2, among all the 90 participants the percentages of strong, moderate and mild sequential learners are 3.3%, 12.2% and 23.3% respectively, while the percentages of strong, moderate and mild global learners are 5.6%, 25.6% and 30% respectively.

5.4. Experimental procedures and measurement techniques

Fig. 5 shows the procedures of the experiment in the study in this paper. The Measurement techniques in this experiment included the learning achievement tests, and the questionnaires for measuring the students’ learning perception, habits, preferences, and so on.

In the preparatory phase of the experiment, all the participants took the ILS questionnaire, the pre-test and Questionnaire-1 which involved learning attitude (Hwang & Chang, 2011) and motivation (Pintrich & DeGroot, 1990), the habit of “learning from the comparison of related KPs”.

According to the participants’ learning style in Sequential/Global dimension and their learning habit of “learning from the comparison of related KPs”, students from each class were assigned to be the experimental group and the control group, so as to minimize the group composition differences.

Based on the answers to the question about learning habit in Questionnaire-1, participants are divided into “learners who don’t have habit of ‘learning from comparison’ (N-learners)” and “learners who have the habit of ‘learning from comparison’ (H-learners)”. As shown in
Fig. 6, “N-learners” of experimental group included 2 students who completely did not have the comparison habit and 32 students who sometime would compare the related KPs while reminded by the instructor or other learners; “H-learners” of experimental group included 21 students, who most of the time would realize the relations between acquired GPs and new GP and would like to compare them to increase the understanding of the knowledge, and 5 students, who already have the comparison habit and always record the contrast between related GPs in notebooks, even organize their related practices. Meanwhile, the control groups included 16 “N-learners” learners and 14 “H-learners”.

The learning style profiles of participants suggested by results of the ILS questionnaire (shown in Table 2) are already discussed in Section 5.3. The learning styles (Sequential/Global Dimension) of participants in both experimental and control groups are displayed in Fig. 7. The experimental group included 25 Sequential learners and 35 Global learners while the control groups included 10 Sequential learners and 20 Global learners.

After the assignment of experimental and control groups, five GPs “~hoshigaru”, “~tagaru”, “~tekuru”, “Causative Sentence”, and “~hazuda”, which have one, two, three, five and seven related GPs respectively in this grammar course, were chosen as target learning contents.

The learning activity of experimental group was performed in the computer-assisted language learning lab. During the whole experiment, students in experiment group used the Chinese version of CLLSS 2.0 presented in Section 4. After 25 min training, the experimental group with 60 students used the comparison function provided by the relation panel of CLLSS 2.0 to study the target contents. They were required to compare the target contents with their prior knowledge points shown in relation panel during the learning activity. Meanwhile, the control group in another classroom with 30 students studied with the textbook (Shigeno et al., 2009). For both experimental and control groups, the time of the learning activity towards the target contents was 60 min. Students in both groups were encouraged to mainly compare “~hoshigaru” with “~hoshii”, “~tagaru” with “~tai”, “~tekuru” with “~teiku”, “~hazuda” with “~darou”, “Causative Sentence” with “~temorau” respectively by an expert teacher.

After the learning activity, all the students took the post-test and another questionnaire (Questionnaire-2) which involved their learning attitude and motivation. Unlike the control group, the experimental group was required to answer some additional questions on the Questionnaire-2, which involved the satisfaction for learning mode (Chu, Hwang, & Tsai, 2010), technology acceptance measures (Chu, Hwang, Tsai, & Tseng, 2010; Davis, 1989), and cognitive load (Sweller, Merrienboer, & Fred, 1998).

The test sheets were created by two experienced teachers. The pre-test aimed to evaluate the students’ prior knowledge of Japanese. It contained ten fill-in-blank items, twenty-five singe-choice items and ten translation items with a perfect score of 100. The post-test
contained fifteen fill-in-blank items with a perfect score 90. Those fifteen items were designed for assessing the students’ knowledge of target contents after the learning activity.

Both Questionnaire-1 and Questionnaire-2 written in Chinese were designed based on the measure tools of other researches (Chu, Hwang, & Tsai, 2010; Chu, Hwang, Tsai, et al., 2010; Hwang & Chang, 2011; Pintrich & DeGroot, 1990; Sweller et al., 1998) with some modifications.

5.5. The analysis of learning perception of the experimental group

The feedback about the learning activity and the system evaluation from the experimental group, are shown in Table 3. According to this table, for the answers to “What is the maximum number of the relations shown in the relation panel of the system at one time that do not make you feel pressure and disturbed?”, the average number given by the 60 students in experimental group is 4.67; this means that when a GP involves more than 4 relations in the course the optimum number of its related GPs to be shown in the relation panel at one time is 4.

The average ratings of “Effort for understanding the target GPs” (the maximum is 7) is 4.05; this suggests the learning activity was moderate (neither too easy nor too difficult) for the students in experiment groups. The average ratings of “Effort for understanding the purpose and the explanation of learning activity” (the maximum is 7) is 3.02; this means most students in the experimental group could easily understand the learning purpose of this activity.

In terms of mental load, the average rating of the degree of distraction and pressure of experimental group are both lower than 2.2, implying that using the CLLSS 2.0 the learners could concentrate on learning with low pressure.

In terms of technology acceptance measures of the experimental group, the average rating of the item “It is easy to use this Comparison function of CLLSS.” (1–3: strongly to slightly disagree, 4–6: slightly to strongly agree) is 4.75; this means that most students in the experimental group felt that it was easy to operate and get familiar with the system. The item “This Comparison function of CLLSS is useful for study.” (1–3: strongly to slightly disagree, 4–6: slightly to strongly agree) received the average rating 4.83, implying that most of the students in the experimental group identified the usefulness of CLLSS 2.0 in improving their learning performances.

For items shown in Table 3, the analysis results from learning style perspective are described in Table 4, in which the analysis of the learner data focuses on the learning style differences in Sequential/Global dimension (shown in Fig. 5). In Table 4, the MANOVA result of “Technology Acceptance” (Wilks’ Lambda, \(p < 0.05\)) indicates that there was significant difference between “Sequential learners” and “Global learners” of experimental group in how they accepted the technology of CLLSS 2.0. The results of individual univariate analysis further indicate that this significant difference is caused by the difference of the rating of “Perceived usefulness” between “Sequential learners” and “Global learners”; this suggests that compared to “Sequential learners”, most “Global learners” had stronger feeling that the comparison function provided by CLLSS 2.0 is useful in improving their learning performances. For the other rating items in Table 4, the results suggest that there was no significant difference between “Sequential learners” and “Global learners”.

On the other hand, Table 5 describes the analysis results of the learning perception of experimental group from learning habit perspective, in which the analysis of the learner data focuses on the learning habit differences. According to Table 5, the MANOVA result “Mental Load” (Wilks’ Lambda, \(p < 0.05\)) indicates that there was significant difference between “N-learners” and “H-learners” of the experiment group. The results of individual univariate analyses further indicate that there were significant differences in the rating of “Distraction” and “Pressure” between “N-learners” and “H-learners”; this suggests that the learners who don’t habitually “learning from comparison” were easier to lose their attention and felt more pressure than those who already have that habit while both using CLLSS 2.0. For the other rating items in Table 5, the results suggest that there was no significant difference between “N-learners” and “H-learners”.

Besides those 8 items shown in Table 3, experimental group had 7 additional questions about the satisfaction for learning mode. The results of the answer of experimental group are shown in Table 6. The maximum is 6 for the rating of every item (1–3: strongly to slightly disagree, 4–6: slightly to strongly agree). According to Table 6, for experimental group, most of them slightly agreed that the learning content were provided in a vivid way, but most of them showed general agreement with the fact that using the “comparison function”
provided by the relation panel did help them find some new information and did help them understand the knowledge points in new ways. Also, most of the student in experimental group generally agreed that they (a) liked to use the “comparison function” during the activity of this experiment, (b) hoped this function could be used while studying other subjects or in future study, and (c) would recommend this method to other learners.

To investigate user satisfaction for learning mode, MANOVAs were also conducted by focusing on the learning style differences in Sequential/Global dimension and the learning habit differences respectively. However, significant differences are found neither between “N-learners” and “H-learners” nor between “Sequential learners” and “Global learners”.

5.6. The analysis of learning achievement

The analysis of covariance (ANCOVA) was used to test the learning achievement difference between the experiment group and control group by using the pre-test scores as the concomitant variable and the post-test scores as dependent variable. The purpose of using pre-test scores as concomitant variable in ANCOVA is to use the information about pre-test to reduce the variation in post-test scores and thus increase the chance of detecting differences between the different treatments.

Before performing the ANCOVA, a series of tests, which includes the tests of Between-Subjects Effects, Shapiro–Wilk test, the checking on P–P plots of Standardized Residuals and the Liner Regression test, were conducted to confirm the sample data satisfy the ANCOVA assumption (those tests were conducted before every ANCOVA in this section). Based on the results of these tests, sample data appear to conform to the assumption of the ANCOVA.

Table 7 shows the descriptive data and ANCOVA results of the experimental group and control group. The result ($p > 0.05$) of Levene’s test of Equality of Error Variances suggests the homogeneity of variances. The adjusted mean value and standard error of the post-test scores are 52.67 and 2.74 for the experimental group, 41.71 and 4.61 for the control group. According to results ($F = 4.139, p < 0.05$) shown in Table 7, there was a significant difference between these two groups; this suggests that the students who learned with the learning support system achieved significantly better learning achievements than those who just did self-study with textbook after studying the same target contents for the same time.

ANCOVA was also used to test the learning achievement difference between sequential and global learners of experimental group. As shown in Table 8, the result ($p > 0.05$) of Levene’s test of Equality of Error Variances suggests the homogeneity of variances. The adjusted mean value and standard error of the post-test scores are 54.66 and 3.78 for global learners of the experimental group. According to results ($F = 0.218, p > 0.05$) shown in Table 8, there was no significant difference between sequential and global learners of experimental group; this suggests that no matter the sequential or global learners of experimental group, who studied with the learning support system, their learning achievements did not have significant difference.

For the learning achievement difference between “N-learners” and “H-learners” of experimental group, the ANCOVA result ($F = 2.801, p > 0.05$) shown in Table 9 suggests that there was no significant difference between these two groups; this suggests that no matter the learners have or don’t have the habit of “learning from comparison”, using CLLSS 2.0 their learning achievements did not have significant difference.

6. Conclusion and further work

In this research, “course-centered ontology” is presented as the domain model for learning support systems. This ontology design was applied to the construction of a course-centered ontology (COJG) for an existing Japanese grammar course. For the domain of the grammar course, the classes of ontology are used to reflect the knowledge classification and the individuals of those classes are used to represent

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The analysis results of experimental group’ learning perception from learning style (sequential/global) perspective.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning style</th>
<th>Item</th>
<th>Optimum number of relations</th>
<th>Mental effort</th>
<th>Mental load</th>
<th>Technology acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential (25)</td>
<td>Mean</td>
<td>4.88</td>
<td>3.84</td>
<td>2.76</td>
<td>1.72</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.30</td>
<td>1.49</td>
<td>1.16</td>
<td>0.98</td>
</tr>
<tr>
<td>Global (35)</td>
<td>Mean</td>
<td>4.51</td>
<td>4.20</td>
<td>3.20</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.44</td>
<td>1.39</td>
<td>1.55</td>
<td>1.06</td>
</tr>
<tr>
<td>MANOVA</td>
<td>Wilks’ Lambda</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Levene’s Test</td>
<td>0.322</td>
<td>0.475</td>
<td>0.073</td>
<td>0.892</td>
</tr>
<tr>
<td></td>
<td>One way ANOVA</td>
<td>0.381</td>
<td>0.341</td>
<td>0.236</td>
<td>0.612</td>
</tr>
</tbody>
</table>

* Means there is a statically significant difference.
Means there is a statically significant difference.

**Table 5**
The analysis results of experimental group’ learning perception from learning habit perspective.

<table>
<thead>
<tr>
<th>Comparison habit</th>
<th>Item</th>
<th>Optimum number of relations</th>
<th>Mental effort</th>
<th>Mental load</th>
<th>Technology acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Learn the GP (1–7)</td>
<td>Understand the purpose (1–7)</td>
<td>Distraction (1–7)</td>
<td>Pressure (1–7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S.D.</td>
<td>S.D.</td>
<td>S.D.</td>
<td>S.D.</td>
</tr>
<tr>
<td>N-learners (34)</td>
<td>Mean</td>
<td>4.73</td>
<td>4.12</td>
<td>3.12</td>
<td>2.06</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>1.64</td>
<td>1.51</td>
<td>1.47</td>
<td>1.10</td>
</tr>
<tr>
<td>H-learners (26)</td>
<td>Mean</td>
<td>4.58</td>
<td>3.96</td>
<td>2.88</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>0.99</td>
<td>1.34</td>
<td>1.34</td>
<td>0.81</td>
</tr>
<tr>
<td>MANOVA (Wilks’ Lambda)</td>
<td>Sig.</td>
<td>0.033* (p &lt; 0.05)</td>
<td>0.463</td>
<td>0.068</td>
<td>0.064</td>
</tr>
<tr>
<td>Levene’s Test</td>
<td>0.204</td>
<td>0.024* (p &lt; 0.025)</td>
<td>0.015* (p &lt; 0.025)</td>
<td>0.888</td>
<td>0.285</td>
</tr>
<tr>
<td>One way ANOVA</td>
<td>0.665</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A * means there is a statically significant difference.

**Table 6**
The results of the satisfaction for learning mode of experimental group.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1: The system provides the learning contents in a vivid way.</td>
<td>4.33</td>
<td>0.86</td>
</tr>
<tr>
<td>Q2: Using the “comparison function” provided by the relation panel of the system can help me find some new information.</td>
<td>4.98</td>
<td>0.70</td>
</tr>
<tr>
<td>Q3: Using the “comparison function” in the system can help me to understand the knowledge points in new ways.</td>
<td>4.77</td>
<td>0.81</td>
</tr>
<tr>
<td>Q4: I like to use the comparison function in the system.</td>
<td>4.83</td>
<td>0.76</td>
</tr>
<tr>
<td>Q5: I hope other subjects can also be learned with this method.</td>
<td>4.70</td>
<td>0.91</td>
</tr>
<tr>
<td>Q6: I hope I can learn with this method in future study.</td>
<td>5.05</td>
<td>0.70</td>
</tr>
<tr>
<td>Q7: I will recommend this methods to other learners</td>
<td>4.93</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Based on COJG, a customizable language learning support system (CLLSS) has also been built to help instructors to organize the teaching materials and provide personalized LOs in response to the knowledge structure of the learner. These grammatical relations of COJG, which is designed according to pedagogical criteria, enable the system to provide the learner a visual comparison of related knowledge points so as to foster meaningful learning.

Based on the results of a preliminary evaluation on CLLSS 1.0, a study to explore the impact of learning styles and learning habits on learning performance was conducted to further evaluate CLLSS 2.0. The analysis result of learning achievement in this study suggests that the students who learned with the CLLSS 2.0 achieved significantly better learning achievement than those who just did self-study with textbooks after studying the same target contents for the same time. Furthermore, the sequential and global learners of experimental group, who studied with CLLSS 2.0, did not show significant differences in their learning achievement. Moreover, the learners who don’t have the habit of “learning from comparison” and those who have that habit, also did not show significant differences in their learning achievement while both using CLLSS 2.0. In other words, in the experiment of this study the learning achievement of experimental group was not related to either their learning style in Sequential/Global dimension or their habit of “learning from comparison”.

In the terms of the learning perception of experiment groups, the points listed below, suggested by the analysis results, are worthy of consideration. (1) To support the comparison among related KPs, the natural relationship between KPs is indispensable; however, a big number of relations will be too complex for the learner to visually navigate. Therefore, the instructors should be encouraged to describe the priority of the relations to enable the system show only the top 4 (based on the feedback of “the optimum number of relations at one time” in Table 3) of them in the relation panel while making the rest a selectable option. Since individuals in the same class share some common features and have default relations between each other, it is also indirectly suggested that the optimum branching of ontology is 4. (2) Compared to “Sequential learners”, most “Global learners” had a stronger feeling that the comparison function provided by CLLSS 2.0 is corresponding GPs (in total about 205 grammar points). To support e-learning systems to provide the comparison of KPs in response to knowledge structures of learners, COJG not only formalizes all the GPs of the course, but also describes all kinds of grammatical relations between those GPs. Furthermore, 24 types of relations, which include the concept dependences, similarities and contrasts, and even grammatical equivalence phenomena, are designed in COJG to describe 436 grammatical relations in the course. All these grammatical relations and the individuals, which represent corresponding GPs in COJG, constitute a relation network that involves all the GPs in this Japanese grammar course.

**Table 7**
Descriptive data and ANCOVA result of the post-test scores between experimental and control group.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>Adjusted mean</th>
<th>Std. error</th>
<th>F</th>
<th>Sig.</th>
<th>Levene’s test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>60</td>
<td>53.50</td>
<td>19.12</td>
<td>52.67</td>
<td>2.74</td>
<td>4.139</td>
<td>0.047</td>
<td>0.674</td>
</tr>
<tr>
<td>Control</td>
<td>30</td>
<td>39.43</td>
<td>17.68</td>
<td>41.71</td>
<td>4.61</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 8**
Descriptive data and ANCOVA result of the post-test scores between sequential and global learners of experimental group.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>Adjusted mean</th>
<th>Std. error</th>
<th>F</th>
<th>Sig.</th>
<th>Levene’s test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential</td>
<td>25</td>
<td>53.36</td>
<td>18.37</td>
<td>51.97</td>
<td>4.30</td>
<td>0.218</td>
<td>0.643</td>
<td>0.781</td>
</tr>
<tr>
<td>Global</td>
<td>35</td>
<td>53.60</td>
<td>20.11</td>
<td>54.66</td>
<td>3.78</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
useful in improving their learning performances. (3) The learners who don’t habitually “learning from comparison” were more likely to lose their attention and feel more pressure than those who do habitually “learning from comparison” while both using CLLSS 2.0. For future work, we will conduct some analyses to investigate the changes on the learning attitude and motivation of this experiment and discuss the results. Furthermore, in the experiments of the study in this paper, students were required to use CLLSS to learn some chosen grammar points in the grammar course. Only short-term learning performances of learners are discussed. Since there were short-term learning perception differences between learners with different learning styles (in Sequential/Global dimension) and also between learners with different learning habits, those perception differences might lead to differences on long-term learning achievement. Therefore, in the next stage, long-term effects of CLLSS will be studied by conducting more experiments. The system will track the situation of students during the learning processes of the whole course. The learner data will be collected and analyzed in future. Besides, the number and the type of the acquired GPs which have relation with a new GP will be considered for ranking new GPs when more than one GP are suitable to learner's next learning process.

References
H-learners 26 49.85 19.76 47.92 4.30
N-learners 34 56.29 18.69 57.36 3.58

Table 9
<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D</th>
<th>Adjusted mean</th>
<th>Std. Error</th>
<th>F</th>
<th>Sig.</th>
<th>Levene’s test</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-learners</td>
<td>34</td>
<td>56.29</td>
<td>18.69</td>
<td>57.36</td>
<td>3.58</td>
<td>2.801</td>
<td>0.103</td>
<td>0.277</td>
</tr>
<tr>
<td>H-learners</td>
<td>26</td>
<td>49.85</td>
<td>19.76</td>
<td>47.92</td>
<td>4.30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


