Multidimensional Concept Map Representation of the Learning Objects Ontology Model for Personalized Learning

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Abstract

This work presents the creation and representation of an ontology model for the domain knowledge used for learning objects. The purpose of the developed ontology model is to define relations between learning objects that can be applied for their effective search and visualization. As the number of learning objects increases, the representation of the knowledge domain becomes challenging. In this paper, the authors propose the application of multidimensional concept maps (MCMs) for domain knowledge representation. The definition of different attributes used in the ontology model allow for defining the different dimensions needed for MCM ontology visualization. In order to achieve integration of the defined ontology model and MCMs, a software tool named Ontology-based system for learning objects retrieval (OBSLO) was developed. OBSLO's role is to dynamically generate MCMs given the defined ontology with its relations and attributes, while also providing a content delivery environment and working space for learners. Proposed OBSLO architecture with integrated ontology model and MCMs was evaluated and compared to the learning management system where ontology and MCMs were not used. It was shown that learners using OBSLO showed better success rate in learning and positive level of satisfaction.

Keywords: Ontology, Learning objects, Multidimensional concept maps, Personalized e-learning

1 Introduction

Unlike traditional e-learning systems where learning materials are uniform for all learners, the emerging e-learning systems lean towards tailoring to the needs of each individual learner by providing scalable, flexible and personalized systems [1]. Personalized e-learning systems increase learner interactivity, engagement, retention and academic achievements [2]. Personalization in e-learning can be treated as the combination of automatically adapting learning content to the interests and knowledge levels of learners, as well as the possibility of making learning decisions in a self-regulated manner (recommending a next exercise, giving a simple list of relevant exercises, etc.) [3-5]. One of the ways of creating an online environment that is flexible enough to offer personalized learning is by segmenting learning materials into learning objects (LOs). LOs present flexible, reusable and manageable units of knowledge that fulfill a single and affirmed learning goal [6].

The structuring of learning materials from LOs, poses the challenge of LOs search and retrieval. In order to enable effective retrieval of LOs, LOs are assigned with a set of metadata. While metadata are suitable for the description of multimedia, they are not fully helpful in describing semantic meaning of textual information [7]. Although recommended by e-learning standards, metadata is also not sufficient to solve the problems of LOs reusability, flexible retrieval and accessibility [8]. For that reason, LOs have to be enriched with the representation of complementary attributes that can be helpful for both creating new content and for searching through existing content [9].

Among the approaches that enable efficient LO retrieval is the use of domain ontology. The ontology model is used to specify the LOs organizational structure based on the domain concepts. Structuring a course in the form of LOs can ultimately produce a large number of LOs. The challenge that arises from having a large amount of LOs is in dynamically building a personalized learning path without exposing the learner to complex structures of knowledge [10-11].

In order to simplify the complex structure of knowledge presented by the ontology, while allowing learners to learn progressively and effectively by mastering small and independent concepts first, the structure of Multidimensional Concept Maps (MCMs) is introduced. In [12] the concept map is applied for the first time for representing interrelationships among a set of concept as a two-dimensional, hierarchical, acyclic graph that is also known as Novak concept map (NCM). NCM organization and structure provides a good navigation strategy for learners because it reduces learners' disorientation, which often occurs when they navigate through a non-linear structure or complex ontology [13]. However, the grown NCM graph may occupy several web pages in both horizontal and vertical directions, which causes difficulties for learners to study the concepts without using the web page scroll bars [14]. Moreover, NCMs cannot be used for easy explanation of difficult, multiple concepts consisting of many other subconcepts, which may lead to learner overload [15-16].

Typical learning management systems (LMSs) that use learning objects for organization and presentation of teaching and learning materials, deliver this content to learners in sequential order, which may not be suitable for different

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learning strategies (i.e. guided exploration needed in problem solving, self-regulating learning, etc.), especially when the teacher needs to assess students' understanding of specific concepts [17]. Concept mapping can allow learners, with its advanced organization of concepts, to choose concepts they need at any stage of the learning or problem solving, by allowing learners to identify more inclusive concepts that are likely to be familiar to the learners, as well as more specific concepts [18]. Additionally, a concept knowledge map can be used to help learners perform study navigations, but however, the diversity of knowledge domain extremely complicates the dependency among related knowledge and significantly increases the size of knowledge maps [19].

There are several approaches in modeling online courses with ontologies and some concept mapping plugins used in popular LMSs [16, 20-22]. For instance, Moodle offers a variety of plugins such as MindMap. While Moodle mind maps provide an improvement to Moodle's traditional lesson outline, the delivery of the learning content is not suitable for a large course.

In this paper, MCM approach is used to create a scalable visualization of the domain ontology. The structure of the MCM simplifies the complex structure of knowledge and scales the presented ontology of concepts. The MCMs are integrated with an ontology model enabling efficient retrieval of learning objects stored in LMS repository in order to achieve dynamic generation of MCMs and allow for more flexible navigation through learning content.

In this work we consider how to resolve three problems to which available research has given limited attention:

(1) How to automatically visualize ontology of learning content in the online learning environment?
(2) How to integrate the MCM and ontology model approaches to achieve interactive visualization for dynamic delivery of personalized learning content for each learner?
(3) How to provide an easier upgrade of the existing learning systems in order to support personalized learning with ontology models and MCMs?

This work proposes a software architecture for classification, organization and reuse of LOs. This architecture supports creation of LOs ontology with its relations and attributes, allowing the learning content to be visualized in multiple dimensions of MCM. Each dimension is specified using user-defined dimension attributes, such as knowledge level (i.e. basic or advanced knowledge level). MCMs and ontology enable a dynamic visualization and creation of a personalized learning space allowing dynamic delivery of learning content. This is attained through a new software component named Ontology-based system for learning objects retrieval (OBSLO) with architecture that provides the learning environment for personalized learning. OBSLO provides the following capabilities:

(1) Organizing LOs using the proposed ontology model (Section 2)
(2) Visualization of the LOs ontology using MCMs and dynamic creation of personalized learning space for each learner (Section 3)
(3) Easy integration with legacy and external systems that were not designed to support personalized learning (Section 4)
(4) Increase learning efficiency and user satisfaction by integrating ontology model with MCM learning content representation (evaluation shown in Section 5).

In our previous work the ontology model was developed and visualized as a two-dimensional ontology tree [23-24]. This work extends the previous work by enhancing the ontology model with properties that allow automatic generation of multi-dimensional ontology trees and providing intuitive visual representation of the ontology tree by using MCM approach. Dynamic delivery of personalized content in the learning environment is enhanced with capability to include student assignments and to automatically generate student feedback based on their answers.

An evaluation of the OBSLO system is demonstrated using the *Information Management* knowledge domain that is applied in a Database course. OBSLO's evaluation was compared to the use of a traditional LMS using the same learning content.

The paper is organized as follows: Section 2 presents the proposed LO ontology model. Section 3 describes visualization of defined ontology and dynamic generation of MCMs and learning space. Section 4 describes software architecture, while Section 5 presents OBSLO evaluation results. Section 6 concludes the paper.

2 Ontology Model for LO Organization

In this work, the initial structure of the course ontology is set using Noy & McGuinness's guidelines that specify stages of ontology developing and modification [25]. These stages primarily entail defining the concepts and their internal structures (properties), attaching facets to the properties (value type, allowed values, the number of allowed values etc.), and defining the concepts' hierarchy.

The concept hierarchy at the top layer represents the knowledge area, which contains knowledge units that further contain topics and subtopics. In this manner, the curriculum is defined as the most general concept at the top of the ontology and the knowledge area and knowledge units, while topic and subtopics are defined as more specialized concepts at the lower levels of ontology. In this work, only one knowledge area from the curriculum will be considered, without defining relations between knowledge areas (Figure 1).

The ontology is represented as a graph, which contains three types of elements: (i) concepts (knowledge area, knowledge unit, topic, and subtopic), (ii) relations between concepts, and (iii) LOs. Five types of relations are identified:

(1) Part of relation (PO) is established between concepts that describe that a subtopic is a part of another higher-level topic.
(2) Has content relation (HC) is defined between concepts and LOs, indicating that the LO explains certain higher-level topic or subtopic.
(3) Order relation (OR) between LOs. OR can be defined as: (a) a mandatory relation representing that one or more LOs are prerequisite to the LO that follows this

relation and their content must be learned first, and (b) an optional relation representing recommendations of which LOs may be learned in order to gain deeper knowledge about a topic.

(4) Has resources relation (HR) used between LOs and its resources. This relation provides flexibility in searching for a specific part of LO, without having to search through the entire ontology tree. With this relation, the learner can search for the resource, without having to browse through concepts and LOs content. Figure 2 demonstrates an example of the HR relation.

(5) Basic/advanced relation (BA) is used between concepts. This is a bidirectional relation indicating that one concept is on a lower knowledge level than the other. Two concepts connected by *BA* relation can be on different levels in ontology hierarchy.

With such an ontology model, concepts and content are separated. LOs are the only nodes that actually contain content. The separation of concepts from content means that content can be changed without affecting the overall structure of ontology and vice versa [16].

Concepts can be characterized with their properties (attributes). Using different attributes allows for defining different dimensions used for ontology visualization. Each concept can have a multivalued attribute (i.e. a concept may be both *basic* and *intermediate*). However, in order to simplify the presentation of the ontology model in this work, we will consider only concepts with *basic* and *advanced* knowledge levels.

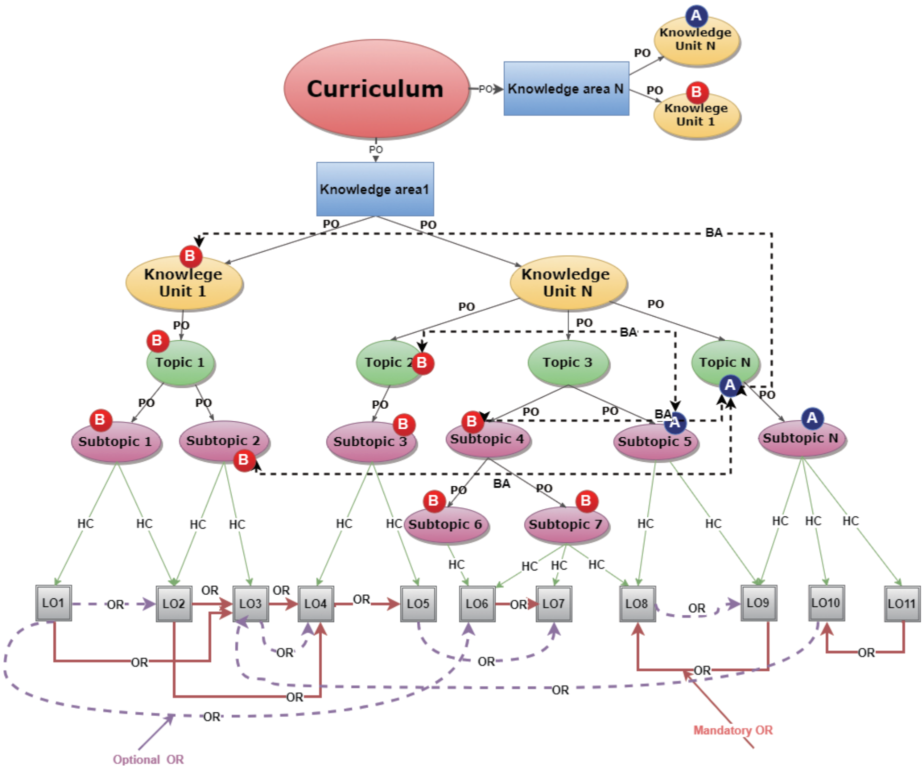

Figure 1. The conceptual model of ontology

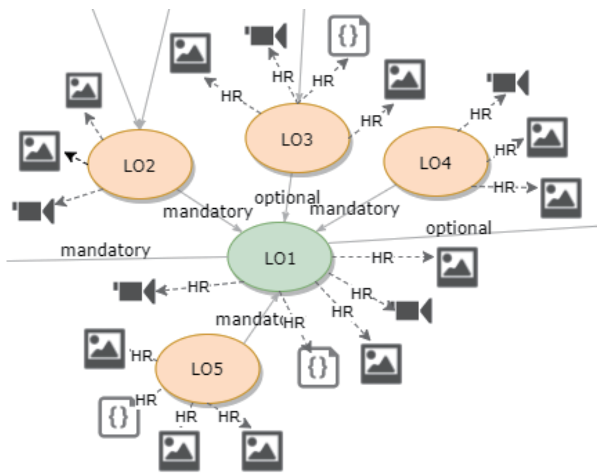

Figure 2. HR relation between LOs and their resources

3 Visualization of the Ontology Model using MCM

3.1 Principles of Visual Grouping

Topics-subtopics-LOs parent/child relationship in MCM is built in several dimensions:

(1) Higher-level topics are parents to their subtopics and are branching down vertically to LO. This child/parent relationship is realized through *PO* and *HC* relations.
(2) Horizontally, LOs are connected with *OR* relation.
(3) Third dimension provides flexibility to narrow down the number of LOs by grouping LOs with similar attributes such as defining topic difficulty level (basic and advanced). This is conducted through assigning attribute "knowledge level" to the concept, and relating them with *BA* relation.

MCM provides flexibility to define more different relations that will help in distinguishing new dimensions. Allowing to add multiple new dimensions allows for dividing concept maps further. New dimensions can also be introduced by defining the new attributes to the concepts and introducing new relations to these attributes.

Once the ontology is defined, the concept map can be generated. Only parts of the concept map are visible to the learner. What part of the concept map is delivered to the learner depends on learners actions and learning pace.

Principles of visual grouping of related concepts developed for the purpose of this work are:

- For the top-level concept, for parent node, only their child nodes are shown, showing only the next level concepts. For example, if the knowledge area is the top-level concept, their child nodes are knowledge units.
- Once the concept on the next level is chosen, its entire subtree is shown. Topics that have *Basic/Advanced* relations indicate that advanced topics exist and that can be navigated to.
- For the topics at the lowest level, its LOs are shown with their mandatory LOs, with an indicator that optional LO exists and that can be navigated to.
- By selecting a LO its content is displayed.

3.2 Creation of Personalized Learning Space using LO ontology and MCM

For the purpose of this work OBSLO software tool was developed to support dynamic creation of learning space while automatically adapting learning content to the knowledge levels of learners. Having software, such as OBSLO, provides several advantages:

- Students can personalize their concept maps in real time,
- Students can learn at their own pace,
- Students can easily see related topics and their organization,
- Students can view learning material in LO structure through smaller chunks.

For the needs of this work the ontology for the Database course, based on the IEEE Computer Society's Information Technology 2008 Curriculum Guidelines for Undergraduate Degree Programs and the knowledge area *Information Management (IM)* was used and implemented in OBSLO. This section demonstrates proposed LO ontology models and MCMs of *IM* knowledge domain used in the Database course. Knowledge units of *IM* are shown in Figure 3.

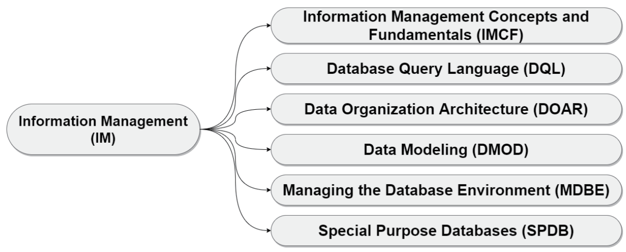

Figure 3. Key concepts for the *Information Management* knowledge area

Figure 4 demonstrates how attributes of "knowledge level" can be used to create different dimensions, later to be used by MCM. The knowledge unit *Database Query Language* (*DQL)* is divided into *basic* and *advanced* concepts, between which *basic/advanced* relation is created. This ontological model allows the learner to either start from fundamental concepts, or to have an easier overview of the advanced topics. For example, the learner who acquired basic knowledge about using of the *WHERE clause* in the *SELECT statement* has the possibility to learn how conditions specified by *WHERE* clause can be expressed in *Query by example language*.

Using the ontology model presented in Figure 4 and by using defined three dimensions, OBSLO can automatically generate MCMs. Figure 5 represents an ontology model corresponding to the *DQL* knowledge unit given in Figure 4. Concepts with similar knowledge levels are grouped together. All concepts in Figure 5 shown within the red line constitute *basic* knowledge level, while concepts within blue line constitute *advanced* knowledge levels (Figure 6). Concepts that contain both basic and advanced parts are presented in both knowledge level subtrees. Both Figure 5 and Figure 6 demonstrate how students in the Database course are presented with MCM in their learning environment through OBSLO.

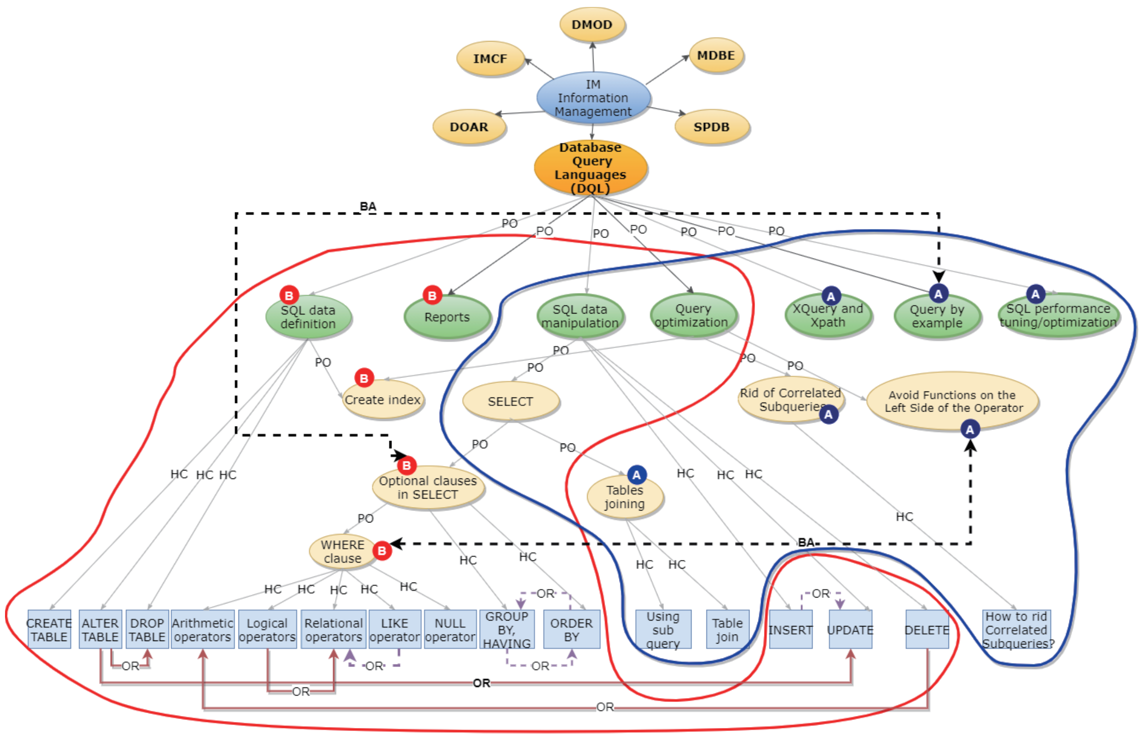

Figure 4. Ontology model for *DQL* knowledge unit

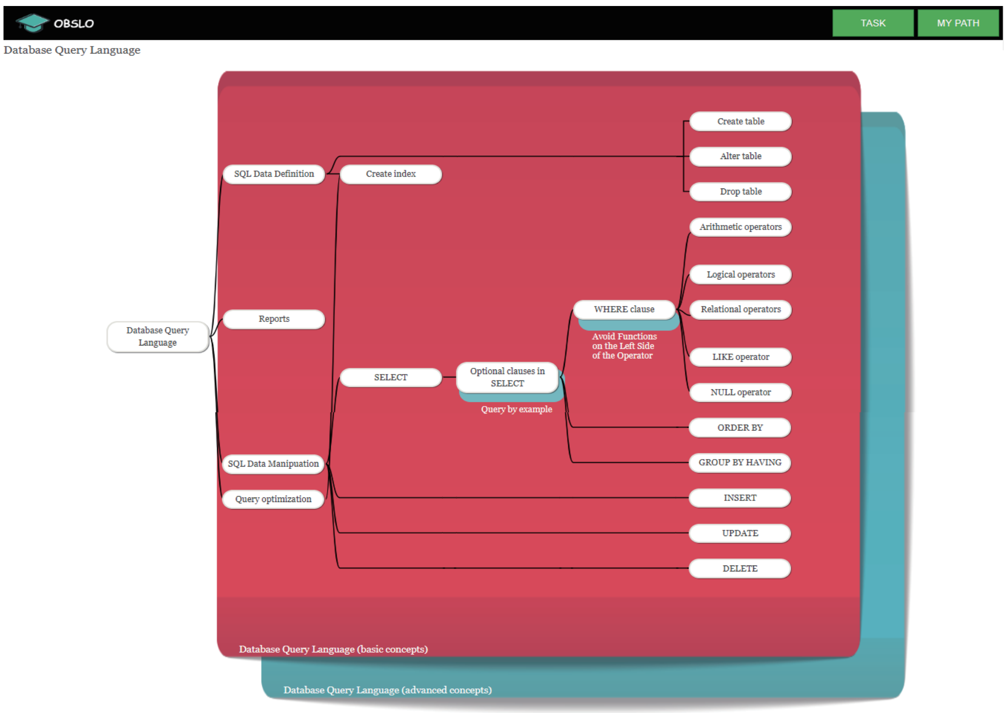

Figure 5. OBSLO visualization of basic knowledge level

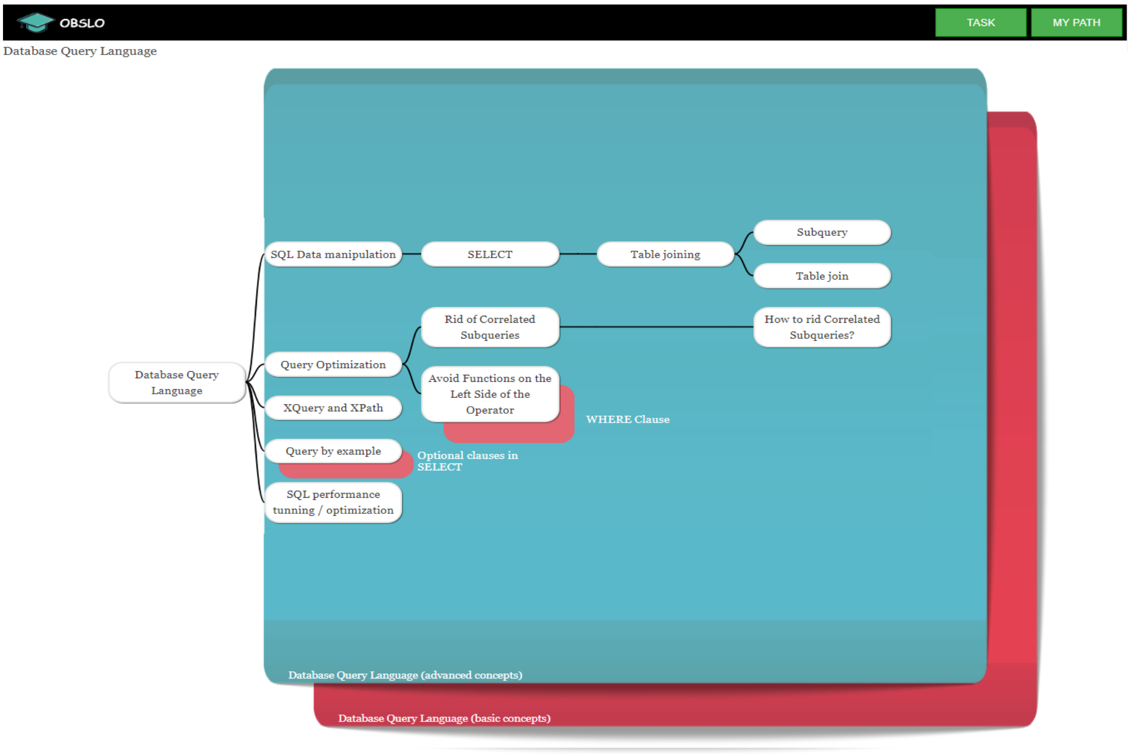

Figure 6. OBSLO visualization of advanced knowledge level

4 OBSLO's Software Architecture

4.1 OBSLO

Previously defined LO ontology model and MCM were integrated and implemented through a newly developed software tool named Ontology-based system for learning objects retrieval (OBSLO). The OBSLO's software architecture consists of four different subsystems (Figure 7):

(1) Ontology authoring tool (OAT)
(2) MCM learning environment creator (MCMLEC)
(3) Assessment reports (AR)
(4) Relational database management system (RDBMS).

OBSLO's component OAT enables an intuitive graphical environment for: (i) ontology creation/hierarchy definition, and (ii) establishing relations between concepts and LOs [26]. Ontology elements are stored in RDBMS.

OBSLO's MCMLEC component enables dynamic MCMs visualization, while delivering learning content and learning assignments. OBSLO allows for ontology structure to be built and automatically generates MCM as an output. Within MCMLEC students navigate through content and assignments, and their navigation creates personalized learning content. All of the student activities, their answers on assignments and information about successfully solved problems are stored in RDBMS for later analysis by AR component.

AR component generates different reports and analyzes students' paths and success during the student activities by using MCMLEC.

4.2 OBSLO's Integration with Other Systems

OBSLO enables easy integration of the Institutional Learning System (ILS) with a heterogeneous set of tools and external tools, such as auto grader of student assignments. The integration of these components is based on service-oriented architecture (SOA) where each individual software component is integrated with other components by its set of RESTFul web services (WSs) or mediator elements. WSs in SOA provide an easy and fast method of integration that allows smooth and seamless communication between the systems and enables data exchange, providing at the same time interoperability, usability and reusability of each individual component [27].

As such, OBSLO implementation can be reused with other systems with similar capabilities. OBSLO is not meant to replace the e-learning system, but to be used for enhancement and extension of existing systems. By using SOA the integration of OBSLO with other components in the architecture does not require any modification of pre-existing components but only uses their embedded WSs.

In our proof of concept (Figure 7), OBSLO is integrated with the following external systems:

(1) Institutional Learning System - consists of two independent systems Learning Activity Management System (LAMS v3.0) and DITA Authoring tool (mDITA)
(2) CodeBox – assignment autograder.
(3) LAMS represents a functional open source e-learning system that supports storage and presentation of: (i) learning content in the form of the series of LOs, and (ii) interactive learning activities. The mDITA Authoring tool allows creation, structuring and improvement of LOs with a set of metadata. LOs repository (LOR), part of LAMS, provides storage for LOs and it communicates with mDITA through "LAMS-mDITA Authoring tool proxy component".

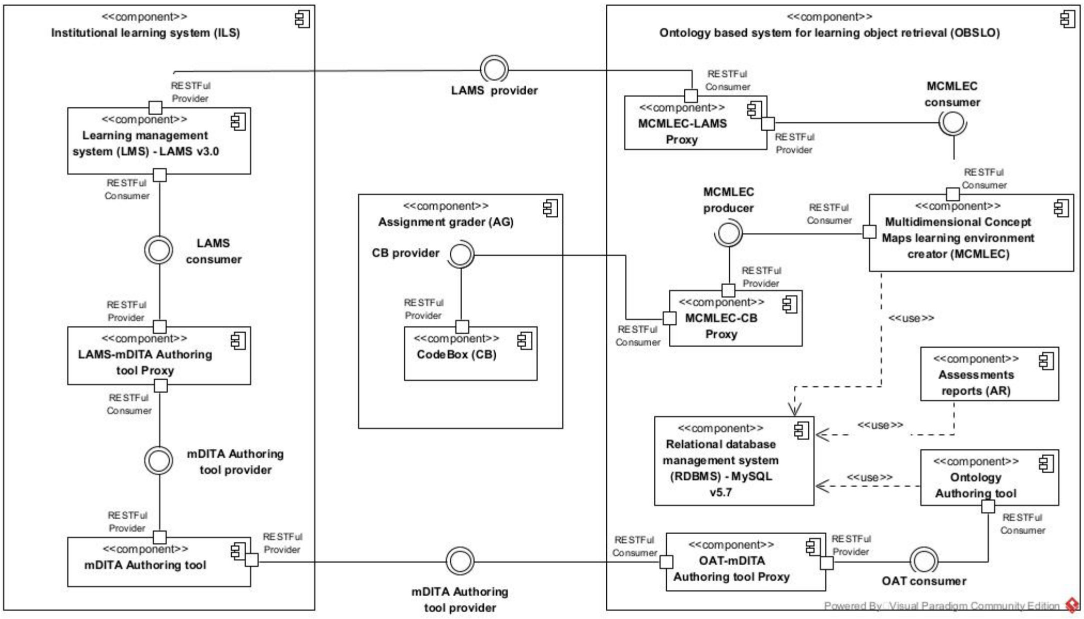

Figure 7. Platform architecture of the integrated systems

OAT is integrated with mDITA by using proxy "OAT-mDITA Authoring tool" which enables LOs to be enriched with the representation of complementary knowledge from ontology.

MCMLEC is integrated with LAMS by using proxy "MCMLEC-LAMS" in order retrieve LOs content and present it in MCMLEC.

OBSLO's capability of integration with external systems is demonstrated through integration with *CodeBox*, the external auto grader for verification of SQL statements. This integration is enabled by using "MCMLEC-CB Proxy". *CodeBox* offers a RESTFul public interface which is used by MCMLEC for checking the accuracy of student solutions. SQL statements are executed in *CodeBox* and results are returned back into MCMLEC.

5 Results and Discussion

5.1 Methodology

In order to evaluate the developed system and implemented ontology model presented through MCMs, OBSLO was evaluated by teachers and students. The teachers' main role was to develop the course ontology by using OAT. Students' role was to access posted assignments and learning materials through MCMLEC using MCMs.

Results of OBSLO evaluation were compared to student experience from the same Database course taken by the students who in the previous school year were using only the LAMS system. The learning content, learning objects for both groups was the same. but their retrieval and visualizations were different. It is important to note that both classes used the same teaching content (instructional text, videos, examples), while students who worked in OBSLO were presented LOs using MCMs of knowledge domain with its own set of assigned assignments and automatic grader, where LAMS presented LOs only in sequential linear order without automatic grader. Assignments from the previous year were slightly adapted, but focused on the same SQL clauses. Student assignments were designed to gradually introduce students from basic level problems to more advanced problems, in order to stimulate them to go through the learning content. On the other hand, LAMS assignments were presented to students at the end of the lesson. However, considering that the used learning content is the same, and that assignments were addressing the same learning outcome of the lesson, it was possible to compare student performance on the similar type assignments with the same difficulty level. Sample content of assignments given to LAMS and OBSLO students are shown in Table 1, and it demonstrates the slight difference in adapted content of assignment questions. Even though this is a limitation of this study as two groups of students did not have exactly the same assignments, given the same learning content and the learning outcomes of the lesson the following was the goal of this analysis:

- Identify how successful were the students in navigating through learning materials using ontology and MCMs approach in OBSLO,
- Evaluate how much OBSLO and its content helped students in mastering the learning content,
- Conduct satisfaction analysis of students using OBSLO for learning.

The OBSLO evaluation included 50 students, while the LAMS evaluation group included 63 students. The OBSLO group completed a survey at the end of the evaluation.

5.2 Comparison Analysis between OBSLO and LAMS Usage

In this section, success rates in completing assigned assignments are compared for both LAMS and OBSLO systems. As these results were collected in two different classrooms and instructors, for the purpose of this analysis, similar assignments and difficulty levels were chosen.

The student assignments were assigned in increasing order of difficulty. Table 2 shows the number of students who completed student assignments (SAs) and the number of students who solved the assignments correctly in OBSLO. It is evident that the percentage of students who have successfully completed assignments using OBSLO is more than 75%. Also, it can be noted that with each additional question the number of students who completed assignments decreased.

Results shown in Table 3 indicate that the percentage of students who solved LAMS homework (HQ) correctly varies from 26.67% to 68.29%, and that unlike OBSLO where the percentage of students who have successfully completed assignments is more than 64% for all assigned assignments, HQ1 and HQ2 are below 30%. It can also be noted that the overall percentage of successful homework assignments solved in LAMS was 38.93%, which is much less than the overall percentage achieved by OBSLO of 75.20%.

Table 1. Example of assignments given to OBSLO (SA1 – SA3) and LAMS (HQ1 – HQ3) groups of students

Questions
HQ1: a) Create tables DOCTOR, PATIENT, DISEASE and DIAGNOSIS that correspond to following relations: DOCTOR (#DoctorID, FirstName, LastName, Specialization) PATIENT (#PatientID, FirstName, LastName, Address, Phone, Age, DoctorID) DISEASE (#DiseaseID, Name, Description) DIAGNOSIS (DiagnosisID, PatientID, DiseaseID, DiagnosisDate) b) Insert at least one row into each table **HQ2:** List all patients with doctor firstname and lastname which age is greater than 25. **HQ3:** List patients without diagnosis. The list should be sorted in ascending order using value of patient firstname (from Z to A)
SA1: a) Create tables *CUSTOMER, ORDERS, ORDER_ITEMS* and *PRODUCTS* that correspond to following relations: CUSTOMERS (#CustomerID, FirstName, LastName, City, Country, Phone) ORDERS (#OrderID, OrderDate, OrderNumber, CustomerID, TotalAmount) PRODUCTS (#ProductID, ProducName, UnitPrice, IsDiscontinued) ORDER_ITEMS (OrderItemsID, OrderID, ProductID, Quantity, TotalAmountPerItem) b) Insert at least one row into each table. **SA2:** List all orders with customer firstname and lastname which total amount is greater than 5000. **SA3:** List customers that have not placed orders (*TotalAmount* is zero). The list should be sorted in ascending order using value of customer name (from A to Z)

Table 2. Number of students using OBSLO who completed assignments and who solved assignments correctly

Questions	SA1	SA2	SA3	Overall
Number of students who completed assigned assignments	37	29	25	
Number of students who solved assignments correctly	33	21	16	
Percentage of students who solved assignment correctly	89.19%	72.41%	64%	75.20%

Table 3. Number of students using LAMS who completed assignments and who solved assignments correctly

Homework	HQ1	HQ2	HQ3	Overall
Number of students who completed their homework	60	55	41	
Number of students who got correct homework	16	12	28	
Percentage of students who solved homework correctly	26.67%	21.82%	68.29%	38.93%

In order to analyze the level of OBSLO usage in relation to LAMS, the time spent on each relevant LO was analyzed (Table 4). It is obvious that students spent more time on LO content learning by using OBSLO than LAMS. The reason is that OBSLO provides more flexibility in accessing concepts that are necessary to solve a specific assignment as MCM enables students to easily navigate to the specific learning content. With easier access to needed content students are more likely to spend more time on it and possibly revisit the content again. On the other hand, in LAMS students need to click through each learning object in the linear sequence. MCM encourages learners to focus on the concepts that can help them in learning by allowing them to choose their learning paths.

It should be noted that total time students spent on learning content for both systems is only given for the web-based version of the lessons where students can click through the learning content either through MCM in OBSLO, or sequential order in LAMS. In both instances, students were given an option to download the lesson in PDF format, however, data shown in Table 4 does not provide information on how much time students spent on downloaded PDF lessons. Shown results in Table 4 only pertain to the time spent on LO content in an interactive part of the lesson.

Given this consideration, it is most likely that students are spending more time on the learning content while using MCMs, and searching for the answers they need in learning content presented in OBSLO, while the students using LAMS most likely used PDF lesson format for learning or searched for answers in other resources. One of the reasons behind this could be the fact that going through the linear sequence of learning materials in LAMS is less convenient for students, and is probably the reason why they choose downloading the lesson in PDF format.

Table 4. Time spent on LO content (in seconds per student)

LO related to assignment	LAMS	OBSLO
Create table	42	226
Alter table	14	6
Arithmetic operators	9	14
Logical operators	7	18
Relational operators	13	64
LIKE operator	11	54
ORDER BY	15	192
GROUP BY HAVING	15	29
INSERT	10	148
Table join	59	61

5.3 Analysis of Student Satisfaction using OBSLO

The questionnaire, for students using OBSLO for learning, was designed with the focus on identifying positive and negative aspects that lead students to learn by using interactive teaching material and learning through problem solving. The analysis of the student questionnaire was mainly focused on whether the students were satisfied in using OBSLO.

OBSLO questionnaire results show the following (Table 5). Students were positive on how much preseneted material through OBSLO helped them in solving their assignments (3.38 ± 1.27), as well as the positive outlook on how much working in OBSLO helped them in achieving the learning outcomes (3.38 ± 0.95). However, it should be noted that students did use additional learning material from the Internet, not provided within the OBSLO (3.41 ± 1.53) or LAMS (3.35 ± 1.51). Indirectly, this does not have to do with the effectiveness of either of the systems, but it could mean that learning material needs to be improved, or that students' learning style incorporates searching for additional learning material on the Web in general.

Students stated that they would like to use OBSLO in other courses as well (3.00 ± 1.28), and also showed great autonomy in working on assignments (3.74 ± 1.1) stating that they succeeded in identifying the LOs they needed (3.44 ± 1.08).

Even though students had a positive level of satisfaction to using OBSLO, the questionnaire results point towards the room of improvement of both OBSLO system, and therefore, the satisfaction of students' satisfaction and learning efficacy. This evaluation analysis addresses students comments, and point to future work and research.

Table 5. Results from the student OBSLO questionnaire

Questions	X ± SD	Median
Q1. How much did the contents of the teaching materials shown through the OBSLO system help in solving the assignments? (helped = 5, did not help = 1)	3.38 ± 1.27	3
Q2. How much has working in OBSLO helped you in completing your assignments successfully? (helped = 5, did not help = 1)	3.38 ± 0.95	3
Q3. To what extent did you use the Internet more than learning materials from the OBSLO system while solving the set assignments? (used = 5, not = 1)	3.41 ± 1.53	4
Q4. To what extent did you use the Internet more than learning materials from the LAMS system while solving the set assignments? (used = 5, not = 1)	3.35 ± 1.51	4
Q5. To what extent have you found the materials that were necessary to solve the assignments in the OBSLO system? (I did not find out what was really bad = 1, I found everything I needed = 5)	3.46 ± 1.1	3
Q6. To what extent have you managed to extract for each assignment learning objects that were better than what you received at the beginning as recommended work objects? (I did not succeed = 1, I succeeded = 5)	3.44 ± 1.08	3
Q7. To what extent were you able to find the content from the previous lessons that you needed to solve the OBSLO system assignments? (I did not succeed = 1, completely = 5)	3.46 ± 1.1	3
Q8.To what extent would you like to use this style of learning in other subjects? (not at one = 1, at all = 5)	3.00 ± 1.28	3
Q9. To what extent did you work with colleagues while solving your assigned assignments (I worked entirely with colleagues 1, I worked completely independently 5)	3.74 ± 1.1	4

Students also added their comments about their OBSLO experience:

"System is good",

"It is a good idea and interesting for problem-based learning",

"I like the system and the most important is that the learning materials are always available during the assignments."

On the other hand, comments also suggested that some improvements of the functionalities and user interface are needed, but also suggested the need for external resources:

"Everything is good, but the first graph is a little confusing",

"I do not see the purpose of the learning object isolated on the working page",

"Links to online resources would be helpful."

The evaluation identified improvements that should be made and further research conducted. Certain interface functionalities can be improved:

(i) Considering that some students found MCM graph a bit confusing, it is necessary to explore more intuitive MCM visual representation, and

(ii) Giving students complete autonomy to search for learning content needed to solve assigned problems showed that students could not always identify necessary concepts and that improvement could be made by highlighting recommended material for students and providing guidance through the material.

During the testing of OBSLO, it was noted that the creation of LO ontology is not only time-consuming, but also prone to some errors. For instance, students were identifying relations between LOs that were not defined by the instructor. Students actually identified alternative ways in which certain assignments can be solved. This is why ontology creation and modification can be improved by developing new models based on the system usage:

(i) Provide automatic suggestions for LO ontology, which can be drawn from the usage of certain learning content by students,

(ii) Provide a model for collaborative creation of domain ontology, including collaboration both between the students and the instructors.

6 Conclusion

This paper addressed the usage of ontology in an online course based on LOs and MCMs for the purpose of enhancing personalization in learning. Defining ontology for the knowledge domain and relations between LOs allowed for easier navigation through the learning content, while allowing learners with different backgrounds to learn at their own pace. Key issues that were addressed were: (i) the usage of MCM approach for scaling the visualization of knowledge domain ontology, and (ii) automatic creation of MCM from the defined ontology for concepts and its LOs. Since a learner can often be overloaded with the amount of material in the learning path, a new tool named OBSLO was created to integrate ontology with MCM to reduce learner information overload and provide efficient learning space. OBSLO provides the flexibility to define and visualize multiple dimensions of MCM, by allowing definition of different attributes as relations between topics, subtopics and LOs within concepts. These relations allow for concept subtrees to be easily identified for each learner. Using multiple dimensions allows for the presentation of the learning content to be simplified. In this work we have presented a model with three dimensions with concepts being organized in a hierarchical fashion, while the additional attributes were used to define the third dimension. This work examined how the attribute "knowledge level" can be used as a third dimension, with the goal to improve visualization of defined ontology and its MCM. The OBSLO system was demonstrated on the knowledge domain *Information management* used for a Database course. Based on the results following improvements are identified. The student usage of the system should be further analyzed in order to use it for collaborative ontology creation and for future improvements of both user interfaces as well as the integration of the needed Internet resources.

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