Ontology Based Adaptive, Semantic E-Learning Framework (OASEF)

Sohail Sarwar, Zia Ul Qayyum, Muhammad Safyan and Rana Faisal Munir

Abstract E-Learning, having a pivotal role in educating diverse communities of knowledge has not prevailed much in addressing individualized needs (i.e. Personalization) of learner while designing didactic contents, and their respective deliverance to the learners in adaptive manner. Moreover, there is sheer need of porting current e-learning systems to ontology backed web3.0 for incorporating context aware provision of learning material with a goal to improve learner's performance. We have developed an adaptive e-learning framework, named OASEF, comprising of backbone ontologies such as domain ontology, learner ontology, content ontology and assessment ontology (to model exercises, quizzes and exams).Concepts of learner ontology are exploited as guideline to offer semantic contents to certain category of learner from content ontology keeping in view his ability, knowledge, prior performance and results in current assessments. Effectiveness of ontological model is evaluated through metrics of correctness, consistency and completeness. Initial experiential evaluation of proposed framework has shown a remarkable improvement in learner's performance due to its adaptive and dynamic nature. Moreover, comparative analysis of our framework with prevalent systems especially [9] stipulates our system as more comprehensive, diverse and versatile.

Keywords Ontology · Learner's profile · Adaptive system · Domain ontology · Learner ontology · E-learning

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K.J. Kim and N. Joukov (eds.), *Information Science and Applications (ICISA) 2016*,
Lecture Notes in Electrical Engineering 376,
DOI: 10.1007/978-981-10-0557-2_114

1 Introduction

Internet has complemented the concept of virtualization that has perceptible dominance in every aspect of human life, specifically education and more specifically "Distance Learning".

"Distance learning" based on concept of "global dissemination of knowledge" is making a great contribution in educating learners around the world by eliminating costs of travelling, infrastructure, human resources etc. Distance learning itself is complemented by E-Learning (or Electronic Learning) which involves online provision of learning contents for the learners (Students) by the learners (Instructors).

E-Learning is formally defined by Drucker as "just-in-time education integrated with high velocity value chains. It is the delivery of individualized, comprehensive, dynamic learning contents in real time, aiding the development of communities of knowledge linking learners and practitioners with experts" [1].

From given definition of e-Learning, it may be derived that soul of e-Learning is not merely confined to prompt deliverance of educational contents, rather it's a line of package ranging from content development to maintaining profile of learners, aligning contents to respective learners as per their ability, from maintaining practice exercises to managing grading, adaptivity of learning material, searching from relevant educational repositories, course administration and its personalization. The multifaceted and ubiquitous view of an e-learning system is illustrated in Figure 1, aiming to improvise the role of e-Learning from information transmission to knowledge-construction [2].

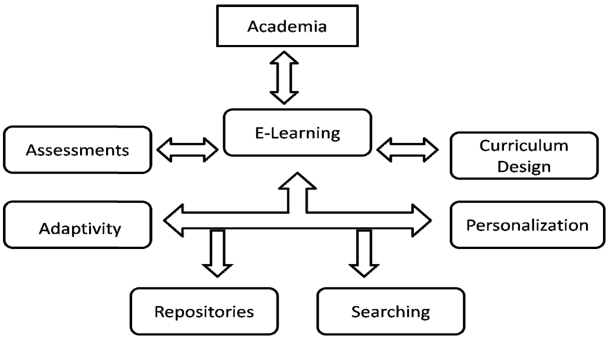

Fig. 1 Dimensions of E-Learning System

Web technologies have a paramount role in ongoing success of e-Learning applications for incorporating usability of learning contents, design of learning components and availability of digital repositories [3]. However, everything on current version of web is syntactical, machine-readable and not machine-understandable [4] making e-Learning solutions less flexible and less interoperable. Furthermore, context-aware alignment of contents to learners initially and after assessment is also a research issue. It is referred to as

"Adaptation" of contents. These problems suggest porting of things to context aware Semantic web (or Web 3.0) based on ontologies.

Keeping above in view, we present an "end to end" ontology based e-learning framework named OASEF (Ontology based Adaptive, Semantic E-Learning Framework). OASEF exploit all the benefits associated with Web 3.0 through different ontologies i.e. domain ontology to present the overall operational concepts of our framework, profile of learner is modelled using learner ontology to capture traits of learner handy in deciding upon his level of abilities and aptitude while offering course contents, course ontology models course of "Object Oriented Programming" and assessment ontology to model quizzes, exercises and exams. A simple but effective way for adaptation of contents is presented for learner's performance improvement, the primary focus of this paper.

The paper is structured as follows: Section 2 provides the review of efforts made for improving e-learning systems. Section 3 describes the proposed architecture followed by implementation detail in section 4. Section 5 concludes the paper and gives future direction of work.

2 Literature Survey

An informative survey report is presented in [7], which highlights the need and importance of an distance learning/e-learning system proportional to technological advancements. Technologies with 3-facets are stated as: 1. Mobile phones 2. Internet and open source apps 3. Virtual Learning Environments (VLEs) and Learning Analytics. Massive Open Online Courses (MOOCs) are another source to benefit excellence of best teaching professionals in the form of courseera.org, futurelearn.org, openuped.org etc. Students can monitor their learning performance through Learning Analytics (LA) in comparison to other students. Moreover, LA can recommend when students need to put in more time and attention to cope up the deficiencies.

In [8], aim is to optimize the learning search at offline ontologies knowledgebase with no reasoning mechanism. Online ontology editing and visualization extract knowledge from ontology; builds course concept maps and reasoning rules for students of grade 7th of junior high school with total of 95 students. Ontology is used as structured representation of concepts/concept maps and relationships among them. Ontology based learning shares common understanding of a structure reuses the domain knowledge and separates the domain knowledge from operational knowledge. It is used to drive additional rules pertinent to concept maps. RacerPro, JESS (Java Expert Shell), Apache JENA may be used for reasoning purpose. JENA is a feature that creates new RDF model containing triples derived as well as asserted in "Base Model" with forward, backward and hybrid reasoning.

Philosophy that learner's style should not be focused than learner's ability for personalization is addresses in [9]. Tests are used to estimate learner's ability dynamically. Different models such as domain model (classes/properties describing topics of domain and pedagogical relations), learner model (for learner's profile, preference and identification) and content models have been developed for building respective ontologies.

In [10], a framework for personalized eLearning system is presented that shows usage of semantic web's "Resource Description Format" for automatic generation of "Hypertext Structure" from distributed metadata (with goal to develop adaptive educational hypermedia systems). Meta data of users, domain and observation has been employed. There is a proposal for Personal learning services capable of interpreting "metadata-annotated" learning resources, capable of understanding annotations with respect to standard Ontologies (LOM, IMS etc) as well as domain Ontologies. Learner's profile is modeled through learner's interaction with system.

Reasoning, sharing and reusing in open world, like semantic web is still an open problem addressed in this paper. The communication between reasoning rules and open information environment takes place by exchanging RDF annotations; rules reason over distributed RDF annotations.

An implementation of e-learning system is presented in [11] that deals with appropriate personalization techniques (for smart curriculum sequencing, navigation guidance, intelligent problem generation and analysis of solutions, adaptive contents, etc.) where user preference and personality are most important factors. Focus of this paper is use of grid agent e-learning model (including registry, directory and discovery). Artificial Psychology (that imitates human psychology with computer to analysis the preference of user) is used for adaptation. Results from experiments show that learners perform better if they use proposed adaptive grid agent model. Three types of agents i.e. students agent, managers agent and teachers agent are used. Agent publishing and agent discovery services were used for ease in communication of agents.

A personalized e-learning system, based on the IEEE Learning Technology Systems Architecture (IEEE LTSA), is presented that automatically adapts to the interests and levels of learners [12]. Feedback extractor and user profilers combine multiple feedback measures (to infer user preferences) and de liver personalized information (via collaborative filtering algorithm) respectively.

Improving e-learning through mobiles is focuses in [13] while engaging students and teachers. Apart from the benefit of ubiquitous learning there is plenty of other advantages such as: Personalized Digital Content: that improvises the learning capability reference to degree of intellect. Good students do not have to wait for average students to catch them. Digital Assessment: it is easy to deploy pop-up quizzes that evaluate comprehension and assess the knowledge of students. Student and Teacher Engagement: Teachers and students report positive impact on learning from digital technologies. This form of e-learning offers an impactful fun by development of student as critical-thinker and collaborative learner to secure their place in the globally competitive economy.

In e-learning system [14], heterogeneity with respect to Background knowledge, age and motivation has impact on curriculum sequencing as in the field of intelligent tutoring system (ITS). This paper addresses generating an individualized course for students in minimal time that is handy in distance education. Genetic algorithm and case based reasoning are employed to construct a near-optimal learning path where initial data is collected using computerized adaptive testing (CAT). The system comprises of GA-based module and the CBR based module. A course on Java Programming was developed by Curriculum experts. 300 examinees who majored in JLP joined the Pre Test contained 18 Topics.

After comprehensive literature survey, we can definitely draw a conclusion that currently e-learning applications lack flexibility, are context- ignorant and need to have learner specific adaptation of contents. This gives rise to need of having a semantics enabled comprehensive e-learning architecture, as OASEF, for delivering learning contents that takes into account not only the pedagogical requirements but considers learning activities as well.

3 System Architecture

Proposed architecture of OASEF is presented in Fig 2, which incorporates numerous aspects that an adaptive e-Learning system must have. It starts with content development of certain "Course" which in our case is modeled in the form of "CourseOntology". Sequencing of this course requires skills of a domain expert initially.

This step is followed by learning activity, assessment and performance analysis of learner for adaptation of contents. Performance results are logged and semantic search is facilitated in given system. A module-wise break up of system is given in the following:

SCO Developer: comprises of functional units dealing with selection of certain course, identification of its topics and sub-topics, pre-requisite course and difficulty level of these topics and relationship among topics. These contents are modeled through "Domain Ontology" as shown in Figure 3.

SCO Sequencer: Adaptation refers to the need of sequencing/re- sequencing the contents of course initially and then based on performance of learner. It utilizes the profile of learner maintained in "LearnerOntology"for offering learning contents. The concepts used for building learner profile are shown in Figure 5.

This phase involves presentation of contents alteration in sequencing of instances of 'CourseOntology' subject to performance and overall results of learner (i.e. adaptation of contents). CourseOntology is presented in Figure 4 that refers to the concepts offered in the course each stamped with certain difficulty level. It aids in offering contents to a learner as per his skill level maintained in "LearnerOntology".

Learning Activity/ Assessment/Performance Analyzer: Initial sequencing of course content is followed by learning activity, assessment through quizzes, exercises and exams. This module deals with assessment of learner undergoing the learning process through quizzes, assignments and exams. exams/assessments are modelled in "AssessmentOntology" as shown in Figure 6.

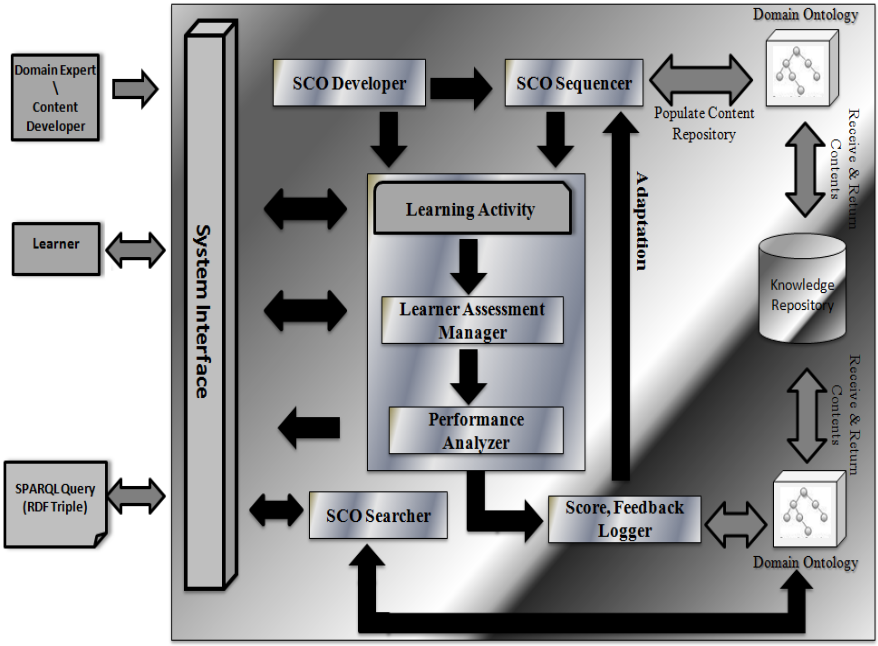

Fig. 2 Proposed Architecture: OASEF

SCO Searcher: this module provides the facility of context-aware searching to the learner. Initially search based on topics/ sub-topics is incorporated that will span to complex searches.

Score, Feedback Logger: This working unit manages the feedback mechanism based on score of learners and logs the grades/score for content sequencing. Logging of these aspects enables us to incorporate personalization for learner.

4 Implementation Strategy

In order to implement prototype application of proposed architecture, preliminary ontologies i.e. “domain ontology”, “CourseOntology”, “Learner Ontology” and “Assessment Ontology” have been developed. These ontologies incorporates concepts pertinent to domain, course, learner and assessment respectively. These ontologies are developed using Protégé 5.1.x, viewed using OntoGraf and are envisaged to evolve over time. A short description of concepts and their rationale is given in the following:

– “Course has Students” Every instance of “Course” is connected to every instance of “Students” through hasStudents property inverse of which is isStudentOf property.

$$\forall(\text{Course})\leftrightarrow(\exists(\text{Student}) \cap (\forall\text{Student})\in(\text{ComputerScience}))$$

– “Course has Lectures” Every course has number of lectures in certain semester. So every instance of “Course” is attached with instance of “Lecture” through property of hasLectures with inverse isLectureOf property.

- "Lecture has Topics" Every lecture has number of topics (topic is generalization of lectures). So every instance of "Lecture" is connected to instance of "Topic" through hasTopic property with inverse isTopicOf property. Similarly every "Topic" has "Subtopic" connected through hasSubTopic property.

$$\forall(\text{Course})\leftrightarrow(\exists(\text{Lectures}) \longrightarrow (\text{Topics}) \cap (\text{SubTopics}))$$

Pseudo-code for offering the contents to learner and adapting after evaluation is given in the following:

<u>ShowLearnerContents</u>
Learner logs-on to the system; given userName && userPassword
Load learnerProfile: learnerClass, learnerCourses, learnerTasks;

```
If(termWeek = =1 && coursePreReq = ='false')
            loadContestsforNoviceLearner(learnerId,courseId)
elseIf(termWeek = =1 && coursePreReq = ='True' && preReqResultPerc   < 40)
            loadContestsforEasyLearner(learnerId,courseId);
elseIf(termWeek = =1 && coursePreReq = ='True' && preReqResultPerc   >  40 &&
preReqResultPerc  < 70)
            loadContestsforLearnedLearner(learnerId,courseId);
elseif(termWeek = =1 && coursePreReq = ='True' && preReqResultPerc > 70)
         loadContestsforProficiantLearner(learnerId,courseId);
```

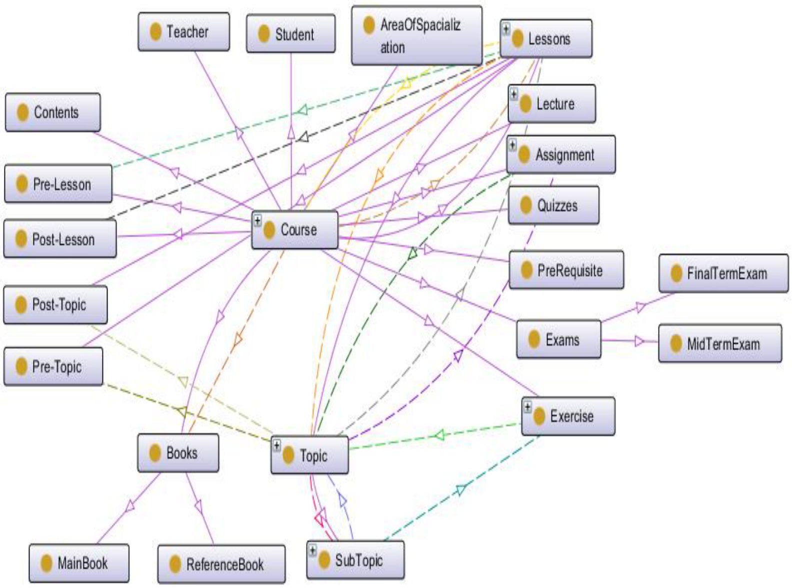

Fig. 3 System Ontology: DomainOntology

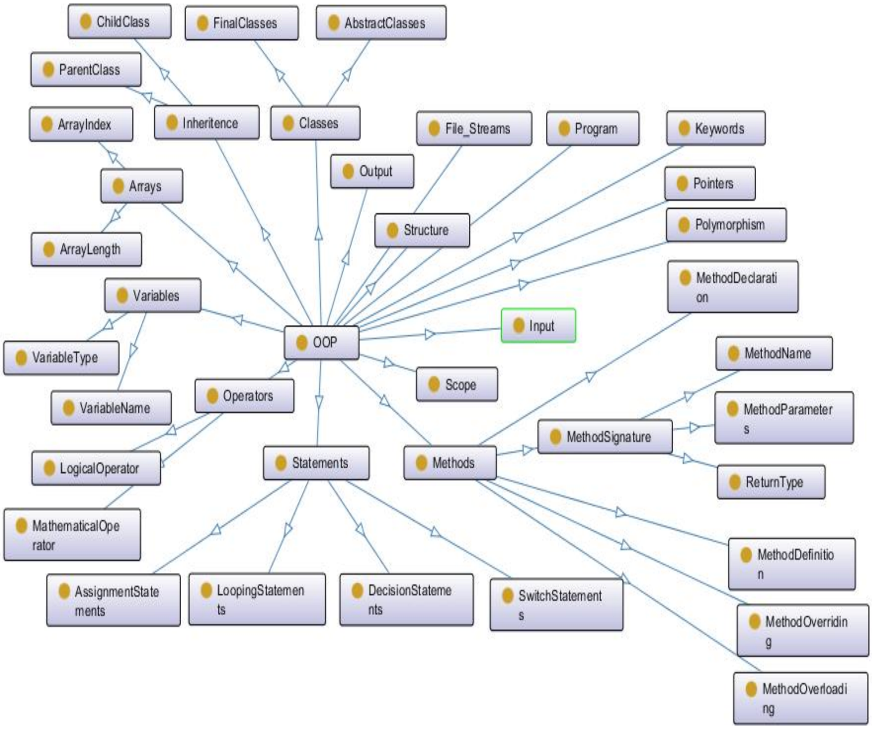

Fig. 4 System Ontology: CourseOntology

<u>*AdaptContents*</u>

If(task = =taskId && termWeek = =week && score<40)
loadContestsforNoviceLearner(learnerId,coursed, tasked,);
elseIf(task = =taskId && termWeek = =week && score>40 && score< 70)
loadContestsforLearnedLearner(learnerId,courseId);
else(task = =taskId && termWeek = =week && score> 70)
loadContestsforProficiantLearner(learnerId,courseId)
elseIf(task = =taskId && termWeek = =week && score>40 && score< 70)
loadContestsforLearnedLearner(learnerId,courseId);
else(task = =taskId && termWeek = =week && score> 70)
loadContestsforProficiantLearner(learnerId,courseId);

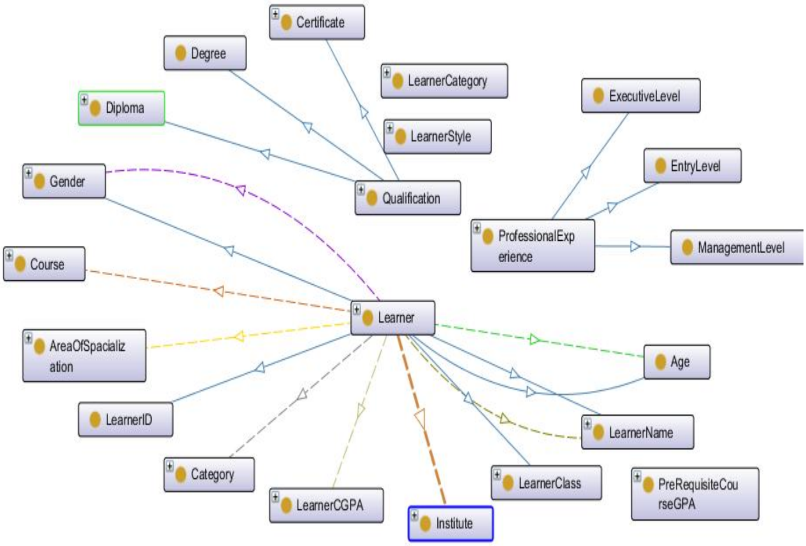

Fig. 5 System Ontology: Learner Ontology

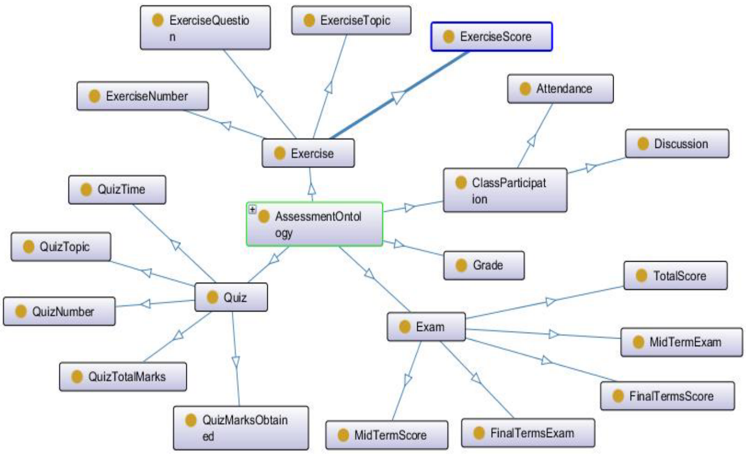

Fig. 6 System Ontology: Assessment Ontology

5 Results and Evaluations

We have taken two aspects into consideration while evaluating the prototype of proposed system i.e. evaluation of ontological model and experiential evaluation of proposed system in terms of learner's performance improvement.

5.1 Evaluation of Ontological Model

We follow three criteria during ontology evaluation. These evaluation criteria are very useful to prove the effectiveness and usefulness of the ontology.

5.1.1 Formal Correctness

Formal correctness of e-learning ontological model is ensured by using the OntoClean methodology [15] as depicted in Fig 3. We applied Ontoclean rules on all our classes, properties, individuals and axioms to ensure their correctness and validity in accordance to stable standard in subject domain (e-learning system in our case). Correctness of our ontology is ensured based on following two factors mainly:

- the logic based argument for cleaning
- validate the ontological taxonomy relationships

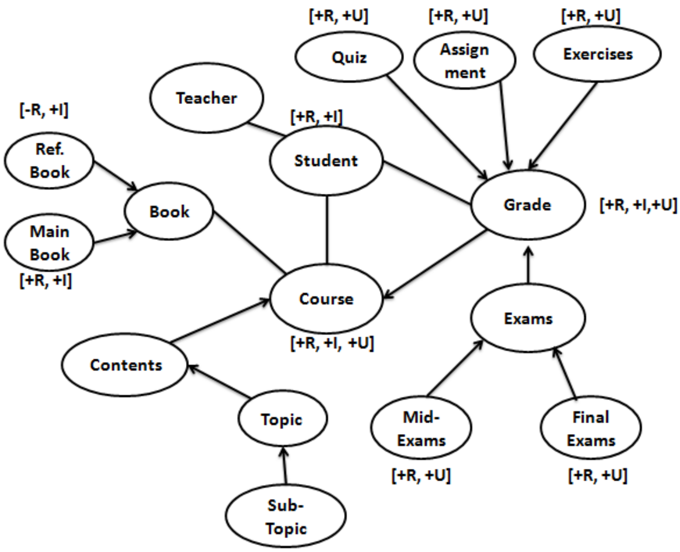

Fig. 7 Core concepts of ontology DomainOntology validated through OntoClean.

5.1.2 Consistency

Ontology consistency is evaluated using Pellet [16] reasoner. This reasoner ensured that ontology is consistent and can be utilized for semantic e-learning operations without creating any inconsistency among concepts/classes and their hierarchical relations.

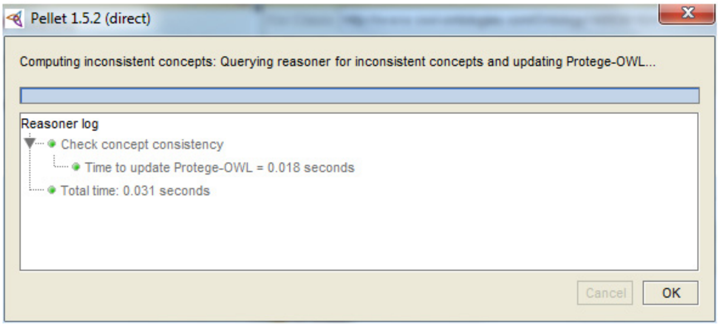

Fig. 8 Consistency Check of Ontology Model

Fig 7 highlights the facts of OntoClean in the light of above two factors using the meta-properties of Rigid, Identity and Unity. Course, Learner, Topic, Lecture etc., are Rigid, Identity and Unity type Meta properties. Rigid property, denoted by +R, is essential for all instances of a class. This can be exemplified with real world analogy of "Having a brain is essential for all human beings".

Identity criterion, represented with +I, works on the basis of recognition of entities to be same or different in the domain e.g. different identifiers of a learner or teacher. Unity criteria, represented with +U or –U, is defined on the basis on which we recognize all parts/property that belong to an entity and form an individual.

5.1.3 Completeness (Domain Coverage)

In order to verify the ontology coverage for fully modeling the domain of e-learning, SCORM [14] was used as a point of reference besides the competence of domain expert. SCORM enlists all aspects i.e. course content development, exams (assessment), quizzes, exercises, exams etc.

5.1.4 Comparative Analysis

Comparative analysis of proposed framework with prevalent techniques especially [9] stipulates OASEF mile ahead in terms of coverage of e-learning aspects, number of concepts and depth of details which have been addressed. In [9], contrary to OASEF, very trivial/vague details pertinent to learner's profile and learning content are described. Moreover, details of ontological model in [9] are not expressive for thorough analysis of effectiveness in terms of adaptation and learner's performance improvement.

5.2 Experiential Evaluation of System

30 university level students, at distant locations, were offered the course of "Fundamentals of Programming". This course is offered in summer semester of two

months with pre-requisite of "Basics of Algorithms". Weekly, it comprised of two Lectures and one Lab exercise of 1.5 hours and 1 hour respectively. Students were assessed at the end of second lectures in every week in addition to lab exercises (followed by remedial exercises and re-assessment when required). Services of 8 academicians were requested for design of topics and subtopics along with respective examples, quizzes, exercises and assignments.

The course, as stipulated by ontology, comprises of topics, sub-topics, quizzes, assignments, lab exercises and exams. We have assigned four difficulty levels [17] to each of the sub-topic examples, quizzes, assignments and lab exercises that can be offered to student's reference to their skill, competence and performance. These levels are novice, easy, learned and proficient entailing in four versions of every sub-topic example, quiz, assignment and lab exercise as given below:

For every topic T:

$$T = 4 \times \{s, e, q, a, l\}$$

where

s= sub-topic, e=example exercise, q=quizzes, a=assignment, l=lab-exercises

Every student is considered to be at learned level at the beginning of course after he has cleared the prerequisite course.

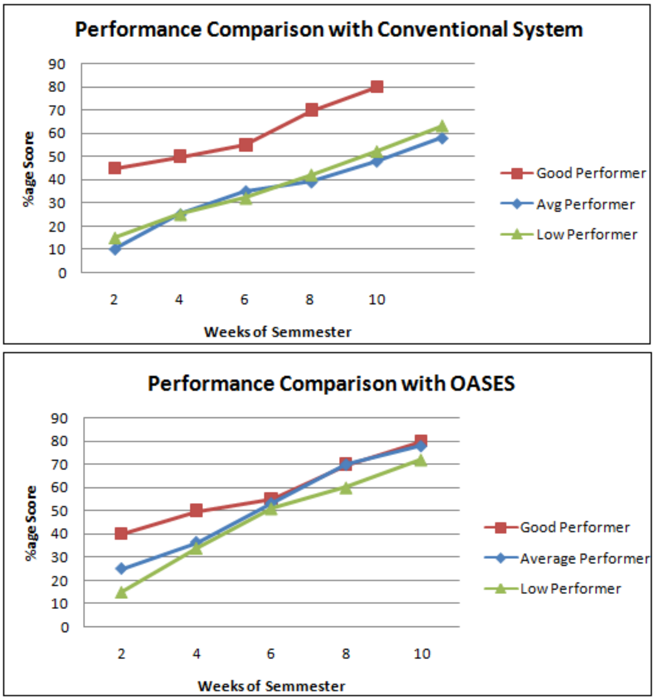

Fig. 9 Conventional e-learning System vs OASEF

Students registered with the course through OASEF, are shown almost the same contents as recommended by the domain expert. Overall learning performance of students (average quizzes and exercises) lagging seems to be improved as we moved along the semester weekly. This uprise in learner's performance is stated in Fig. 9.

With conventional system (one size fits all approach); students with good ability/aptitude, competence and background knowledge keep on performing well. Whereas, ones with average and low abilities struggle along the whole semester relative to good performers. Contrarily, students registered in course through OASEF show improved performance relative to good performers especially 6th week onwards while following the adaptive approach specific to learners.

6 Conclusion and Future Direction

Ontology based e-Learning framework has been presented in our work that is capable of offering contents in an adaptive way with respect to learner's profile and performance. Ontological model has been assessed through prevalent evaluation metrics in order to ensure its correctness, completeness and consistency. Experimental evaluation is evident of effectiveness of proposed approach compared to conventional one.

We look forward to using the fuzzy logic for clustering the learning contents and subsequently the learners based on their performance. Moreover, we will develop a generic ontology backed system capable of developing contents dynamically from any domain.

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