Cognitive Based Learning Environment and Content Description: An Ontological Approach

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***Abstract*—The huge amount of digital educational resources availability and extensive integration of information technology in e-learning domain, have initiated changes in educational paradigm. The higher educational institutions are with a great challenge in how to prepare their students towards cognitive thinking, to solve realistic problems and to meet the demands of the knowledge society. In this connection, In the existing educational metadata standards, there is an apparent lack of metadata elements from psychological and cognitive science perspective to satisfy the needs of e-learner. The assignment of pedagogical metadata that characterizes the learning resources as per the cognitive prerequisites of a learner, is an important step towards delivering contents of a domain. In this work, first we explore some core issues and the implications for the success of web-based distance learning environments. Then, we proposed the cognitive principles based descriptive metadata for the course-based learning environment. In order to make the proposed metadata schema to support the recent Educational Semantic-web Vision, we define the ontological structure of course-contents. Finally, the article ends with an investigation on the assessment of learner's cognitive learning skills through using ANCOVA statistical evaluation approach.**

Key Words: Cognitive Metadata, Course-based Learning, Ontological Structure, Content Description

I. INTRODUCTION

In the educational domain, the psychological processes involve in the acquisition of knowledge and cognitive skills. Learner's knowledge improvement is mainly depends on learning process that involves associating new information and known concepts. Whereas developing learner's cognitive skills depends on learner's prior knowledge, critical thinking ability, and self-paced learning environment. But how to develop an effective e-learning environment that can provide a more flexible learning experience to initiate thinking skills is a technical challenge that motivated for this research work.

Among the researchers of e-learning domain, recently there has been a renewed interest in the situated and embodied roots of student's cognitive skills. As a consequence, there have been attempts to reformulate the approaches of traditional modeling, authoring, and presentation of learning content. The learning content modeling can be seen as the cornerstone of the content management and presentation environment. In student-centered learning paradigm, for structuring and management of learning content, the assignment of metadata with pedagogical and cognitive strategies is an important step towards the content delivery process as par the needs of the learner.

For structuring of learning content there are many metadata standards such as SCORM Metadata [1], IMS Metadata [2], Dublin Core Metadata [3], IEEE Learning Object Metadata [4], etc., developed by different organizations and have proven their benefits to e-learners. But no one of the standards satisfying all the needs of educational domain [5] and they are not adequate enough to provide full-fledged support to e-learning system to improve intellectual abilities of e-learner [6]. So, more prominently the pedagogical dimension of resource description should mainly consider the educational objectives of Bloom's taxonomy [7].

Recently the pedagogical and psychological dimension of e-learning domain has become more prominent. Cognitive dimension of metadata helps in delivering disparate educational resources with various inter-relationships that provide instructional and guided paths as per the learning skills of e-learner. Rumetshofer & Wöß [8] presented an adaptive e-learning system based on psychological factors, where the proposed metadata specification is an extension of IEEE standard and described in XML documents. Although IEEE LOM and similar standards provide various properties, they fail to represent the instructional information about learning contents [9].

Tying up to the needs of student-centered cognitive learning paradigm, this work aims with the development of an ontological approach to represent course concepts on the basis of cognitive dimensions and applicability in practice. Firstly, this work deals with various aspects for the success of online courses and then discussed the content modeling based on cognitive principles. Finally, investigated the practical aspect of proposed ontology-based content model, through considering course based learning environment as use case scenario.

II. Issues and implications

In learner centered web-based learning environments, the learner is the central figure of the educational process. E-learning provides number of benefits that facilitate the development of high-level cognitive skills [10]. But in designing e-Learning courses there are some restrictive factors such as interaction support and presentation, to make it as an alternative to face-to-face teaching at universities. In connection to this, the effective use of online courses also depends on learner's cognitive certainty

A. Design Principles and Interaction Support

The principal task to be supported by an e-learning environment is that of learning and instruction support. In order to encourage higher-order thinking skills of learner, the learning environment needs to support the cognition-oriented metadata attributes such as Bloom's taxonomy. In advanced learning environments, the appropriate instructional procedures encourage the learners to engage in the conscious learning process. The principles of instructional design should be intended to assist in the presentation of information so as to decrease learner's cognitive load and encourages learner towards cognitive learning activities. Through providing an interaction support between the learner and learning environment, it can help the learner to involve in various learning activities related to a subject domain.

B. Content Description and Presentation

In an e-learning environment, the content presentation and instructional approach are expected to produce a desirable learning effect in an e-learner. As mentioned by Dicheva and Dichev [11] the students are often unaware of the context of the learning task when they start to learn new concepts. The content presentation approach needs to make the learner, to learn and interpret the correlated and in-depth concepts of learning domain so that the learner gets exposed to higher order thinking skills. The ontology based content presentation will support learning process in two ways. First, the conceptual structure will be conveyed to the learner, Secondly the embedded semantic knowledge will be expressed in a natural human narrative form to achieve the effective learning.

C. Cognitive Certainty of Learner

Uncertainty is a natural user experience in the process of information seeking and acquiring meaning [12] while travelling beyond what is known to the user. Cognitive learner desire to know from what they already know and wishes to learn more about a particular subject area to increase their knowledge. Cognition is the process of thinking towards achieving the particular solution to the problem or seeking clarity from ambiguous approaches, which needs exploratory or investigative searching of supportive information.

D. Cognitive certainty paves the way to obtain the following

- Familiarity with the domain of their goal
- Process the ways to achieve their goals
- Clarity in explaining his learning and put the learning to use.
- Clarity in between what they know and want to know.
- Ability to tackle complex problems through dividing into manageable smaller tasks

III. Cognitive Process and content description

From the educational domain point of view, in existing metadata standards there is an apparent lack of elements from the psychological perspective to satisfy all the needs of e-learner. When performing the search for any particular topic, the smart learners are frequently looking for additional facts from the context of search topic. So that this work primarily revolves on cognitive-based descriptions of content. In this direction, the proposed metadata can be used to improve the search process, to retrieve additional topics which are related contextually and pedagogically with search topic.

The term cognitive style of learning deals with the learner's activities such as thinking, perceiving, remembering, etc. but not directly with the learning content [13]. But the learner's cognitive activity can be influenced by means of modeling and presentation of supplementary (pedagogical) material of course content. The content presentation environment helps in learning style, which refers to how a learner perceives, interacts with, and responds to the learning environment [14]. The supplementary material for learning environments can be basically identified into different classes, according to Bloom's Taxonomy [7]. The learner's learning skills can be divided into Understanding, Comprehension, Applying, Analyzing, and Evaluating. The spectrum of tasks provided Bloom's Taxonomy are mapped with concerned supportive material type and their Impact on learning process, that are as shown in Table 1. These material types (metadata) enables in the process of building the ontology for e-learning systems to effectively locate learning materials to match learner needs.

TABLE 1. Cognitive Levels Mapping with Pedagogical Metadata and Impact on Learning

Cognitive Dimension	Supportive Material	Impact on learning
Understanding	Explanation oriented materials such as Objectives, Description, Introduction, Example, Summary, etc.	An informational materials for getting the declarative knowledge on the domain through understanding the meaning and instructional details.
Comprehension	Historically oriented materials such as Similar Concept, Prerequisite, Background, etc.	It describe the required further knowledge into new context
Applying	Applicability related Properties, Context, Behavior, Facts (for example)	It helps to solve a problems and to develop deep levels of thinking and practical situations using required skills
Analyzing	Interactive Exercises, Issues, Real World Problems, etc.	It provides explanations or investigation by looking at the macro level on the overall functionality of the system in relationship with the environment to develop divergent conclusions.
Evaluating	Demonstration, Evidence, Procedure, etc.	It gives guidelines for decision making or judgment based on a relevant set of strategies with a given purpose.

IV. Ontological Framework

In this section, we present the ontological framework of course content model to support cognitive skill development process. That needs shared understanding between terms of various metadata vocabularies. In order to meet the needs of cognitive based course content modeling, we categorize the course contents basically into two types, as core concepts and additional supportive resources. Where, the core concepts are the educational resources that constitute as the backbone of student's learning activity and the supportive resources corresponds to the reference material to complement the core concept.

In order to provide an explicit specification of the conceptual model, based on Table 1 in the previous section, we define an ontological approach. That represents core concepts accompanied with the five categories of supportive resources on the basis of cognitive dimensions such as Explanation, Interactivity, Applicability, Evaluation, and History. As per the cognitive needs of e-learner, this representation is useful to identify learner's intended topic along with the related learning material.

The class Course is used to describe the contents of the course. The Course class and Concept class contains data type properties such as: hasName, hasObjective and hasDescription. The name property is to identify the concept and objective property indicates the aim or purpose of course what we are supposed to learn. In the following, we described the core classes and properties of the ontology shown in Fig 1. The ontology was implemented using Protege [15].

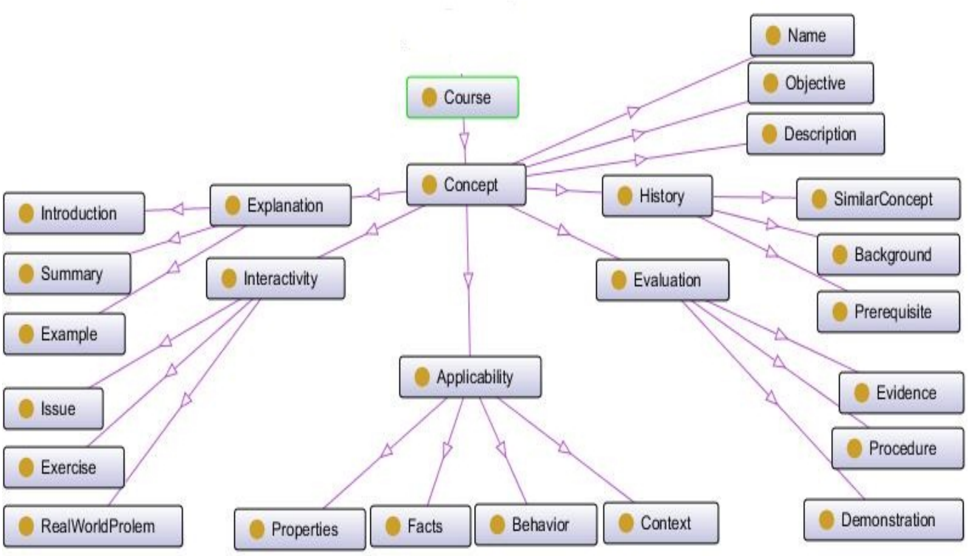

Fig 1. Base Classes of Course Content Model Ontology

1) *Explanation*: Explanation oriented materials such as Introduction, Example, Summary, etc. provides additional information about a concept which gives the basic knowledge of the learning concept.

2) *Interactivity*: It offers some kind of interactive aspects, which helps the learner to develop a skill or ability related to a concept, through verifying the acquired knowledge by solving the issues, exercises, and real-world problems.

3) *Application*: Learner is able to develop knowledge on the applicability of concept through understanding various properties, behavior and context of application to real-life situations and problems.

4) *Evaluation*: this core class contains the information related implementation and applicability of concept so that learner is able to understand what works and what does not work in any particular context or application of the concept. The evidence and demonstration illustrate on how particular task can be performed.

5) *History*: It provides guidance to the learner on, what are the prerequisite and related materials of current learning concept, it improves the relational and comparative skills of a learner.

V. SYSTEM IMPLEMENTATION AND ANALYSIS

Most of the existing course based and adaptive learning environments deliver learning materials based on learner's preferences and context but not construing about what extent the material can influence the learner's cognitive skills and investigative thinking. Learner may have different viewpoints, cognitive skills, and knowledge levels of learning materials [16] and It is important to consider cognitive learning styles while designing the web-based courses [17].

The distinct feature of the proposed system is, when the learner navigates to a particular concept, the learner is able to view other topic titles that are related to current learning topic which improves the learner's understandability. To evaluate the proposed approaches as a proof of concept, the researcher has implemented a web-based prototype in the research center of computer science department in his university. The experiment is performed in an intranet enabled environment using local university database as dataset for learning materials.

Here, the experimental results of the proposed web-based prototype that is being implemented in our university are presented. Fig 2, illustrates the course content presentation approach consists of base concept and other semantically related concepts that can improve the learner performance and the student has the option to freely navigate using any of the onscreen links of the relevant concepts.

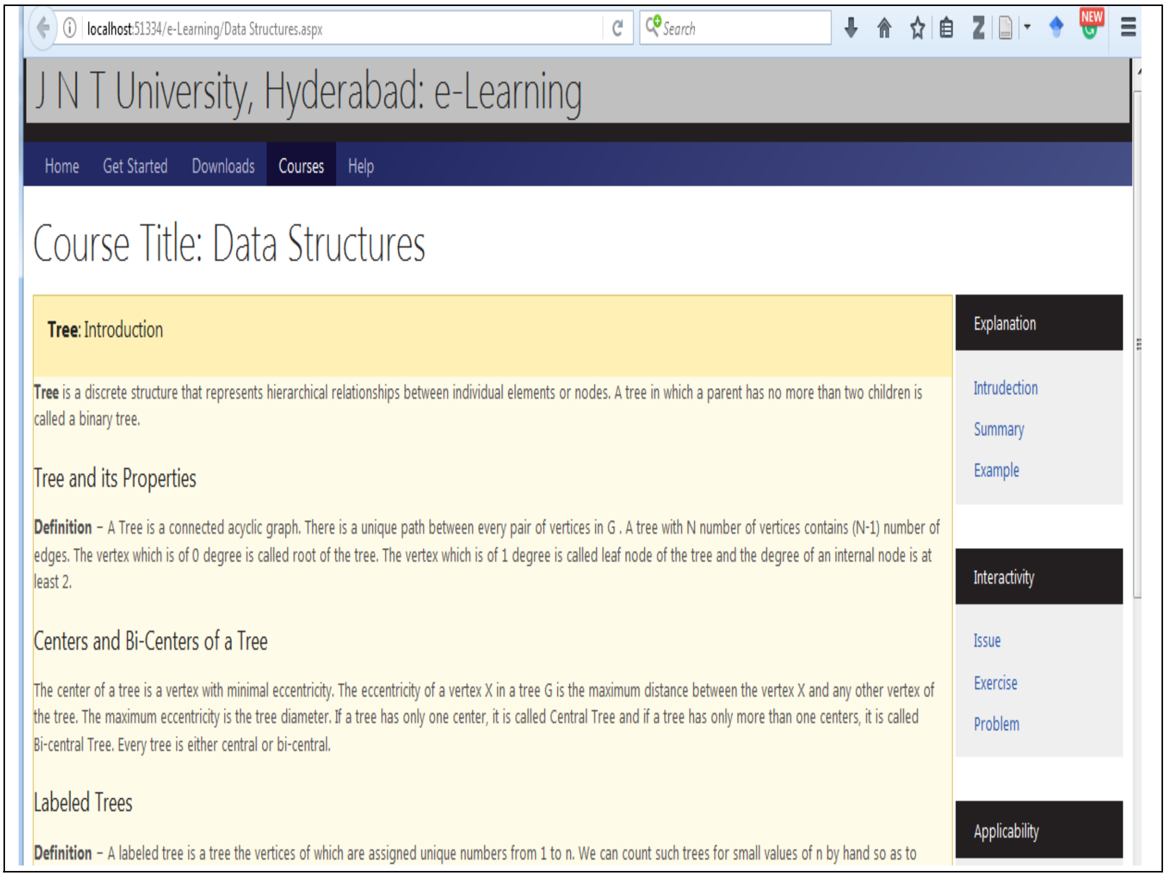

Fig 2. Web-based Prototype implementation

The purpose of the experiment is to evaluate the performance of the proposed e-learning system through utilizing statistical approach, pre-test and post-test experimental design. The researcher preferred to test the difference of achievements between the experimental group and the control group using one-way Analysis of Covariance (ANCOVA) as it makes the group comparisons more fair [18].

In this study, the aim was to determine whether the proposed system meet most learners' requirements to promote their learning performance. To perform this test the course experts identified learning concepts on "Data Structures" subject for the students, to whom the subject is in their curriculum and then designed a corresponding test item for each learning concept. The students were asked to complete a pretest with 20 test items; after completing all course units, the learners were asked to take another 20-item post-test to evaluate their learning achievements.

A. The experimental procedure comprised the following phases

Groups: A total of 24 undergraduate students were enrolled to participate in the test exam; the students were equally divided into experimental (treatment) group and control group. The control group students were allowed to browse and learn the concepts through the traditional approach. The experimental group was allowed to study the stipulated concepts through using the proposed system.

B. Pre-test

Through the pre-test, the system could obtain information about learners' prior knowledge levels of the learning concepts as well as the basis of comparison for post-test results.

C. Post-test

Learners were allowed for taking post-test when they finished their learning processes and the test results were aimed to compare the learning performance of the two groups of students after taking the course with different learning environment approaches.

D. Data analysis

This study analyzed and estimated the performance of system through the Analysis of Covariance between the experimental group and the control group.

The difference in the experimental group's score from the pre-test to the post-test indicated the change in the value of the dependent variable that could be expected to occur with exposure to the treatment. The descriptive statistics for the analysis is shown in Table 2, whereas Table 3 presents a summary result of the ANCOVA analysis on the overall post-practice achievement test.

The analysis of covariance results ($F=4.77$, $P=0.038$) indicates that the experimental group scored significantly higher than the control group in the post-test and we can acknowledge the same from Table 2. Table 3 shows that the research hypothesis holds well with significant level $\alpha=0.05$ and $P = 0.038552 < 0.05$. This means that the proposed learning model provides benefits in terms of learning performance promotion.

TABLE 2. Descriptive statistics of the pre-test and post-test

Group	N	Post-test scores		Pretest scores	
		Mean	SD	Mean	SD
Experimental Group	14	69.78	13.8315	55.50	11.7579
Control Group	14	64.78	10.9881	59.07	11.4920

TABLE 3. Summary of the analysis on the post-test scores

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (d.f.)	Mean Squares (MS)	F	P
Between Group	409.32	1	409.32	4.77	0.038552
Error	2146.89	25	85.88		

VI. CONCLUSION

The goal of this work is to come up with ontology with a limited set of classes that describes a learning resource, where each class of the ontology stands for a particular instructional or pedagogical role of learning resource. We believe that the proposed resource description metadata based on cognitive flexibility can help students in advanced knowledge acquisition and it should encourage learners to explore new knowledge in various concrete situations. Here, we dealt with the investigation of cognitive style of learning and ontology based content modeling paradigm that provides the environment for improving cognitive skills of the learner through exploiting all aspects of learning concept. As a proof of concept, the proposed prototype has been implemented to achieve the effectiveness of the proposed system; a qualitative evaluation of the performance of the system is performed.

REFERENCES

[1] SCORM, http://scorm.com/scorm-explained/technical-scorm/content-packaging/metadata-structure/
[2] IMS Global Learning Consortium. http://www.imsproject.org/metadata/imsmdv1p2p1/imsmd_bestv1p2p1.html
[3] DCMI (2008). Dublin Core Metadata Element Set, Version 1.1. DCMI Recommendation. http://dublincore.org/documents/dces/.
[4] IEEE LTSC. (2002). Draft Standard for Learning Object Metadata (IEEE 1484.12.1-2002). http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf.
[5] Palavitsinis, N., Manouselis, N., & Sánchez-Alonso, S. "Metadata quality issues in learning repositories." (2013).
[6] Sudhana KM, Raj VC, Suresh RM. An ontological approach for enriching metadata of learning objects to support effective e-learning. International Journal of Computer Science and Network Security. 2012 Oct;12(10):68-73.
[7] Bloom, B.S. and Krathwohl, D.R. Taxonomy of Educational Objectives: The Classification of Educational Goals Handbook I: Cognitive Domain, Longmans, Green, NY. (1956).
[8] Rumetshofer, Hildegard, and Wolfram Wöß. "XML-based Adaptation Framework for Psychological-driven E-learning Systems." Journal of Educational Technology & Society 6, no. 4 (2003): 18-29.
[9] Ullrich C. The learning-resource-type is dead, long live the learning-resource-type. Learning Objects and Learning Designs. 2005;1(1):7-15.
[10] Otero WR, Petch JR, Catapan AH. Developing high-level cognitive skills in e-learning. InterSciencePlace. 2015 Jun 11;1(20).
[11] Dicheva D, Dichev C. A framework for concept-based digital course libraries. Journal of Interactive Learning Research. 2004 Oct 1;15(4):347.
[12] Kuhlthau, C. C.. Seeking Meaning: A Process Approach to Library and Information Services (2nd Edition). Westport, CT: Libraries Unlimited. 2004.
[13] Stash N. Incorporating cognitive/learning styles in a general-purpose adaptive hypermedia system. Dissertation Abstracts International. 2007 Dec 1;68(04).
[14] Keefe, J.W.. Learning style: an overview. In J.W. Keefe (Ed.), Student Learning Styles: Diagnosing and Prescribing Programs. Reston, VA: National Association of Secondary School Principals. (1979).
[15] Gennari JH, Musen MA, Fergerson RW, Grosso WE, Crubézy M, Eriksson H, Noy NF, Tu SW. The evolution of Protégé: an environment for knowledge-based systems development. International Journal of Human-computer studies. 2003 Jan 31;58(1):89-123.
[16] He, Daqing, Ming Mao, and Yefei Peng. "DiLight: a Digital Library based E-Learning Environment for Learning Digital Libraries." In World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, vol. 2006, no. 1, pp. 2845-2852.
[17] Hammoud, Lamis, Steve Love, and Willem-Paul Brinkman. "Does cognitive style affect student performance on a web-based course?." In European Conference on Cognitive Ergonomics: Designing beyond the Product---Understanding Activity and User Experience in Ubiquitous Environments, p. 3. VTT Technical Research Centre of Finland, 2009.
[18] Owen, Steven V., and Robin D. Froman. "Focus on Qualitative Methods Uses and Abuses of the Analysis of Covariance." Research in Nursing and Health 21 (1998): 557-562.

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