AN ADAPTIVE LEARNING ONTOLOGICAL FRAMEWORK BASED ON LEARNING STYLES AND TEACHING STRATEGIES

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Abstract - Ontology are increasingly being used in a variety of applications, and particularly in adaptive e-learning. They have the potential to enable developers to create adaptive course content for specified domains. E-learning applications are thus able to use technology and educational content in order to generate content that matches the student's capabilities and knowledge. This personalises learning, rather than assuming that "one-size-fits-all" and providing all learners with the same content, which is what the majority of e-learning systems do. This study introduces a new approach that takes into account the fact that each learner has an individual learning style and needs. The approach enables to adapt the course content, teaching strategy and learning objects so that they correspond to each student's learning styles. This is achieved with the use of artificial intelligent in the form of an ontology and rule-based reasoning.The proposed system takes some of the key design aspects such asextensibility, reusability, and maintainability into consideration in order toenhance performance of adaptive course content recommendation.

Index Terms - E-learning, Ontology, Semanticweb, Adaptive Student Profile, learning style(LS), teaching strategy ,Learning objects(LOs) , Adaptive Educational Systems (AES).

I. INTRODUCTION

Adaptive Educational Systems (AES) are an interesting resource for supporting teaching and learning activities. Such environments make use of intelligent techniques to adapt educational content to the real needs of students. The aim is to provide a more personalised and individualised learning course content. These systems should be able to generate learning paths and learning objects (LOs) for the students that match their perceptions, understanding and preferences etc. Learning content is considered as the digital representation of learning objects (LOs). LOs can be used, reused or referenced in a technology-supported learning system. These objects are rather small and are usually assembled into larger units to provide adaptive learning content according to the needs of individuals or groups of learners before they are presented to them [1]. Semantic Web is a group of methods and technologies that permits machines to comprehend the importance of information on the World Wide Web. It is about explicitly declaring the knowledge embedded in many electronic applications, coordinating data. An ontology-based approach has been chosen because of its inherent features for representing concepts, the relationship between them and the logic in this relationship, as well as the possibility of inferences from represented information.

In the e-learning content domain, diverse learners have particular characteristics with respect to their experience, competence level, learning style and learning activities [2]. This makes recommending learning resources to a particular learner more difficult. Therefore, even if two learners have similar evaluations, they will require different recommendations if the learner characteristics are not the same.

This paper proposed a new ontological model as an effective way of adapting course content and LOs based on learning styles and teaching strategies. The main contributions of this paper are fourfold:

1. An ontology building framework (Sect.2), describing a step-by-step process for developing an ontology for an adaptive learning system.
2. An adaptive learning model (Sect. 3), depicting the different components of an adaptive learning system, their functional behaviours and interactions.
3. A course reference ontology for adaptive learning (Sect. 4) that integrates teaching strategies and learning styles to support adaptive learner profiles.
4. Finally, an algorithm for adaptive course content delivery (Sect. 5), is proposed to synthesise dynamically personalised course content based on learning styles, teaching strategies and learner profiles.

II. PROPOSED ONTOLOGY BUILDING FRAMEWORK

A. Proposed ontological model

This section presentsthe method used todevelop the domain ontology forthe proposed model. An ontology is built step by stepby linking concepts and the extracted relationships. Theproposed work will focus on relationships that allow usto model rich domains effectively as shown in Figure1 and described asfollows.

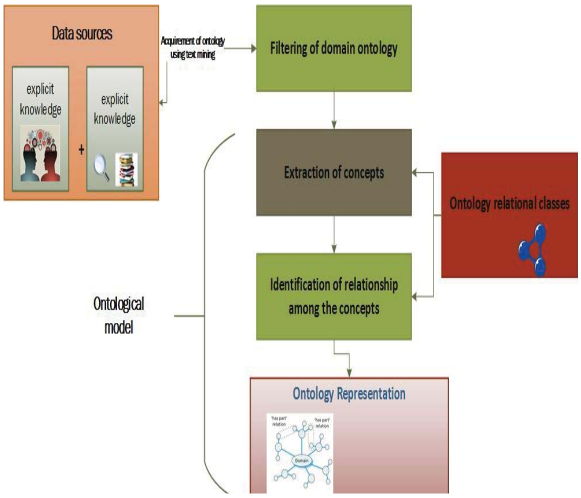

Figure 1 proposed approach to build ontological model

Step 1: Data Source. The first phase of the ontologybuilding process is identifying the ontology goal andscope, in order to specify the domain ontology and identifythe required resources.

A. Explicit knowledge sources: explicit resources are any tangible knowledge source. They can be collected from several sources such as documents, books, web pages and electronic documentations. These sources of information allow ontology developers to identify the domain concepts, define these concepts and the relations between them.
B. Tacit knowledge sources: one or more experts may help by operating fuzzy concepts, setting the rules and validating the ontology construction.

Step 2: Acquirement of Ontology using Text Mining.Text mining, also known as Intelligent Text Analysisor Text Data Mining, is a process of extracting interesting,nontrivial information and knowledge from unstructuredtext [3]. Knowledge may be discoveredfrom many sources of information but many unstructuredtexts remain the largest source of knowledge. Theproblem that Text Data Mining faces is acquiring implicitand explicit concepts and semantic relations betweenconcepts.

Step 3: Filtering of Domain Ontology. This step startsto convert the collected text documents (in unstructuredform) into a structured form. Parsing is the first step inconverting unstructured text to a structured format forease of analysis.

B. Inferencing and Reasoning

Due to their simplicity and popularity,Protégé and OWL Editor [3] were employed to construct the domainontology. This is todiscern the relationship between the course content with the learning style, and teaching strategy during a session.Specific input data arerequired by the reasonersuch as ontology, relationship and rules etc as shown in fugure 2. The generic T-Box and logical rulesreasoning is done automatically withinternal reasoners, or could be done by connecting one of the wide varietiesof external reasoners available such as Hermit, Pellet andFaCT++. Furthermore, Palletwas used as semantic web reasoner to build proposed ontology.

furthermore, adaptive course inferencing isperformed by using A-Box approach to infer from loadedknowledge model with specific learning style as well as teaching strategy rules using SPARQL[4].This is to enable or grant the reasoner access to the domainontology, semantical data store accessed via SPARQL based query languages and the sensor data streamed mapped in RDF format. Therefore enabling the reasoner with the capacity tosupport T-box and A-box reasoning to extract which course content/learning objects are most suitable to learning style and teaching strategy for example:

If LS (student)= "visual " Then apply content with pictures modes and Appear in the top of page content with picture sequence with an example followed by links to presentation and interactive simulation

Else if LS (student)= "verbal" Then apply content with text modes

If LS (student)= "sequential " Then apply content with details modes

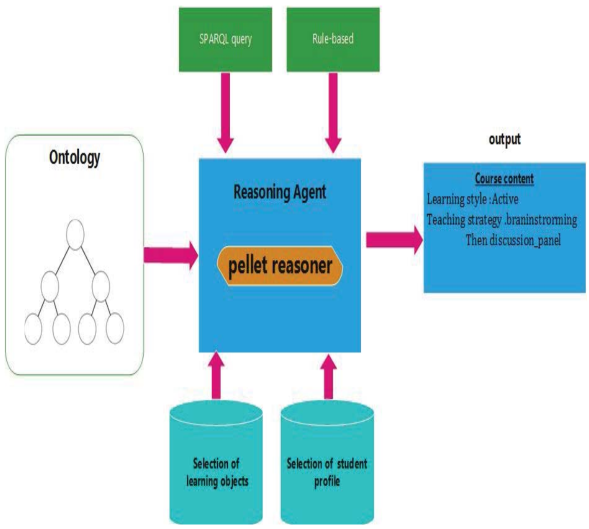

Figure 2 describes the overall inferencing and reasoning approach for course content

III. PROPOSED ADAPTIVE LEARNING MODEL

The following section illustrates the proposed adaptive e-learning system that is based on ontologies. It also demonstrates the individual components needed to implement the novel approach, as shown in Figure 3. The structure of the proposed model consists of three major components: namely course reference ontology, student reference model and assessment reference model.

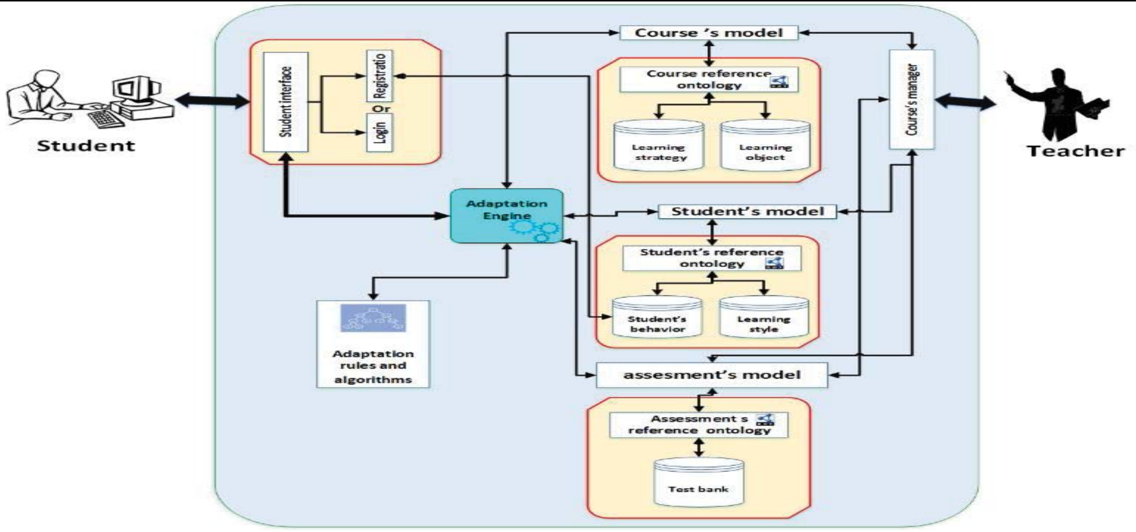

Figure 3 Proposed adaptive learning model

We now describe the functionalities of each component of the proposed adaptive learning model as follows.

Student Interface: Is the communication component that controls the interactions between the students and the system. It deals with the learners' accounts, such as registration and login, and facilitates the learners' interaction with the learning components. It also captures the learners' responses in interactive activities and transfers them to the adaptive engine. This information is used in order to choose the correct course material from the course adaptation ontology machine.

Student Model: Holds information about the students. Such information comprises categories of student's perceptions and understanding, and is based on their behaviour, for example, number of visits and time spent on exercises and reading materials etc.The system uses this information in order to adapt to the learner's individual needs. The system updates the learner model step by step during the learning process, in order to keep track of the learner's actions and progress, and possibly guide the learner accordingly. The student model is responsible for retrieving the characteristics of a particular learner, making the necessary changes and sending it to the adaptation model through interaction with the repository. The system also receives information about new learners from the User Interface and stores it in the student model. The student model is updated when it receives new information about the learner from the adaptive engine. This data is utilised as a part of request to build an ontological model taking into account the students' own particular inclinations.

Assessment model: Contains all crucial test specifications to accurately evaluate the learner's level of knowledge. It also searches the test bank to find appropriate assessments required by the adaptation model. This data is utilised as a part of the request to suggest tests at different levels, taking into account the student's level from the test adjustment ontology machine.

Adaptation Engine (AE): Is at the core of the system design and contains rules to support the adaptive functionality of the system. Different conditions are modelled in the body of the rules. These conditions are all obtained from different models such as the student, content and assessment models. In addition, adaptive learning paths have been generated and recommended according to the learner's behaviour and their progress. This ensures that they receive the most suitable adaptive content to meet their learning style.

Course Model: Stores all essential learning content and teaching strategy. It also describes how the information content is designed. It is responsible for finding the LOs stored in the repository that match a suitable learning style.

Course Manager: Handles requests from the authors and instructional designers for inserting, updating and modifying the structure of the course, instances of LOs and adaptation rules. It also allows the test developer to add new assessments and update them through the assessment model.
In this paper we will focus on adapting course content based on ontology, as explained in the following sections.

IV. PROPOSED COURSE REFERENCE ONTOLOGY

Course content presents storage for all essential learning content and also describes how the information content is structured. It is responsible for finding the LOs stored in the repository, which meet some given criteria. One of the key objectives of the ontology is to improve the flexibility of the system for generating personalised learning content. In order to meet this goal, we have defined two technical objectives that need to be fulfilled beforehand. First, the learning content should be separated from the adaptation logic, which results in the LOs being no longer specific to any given adaptation rule or instructional plan. Secondly the teaching strategy should match the learner's learning style. In this section, we describe the modelling of content that realises these two technical objectives.

A. Ontology engineering (course content hierarchy)

In our approach, an ontology-based model has been developed towards semantically enhancing learning content as shown in Figure4.

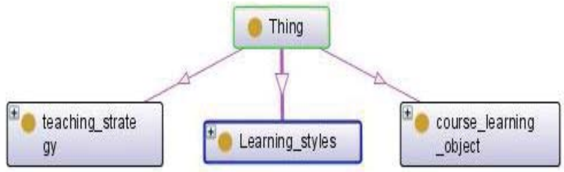

Figure 4 Course content class hierarchy

The first step was to give the teaching strategy and course LOs related classes or concepts. Figure 5 shows that the structure of the proposed domain ontology is based on several important classes or concepts including teaching strategy, learning objects, and learning style. For instance, the teaching strategy concept defines a variety of teaching strategies that can be used to match students' different learning styles. The teaching strategy concept is divided into the subclasses brainstorming, case study, discussion panel, game-based learning, presentation, project design method, question and answer method and role playing. Similarly, other concepts and sub-concepts are mentioned in this domain ontology for providing the learning content.

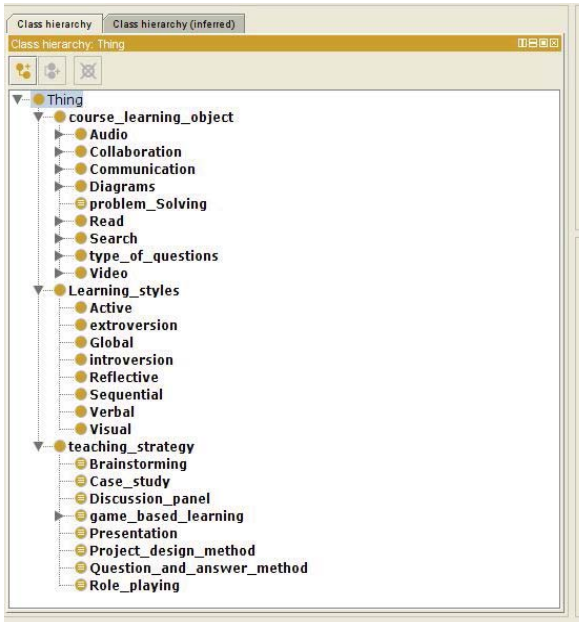

Figure 5 Course content class structure

B. Modelling teaching strategy

The teaching strategy includes brainstorming, case study, discussion panel, game-based learning, presentation, project design method, question and answer method and role playing, as shown in Figure 6.

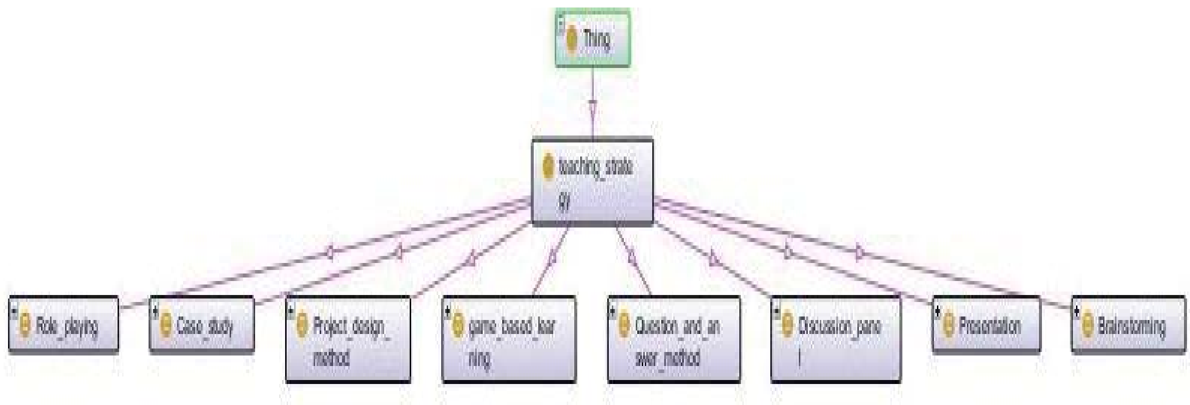

Figure 6Teaching strategy class hierarchy

C. Modelling the course learning object:

Learning objects include Audio (audio recordings, Audio-conference), Collaboration (forums, on-line learning communities, Weblog or blog, Wikis), Communication (chat, e-mail), Diagrams (animations, graphics, pictures, simulations), Problem Solving Read (eBooks, hypertext, slideshows), Search, Type of Questions (analysis, application, comprehension, evaluation, knowledge synthesis) and Video (recorded live events, video-conference) as shown in Figure7.

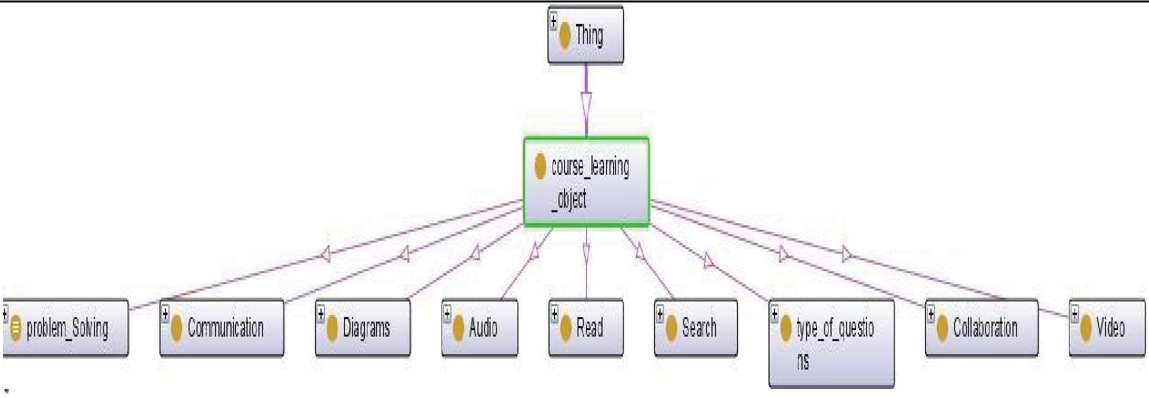

Figure 7Course learning object ontology

V. ONTOLOGY VISUALISATION

Ontology visualisation provides a visual language for the representation of ontologies. It provides an intuitive way for hierarchy representation. The ontology is presented as a 2D graph. It has the capability to present, apart from the name, the properties, inheritance and relations of each class. It gives support for interactively navigating the relationships of OWL ontologies. Various layouts are supported for automatically organising the structure of the ontology. Different relationships are represented: subclass, individual, domain/range object properties, and equivalence. Figure8 shows the whole picture for our reference ontology.

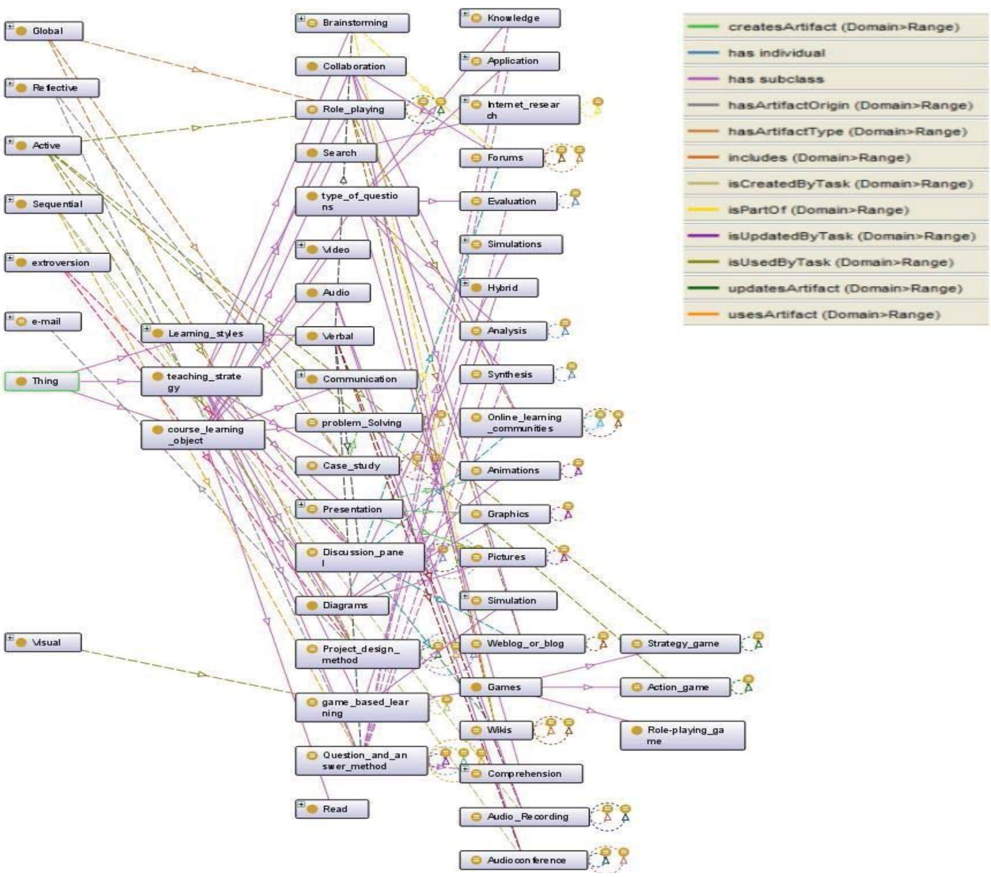

Figure8Graphical representation of the proposed ontological model

VI. PROPOSED WORK-FLOW FOR ADAPTIVE COURSE CONTENT DELIVERY

The adaptation flowchart depicted in Figure 9represents the cycle of creating an adaptive learning environment. The corresponding pseudo code is given in Figure 10.First of all, a student logs into a system if successful the system will start and retrieve the student's behaviour, otherwise it will start to collect the student's behaviour through the learning management system. After that, the system will start to read the student’s learning style from their learning profile. For example, if the learner is not visual then it will go to another learning style model such as verbal or global etc. Then it will start to generate course content that matches the learner's learning style and preferences. It will also generate an adaptive course assessment. It will check whether the assessment result is greater than or equal 70 and if it is, it will print the assessment result. If not, it will update the student's profile again in order to start new recommendations.

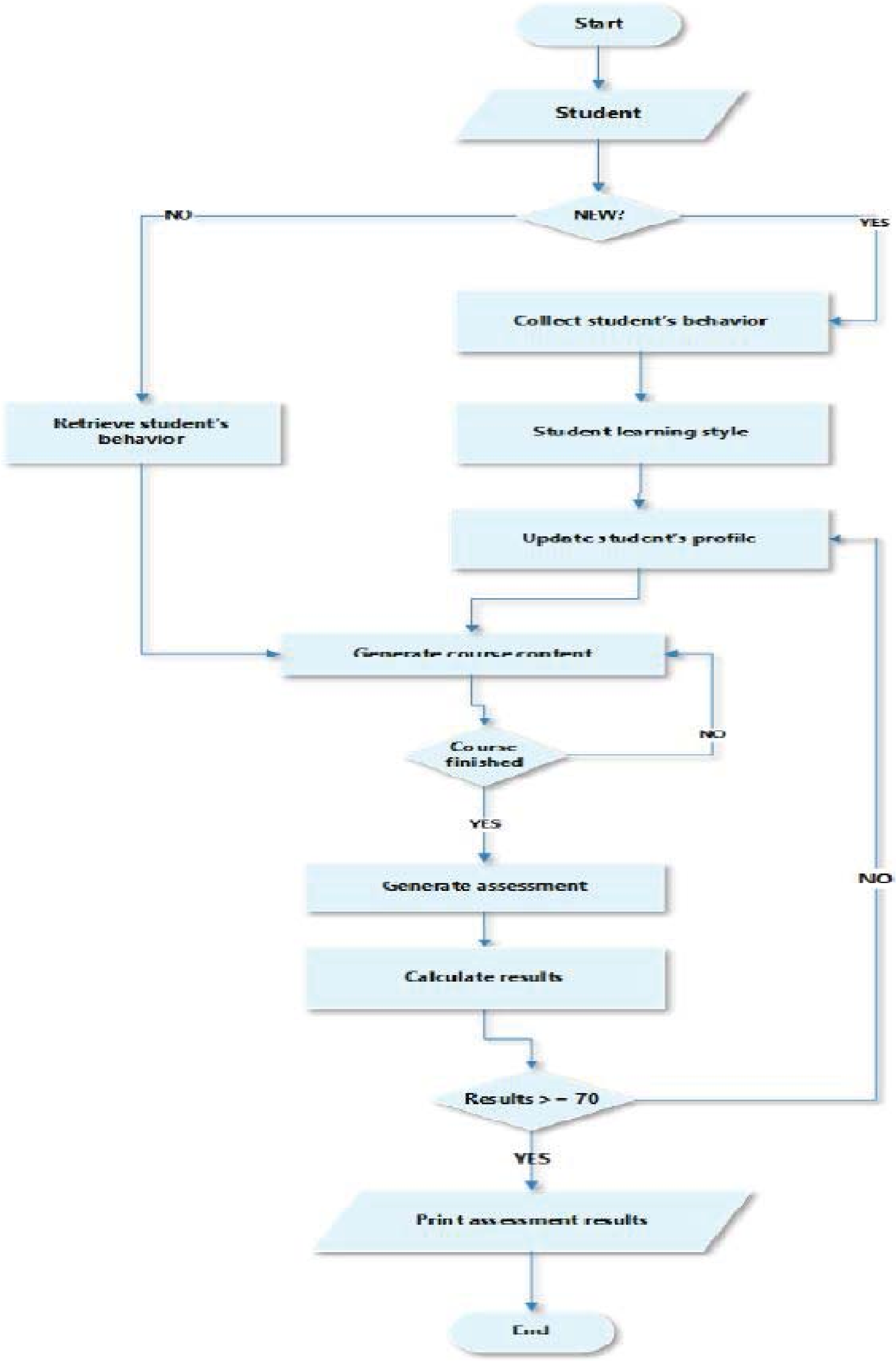

Figure 9 Flowchart for adaptive course content

```
1. Read student login information
2. IF new student THEN
    2.1 Collect student's behaviour
    2.2 Read student's learning style
    2.3 Update student's profile
3. ELSE
    3.1 Retrieve student's profile (learning style)
4. Generate course content
5. IF not course finished THEN
    5.1 Go to 4
6. Generate assessment
7. Calculate results
8. IF results <70 THEN
    8.1 Go to 2.3
9. Print assessment results
10. END
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Figure 10 Pseudo code for the adaptive course content algorithm

The proposed system(adaptive engine) may be integrated into any LMS conforming to the Web services . This means that by using the adaptive e-leariningsystem ,student can benefit from the adaptive course contents that match their adaptive profile .It presents course content in the form of different sequencesdesigned for each topic based on learning style and teahcning strategy .

The following scenario has been simulated on adaptive system . Figure 11shows the information about learners and course material in this scenario.

As shown in this figure, there are two learners with their own learning styles. There is also a course named e-commerce which has 2 topics. Each topic has appropriate learning content sequences based on the learner's learning style.

VII. DISCUSSION

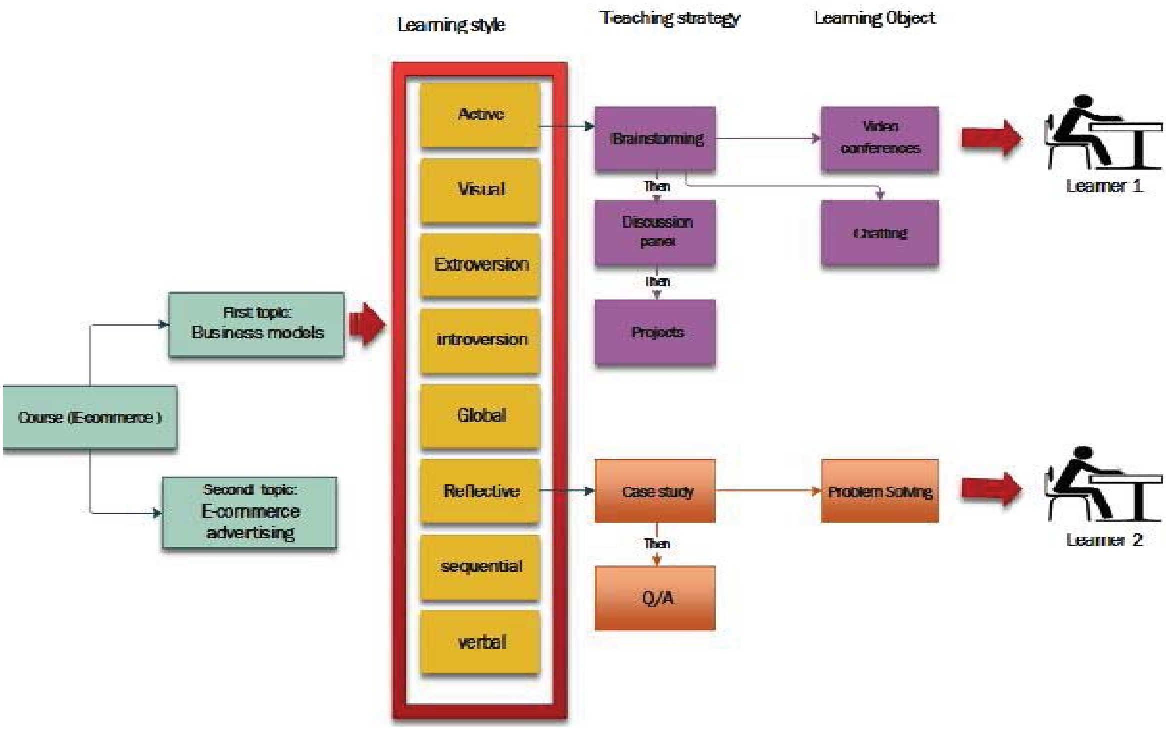

Figure 11 Theadaptive course scenario simulation.

VII. RELATED WORK

In[5] the authors outline how Semantic Web technologies based on ontologies can be used to realise sophisticated e-Learning scenarios and improve the management of their resources. In this case the ontologies are used for describing the semantics and defining the learning context of the material, as well as for structuring the courses. An ontology based tool suite that allows optimising use of the e-Learning resources available on the Web is presented in[6]. Another survey explained that adaptive e-learning could be achieved through resource modelling based on domain ontology, learner ontology, instructional role ontology, structural ontology and instructional goals/levels by using Semantic Web technology [7]. [8]introduces an OWL ontology named CONON, which stands for "Context Ontology". CONON is supposed to be used in pervasive computing environments, identifying location, user, activity and computational entities as fundamental context categories to enable context modelling and logic-based context reasoning. The author provides several reasons to use ontologies for context modelling: knowledge sharing, logic inference, and knowledge reuse.Learning style has been considered to be a very important factor that affects the learning process [9] [10] [11]. The ways that learners learn differ. Learning styles impact the learning process, help to improve the content delivery and are useful for personalising the learning process. They are considered to improve the quality of learning [12]

[13]. Learning styles are recommended as important parameters for personalisation. Therefore, the proposed modelconsiders learning style and teaching strategy as critical parameters for adaptation, in order to recommend adaptive course content. Moreover, it uses the interactivity level as one of the parameters that helps to improve performance. Table Table1 provides a comparative study between some existing works.

Reference	Components	Technologies
[14]	Context-aware semantic, learning process.	semantic web
[15]	Adaptive course construction, learning activities and learning components.	
[16]	Learning materials, domain model, student model, and adaptation model.	(OWL/RDF)
[17]	Learning objects, learner model, group model and adaptation model.	
[18]	Learner model, learning activities and learning objects.	Web service
[19]	Learning objects (shareable content objects).	(OWL/RDF)
[20]	Instructors Agent, learner agent, resource location agent, personalisation agent, learnercentred agent and collaboration agent.	RDF, OWL
[21]	Course registration, uploading course documents and student assignments, interactive tutorial announcements, useful links, assessment, Simple semantic search.	RDF, OWL and XML
[22]	course content, learning object	ontology
[23]	Content personalisation in e-learning, learning objects.	Metadata and ontology
[24]	Personalised e-Learning scenario.	ontologies
Our work	Adaptive course content based on teaching strategy, learning style and learning. Adaptive student profile using a rule-based adaptive engine.	OWL, Metadata and rule based system

Table 1 Comparative study

CONCLUSION

In this paper we propose a new model for adaptive course content based on matching the teaching strategy and learning objects with the learning style in an e-Learning environment. There are two significant implications of the proposed system. First, a student profile is built based on the student's behaviour through the learning management system (AAST-student portal). Second, course content is recommended by finding suitable learning objects for the successful achievement of the learning process based on teaching strategy and learning style. Future study will focus on validating the performance and quality of the course content recommendations of the semantic recommendation algorithm, and implementing the proposed framework on a recommender system prototype.

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