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New Approach for Context-dependent Learner Model for Technology Enhanced Learning System

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ABSTRACT

Learner modeling still the object of very active research in the technology-enhanced learning system. It makes it possible to represent a complete description of the learner. In this paper, we have proposed a new learner modeling approach which is independent on the learning system and dependent on the learning context. The proposed model involved four information categories: Personal data describing the general information about the learner; Cognitive data representing the learner performances and knowledge; Activity data providing details about learner activities during the learning process. Finally, contextual data presenting a description about learner context such as location, device, accessibility, connectivity, etc. To ensure a better representation of these characteristics, we have proposed an ontology-based learner model in order to benefit of advantages gained from the use of ontological technology, like extensibility, usability, exchanging information, inferring new knowledge by reasoning on an existing one.

Key words : Technology enhanced learning, Learner Modeling, Ontology, Context-aware, Learner context.

1 INTRODUCTION

The vast majority of authors consider that the learner model is a core of Technology Enhanced Learning (TEL) systems as it enables the learning system the storage of relevant information about learners such as performances, frequent errors and misconception, psychological characteristics, learning style, preferences, experiences, as other types of learner-related information[1]-[2].
In TEL systems, the learner model have played a significant role in personalizing and adapting learning content to the learner needs and expectations[3]-[4]-[5], if a learner model represents all relevant information about learner. Therefore it improves an effective adaptation process as well as successfully personalization and recommendation process.
A review of the literature indicates that there are several different uses of learner models. According to self [6] and Matsuda[7], the learner model could be useful to trigger the learner misconceptions from the error made in a learner's problem-solving process. As VanLehn[8] it pointed out the uses of learner Models according four categories : (i) Advancement: enhancing the knowledge and skills of learners by just moving on to the next topic once mastering the current topic; (ii) Offering unsolicited advice: intervening while an error occurred and proposing unsolicited advice; (iii) Problem generation: generating problems dynamically rather than only manage the sequence of predefined problems ;(iv) Adapting explanations: individualizing the explanations according to the level of knowledge of the learner. According to [9], the purpose of using the learner model in adaptive learning environments, is using the learner's understanding as revealed (or inferred) from their actions in the environment. So that to be able to individualize and personalize the interaction according to learner's educational needs. As for [10] , the learner model is also playing a role in problem difficulty, it is used for inference of the learner's problem solving ability, and for acquisition of new topics and retention of earlier topics. Moreover, [11]-[12]-[13] affirmed that a learner model allows assisting learner during the learning process, adapting information and presentation of the content to the learner needs and expectations, facilitating information searching , diagnosing the learner behavior in a procedural problem solving session and it also furnish to the learner a feedback of information as to his activities.
Such beneficial use of learner Models provides the TEL systems with relevant information about learner. However, such modeling turns to be complex. There are a several challenges related to the learner modeling. On the first hand, the importance of ensuring that we have a complete description not only about learner but also about the learning context. To face this first challenge, we propose a context-dependent learner model for technology enhanced learning system. The learner model presented in this paper has been developed to be applied to different domains and environments, it is independent to the learning domain and it includes both learner characteristics (e.g. personal data, performance, preferences, learner activities, competency, skills, etc.) and contextual information such as noise level, location, brightness, and the device context as the display, network, software, screen resolution …etc. On the other hand, the absence of a standardized and generic method to represent and exploit the learner model component for TEL systems. To meet this second challenge, our proposed model is based on ontologies as they play an essential role in distributing and representing knowledge so that they can be used by the other components of the system.
After this introduction, this paper is organized as following: in the next section, we will present a literature review about the most important and widely used learner specification in TEL environment. A motivation for the context-aware learner model is demonstrated in this section. In the third part, we will

try to justify the use of ontology to represent our model. Then, in the fourth section we will present the research methodology and then we will introduce our proposed model L-MONTO (Learner Model Ontology) and we will present its different dimension in details. In the last section, we will conclude with some perspectives and future work.

2 LEARNER MODEL: LITERATURE REVUE

The learner model is considered as component that is responsible for storing relevant information about learner, such as performances, general information, psychological characteristics, frequent errors and misconception, etc.[14].The research work on the field of TEL system has been interested on learner modeling for a long time, and several learner modeling approaches are proposed.

2.1 Learner model specifications

In front of diversity of approaches and perceptions, they are several attempts of standardization, in literature, that gave rise to standards and specifications. In this section, we list the most important specifications and the most used in TEL systems. These specifications that serve to represent and manage information about learners are: the Public and Private Information for Learners (PAPI Learner) [15] and the IMS Learner information package (IMS-LIP) [16] that contain relevant information about learner and represent them in a standardized way.

A. The Public and Private Information for Learners (PAPI Learner) specification

The PAPI Learner standard is developed by IEEE P1484.2 Learner Model Working Group. It is intended to represent the basic bricks of learner model and provides the uses, the retrieval, the storage, and the exchange of the learner information between different users and systems. The PAPI Learner specification classified the learner information according six main categories that support extension: (1) PAPI Learner Personal category describes information related to names, contacts and addresses of a learner;(2) PAPI Learner Relations category contains information about learner's relationships to the other users of learning systems such as teachers and other learners;(3) PAPI Learner Security stores information about access rights and security credentials of the learner such as passwords, private keys, etc.; (4)PAPI Learner Preference stores information about learner preferences that may improve human computer interactions; (5)PAPI Learner Performance stores information about measured performance of a learner such as learner's history, current work, or future objectives (we note that this information is created and used by learning technology components to provide improved or optimized learning experiences); and finally (6)PAPI Learner Portfolio describes the previous experience of a learner.

The PAPI Learner specification describes a minimal subset of learner information. These categories were extended and developed later by the IMS LIP standard.

B. The IMS Learner Information Package(LIP) specification

IMS LIP presents a better categorization and larger description for the learner than PAPI Learner. The IMS LIP specification is divided into eleven main categories of learner data: *(1) Identification* that contains demographic and biographic data about a learner; (*2) Goal* represents a description of the personal objectives and aspirations of the learner. (*3) QCL* represents qualifications, certifications, and licenses; (*4) Activity* describes any learning activity in any state of completion. *(5) Interest* describes any information about learner hobbies and recreational activities; (*6) Competency* is responsible for storing learner skills, experience and knowledge acquired; *(7) Transcript* represents information records used to provide a summary of academic achievement;*(8) Affiliation* presents information about membership in professional organizations and *(9) Accessibility* stores a general accessibility such as language capabilities, eligibility requirements, disabilities, and learning preferences; *(10) Security* contains all password and security keys assigned to the learner and *(11) Relationship describes* relationships between core data elements. However, both of these standards have a several limitations. They were developed in order to describe the learner in Online learning system but they are not sufficiently complete to cover all descriptive information about the learner. For example, in case a learner would like to use his mobile with a 3G connection in order to access the course online. By filling out the various elements of his profile in IMS-LIP or PAPI Learner, the learner is unable to choose the learning device on which he will work. Indeed, these standards do not allow a geographical representation of learners and do not allow learning system to personalize and adapt the learning content to specific characteristics of device taking into account the different contextual elements.

2.2 Motivation for context-aware learner model

In the field of a technology-enhanced learning system and more precisely adaptive and recommender learning systems, the incorporation of additional information about learners and their context is important. The learner devices, the location, the connectivity, the accessibility, the learning environment, the interaction between learners, etc., are all implicit factors influencing the recommendation, personalization, and the adaptation process. In this section, we will present the context concept related to the educational field. The contextual information may influence the learner's overall learning experience in many ways. For example, the learner's location can impact his ability to concentrate because of the likelihood to be interrupted by others or of the noises or the brightness of that location. Accordingly, this information proves very useful for adaptation and must be considered during the learner modeling process.

Since the first introduction of the term "context" by Schilit in 1994, this term attracted considerable interest from several researchers in the field of computer science and exploited in a wide variety of application. Besides, each of them defines the context according to his need and his uses. Schilit[17] defines the context by the environment and location of use, the identities of nearby people and the accessible devices. As

Brown [18] and defines the context by adding to the definition of Schilit the time of the day, season of the year, and temperature. A similar definition is given by [19] that define the context by the information about the environment, such as location, time, temperature or user identity. According to Schmidt[20], enumerates context as knowledge about the user, the user's social environment, location, infrastructure, time, tasks and physical conditions. Moreover,[21]-[22] refer to context as the set of environmental states and settings that either determines an application's behavior or in which an application event occurs and is interesting to the user. Other authors give a more generic definitions, Mostifaoui [23] defines the context as "what surrounds the center of interest, provides additional sources of information "where, who, what" and increases understanding". The definition proposed by Dey is a reference in the field of context-awareness systems; Dey defines the context by "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves."[24]

3 ONTOLOGICAL TECHNOLOGY FOR LEARNER MODELING

The term "ontology" appeared twenty years ago in the field of Artificial Intelligence (AI), but existed since the 19th century in philosophy where it refers to the subject of existence. However, this notion is more modest and pragmatic in AI. Indeed, ontology pretends to represent only the entire knowledge of a domain[25]. The literature on AI contains several definitions for the word «ontology». The general definition adopted is that of Gruber[26], he defines the ontology as "an explicit specification of a conceptualization.". In this fact, ontology defines the concepts, relationships, and other distinctions that are relevant for describing and modeling a particular field of knowledge. The specification takes the form of the definitions of representational vocabulary such as classes (or sets), attributes (or properties), and relationships (or relations between members of the class). The representational vocabulary definition provides meanings for the vocabulary and formal constraints on its coherent use [27].

In the context of TEL systems, the ontologies are used in various ways and for various reasons.

In his work [28],Winter present the advantages of using an ontology for modeling learner and mention that learner model based on ontology provides us with benefits in reusability, portability, flexible access and information integration due to the inherent connectedness (inference), availability of effective design tools and reasoning. Furthermore, Clemente et al. point out that Ontological Engineering is useful to support the representation of abstract concepts and properties with the purpose to be reused by many component of the systems and extended if needed, and to provide the extraction of new knowledge by reasoning on the knowledge described in the ontology [29].

In this paper, ontology will be seen as a solution for representing and describing learner data and contextual information, in order to support the learning system in assessment and personalization according to the learner requirements. This section lists the different learner modeling approaches based on ontology[30], it presents an ontology-based student model in Intelligent Tutoring Systems for Distance Learning. The proposed Student Model Ontology consists of two main taxonomies: student's academic information and student's personal information. In the same direction, Sani[31] develop a learner model through an ontology-based architecture for describing learners data according two categories the personal data and behavior data. Moreover, Ding[12] propose a learner model ontology in Adaptive Learning System. This model includes basic information, learning style, knowledge state and cognitive ability, combined with the development of a real system. Another ontology is ON-SMMILE presented by Yago[32], it is an Ontology Network-based Student Model for Multiple Learning Environments which is represented as an ontology network describing information related to students and their knowledge state, assessments that rely on rubrics and different types of objectives, competences and student performance, units of learning and educational resources. As for [33], they present a Learner's Characteristics Ontology based on creating interconnections between the different learning style model dimensions and learning styles with the relevant learner's characteristics. This ontology aims to support the instructor to semantically search for suitable contents during the learning content authoring process in order to reuse this content. Additionally, the authors in [34], proposed a an ontological approach in order to create an personalized student profile based on ontology and rule-based reasoning by analysis of learning patterns through a learning management system, according to the Felder-Silverman learning style model (FSLSM) and Myers-Briggs Type Indicator (MBTI) theory. Furthermore, Rezgui [35], introduces a learner profile represented by an ontological structure for learning networks. The proposed model is based on well-known learner model specifications and intended to describe aspects related to the managing and tracking the different learner's characteristics. In [36], authors illustrated a novel approach to build ontology based semantic student profile for a learning system. This ontology includes the dynamic characteristics of the student, particularly the student interest and learning style.

As a conclusion to this section, we note that ontologies are getting more and more used in the field of online learning systems and, particularly in Learner Modeling. The difference between the previously cited approaches is related to the content of the learner model e.g. the type of information and characteristics considered when modeling the learner. Each proposed approach depends on the creating objectives of the learner model. Besides all these approaches benefits from the use of ontology as a technique for representing the learner model. First, the ontology is representation formalism which facilitates the expression of abstract concepts and properties easily reusable and extensible in different learning environments. Second, it provides the ability to infer knowledge about the information represented in the ontology.

4 CONTEXT-DEPENDENT LEARNER MODEL: INNOVATIVE CONCEPTION

4.1 Research methodology

In the previous section, we presented a literature review related to our research work, justifying the need of integrating specific context information into learner model. The purpose of this section is to conceive a learner model integrating the sub-mentioned context requirements. This modeling process is described in this section in order to provide a better understanding to the proposed L-MONTO (Learner Model Ontology) that is described in detail in the following section.
First, we have replied to the question "which information will serve to represent and reflect better the learner?" In fact, we reviewed the literature on learner modeling practicing in the field of TEL systems. A study of specifications and standards of learner modeling was also carried out, and a set of limitation related to these specifications were examined. A list of requirements that must be acquired for design such a model was established. As result, we have selected pertinent learner characteristics including representation of learner personal information and performance, goals, language and learning styles preferences, identification, Affiliation, previous experience and Interest. We also integrate general cognitive characteristics such as courses and lessons passed by the learner as well as general technical skills and competencies. Furthermore, another problem related to learner modeling is that the learner can access to the learning system at every time, in everywhere and with any device. In this case, for example, time, location and device features are also considered important in learning systems delivering personalized learning contents according to the learner's requirements. Cognizant of this fact, we integrate the contextual information in the proposed learner model.
We subsequently conducted a study on context-awareness, and particularly on the field of online learning systems. This study led to us valuable information and puts forward a series of ideas and ways of integrating the contextual information in the Learner model. Choosing a good formalism for representing and managing the learner model was another challenge we have to overcome. So, we have carried out a study on learner modeling techniques. Since the advantage provided by ontological technology, we have chosen it to represent the proposed learner model.

5 L-MONTO

Based on analysis of different modeling learner techniques, we choose to describe context-dependent learner model by using ontology written in OWL (Web Ontology Language) created by the W3C (Web Ontology Working Group) Consortium[37]. To build L-MONTO, we used the Protégé 5.2 ontology editor [38].
The proposed approach evolves from the existing learner models cited in section 2. However, it integrates other information which seems to be useful and ensures a better representation of the learner.
As shown in "Figure 1", L-MONTO incorporates the relevant characteristics of learners plus specific information about their learning context. It is described according to four mains categories of information : *Personal Data*, *Cognitive Data*, *Activity Data*, and *Contextual data.*

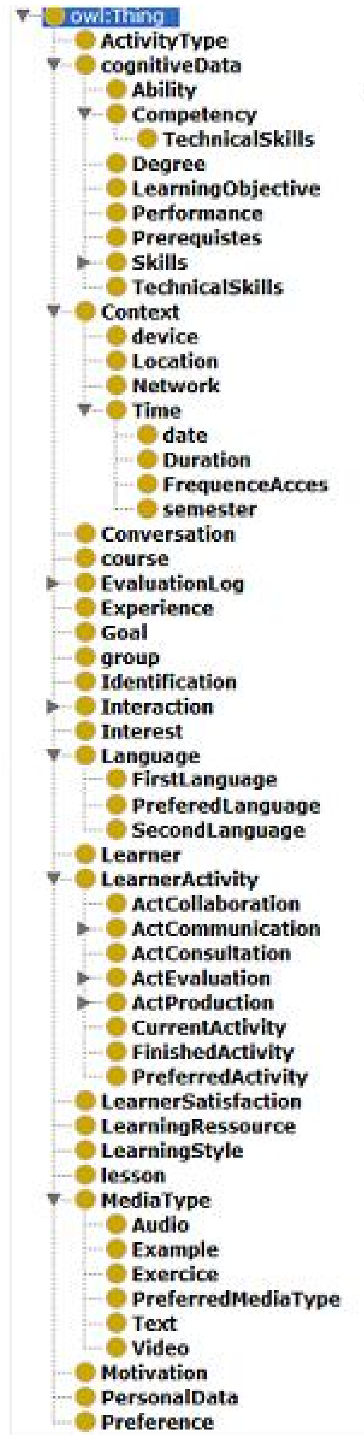

Figure 1: An overview of L-MONTO

5.1 Personnel data

This category is represented by a number of classes describing the learner's general information: *Learner class* which contains general information such as name, surname, age, gender, email, age, educational level, etc. *Identification class* describes the security information and learner identifying data (i.e. login, password) witch enables learner authentification and access to the learning system. *Experience class* represents information about personal learner's previous experiences. Such information may be useful in adaptation process. For example, If the learner had previous experiences in the learning domain, then the learning system can deliver high-level exercises to him as it can also overlooking the sections of initialization and providing an advanced content according to these experiences. *Preference class* stores the individual preferences of a learner concerning the way learning object are represented in learning system such us graphical representation, colors, preferred language, device preference, preferred time to study. According to Popescu[39], some learners prefer to work in groups and others learn better alone. *Goal class* reflects the personal learner aspirations and objectives that he desires to achieve in the educational process. Finally, *LearningStyle* class contains information about learner's learning style, in others words, it describes the way learner prefers to study. Different individuals learn in different ways. It's important to incorporate a variety of education techniques within the learning process. For example, audio-visual learners do not prefer to perceive the learning material as text. In this case, video lessons are best situated for them. Another example, some students are active and prefer to try things by themselves, work in group and others are reflective they prefer to think about the learning materials and to work alone. To get this information we have used the Felder-Silverman Learning Style Model [40].

5.2 Cognitive data

Cognitive data category provides information about learner's performance during the learning sessions. It is represented by the main class *Cognitive Data* and its subclasses which are: *Course* class that stores the different courses taken by the learner in the educational process and it is related to "Prerequisites". *Prerequisites* class contains a requirement that must be completed before taking an advanced course. It can be used to deduct the learner competencies. For example, when the learner is enrolled or passed a course, learner skills can be inferred by reasoning on prerequisites of that course. *Lesson class* includes information about lessons passed by the learner. Each course can be divided into several lessons. These lessons can be ordered in such a way that it impossible for the learner to pass to a lesson without completing the previous lesson. So, it is necessary to store information concerning learner previous and current lessons. *Competency* class is responsible for retrieving the competencies acquired during the overall learning process. It includes learner abilities (*Ability* class) such as concentration, memory, perception, organization and remembers information. Another competency subclass is *Skill class* which stores general technical skills or specific skills depending on the field of learning. Finally, in this category we find *Languages class* which includes learner's native languages (*SpokenLanguage* class) and the learner preferred language for (*PreferredLanguage* class) that can be used to decide what kind of language in which the learning objects is to be presented.

5.3 Activity data:

The main class defined in this category is "Learner Activity" This class is responsible for storing information about learner activities during the learning session. On the basis of several works quoted in [41], we propose a classification that consolidates learner activities. To have a good representation and a completed description we classified learner activities according to five types of activities. In order to define the activities' categorization, we had investigated and based on bloom theory [42]. As it is presented in "Figure 2", Learner Activity has five sub classes: *ActCommunication*, *ActConsultation*, *ActProduction*, and *ActEvaluation*: (1) ActCommunication class includes information about any activities that require a learner communicate with other learners, as well as with other users in the learning system. Each type of communication activity is represented as a sub-class of Act-Communication. Forum class describes all exchanged ideas between learners and teachers by posting comments. The learner can create several threads in such a forum; these threads are represented via *Discussion* class. *Chat* class describes a real-time synchronous discussion. Message class describes exchanged asynchronous message. All classes in this category can be a basis for inferring information about the learner sociable aspect; (2) *ActConsultation* class stores information about learner consultation of a lesson or learning resources. Each consultation activity has duration; by reference to this duration, we can calculate the effort made by the learner, and we can also make hypotheses concerning learners who take longer duration in their consultations; (3) *ActProduction* class includes information about any cognitive or mental or practical activities in which a learner can produce such as assign activity (*Assign* class) that describes assignments attributed to the learner and Practical work activity presented by Practical Work class. Both of these classes store all learner submitted works as well as learner's attempts, grades and teacher feedback, and comment (learner comment to his teacher during the procedure of submitting his work, and (4) *ActEvaluation* class presents and records several reports regarding learner tests (*Test* class) such as his outcome, errors, grades, and the number of attempts to answer a question. Based on these reports we can easily infer the new skills acquired by the learner.

5.4 Contextual data

Contextual data category is responsible for storing any details related to the context. It constitutes a significant portion of our contribution. *Context* class is the main class defined in this category, it is a super-class of five classes: (1) *Location* class provides further details about learner location including IP address, location type (i.e. outdoor, indoor, home, class or transportation, etc.), communicative capability, noise level,

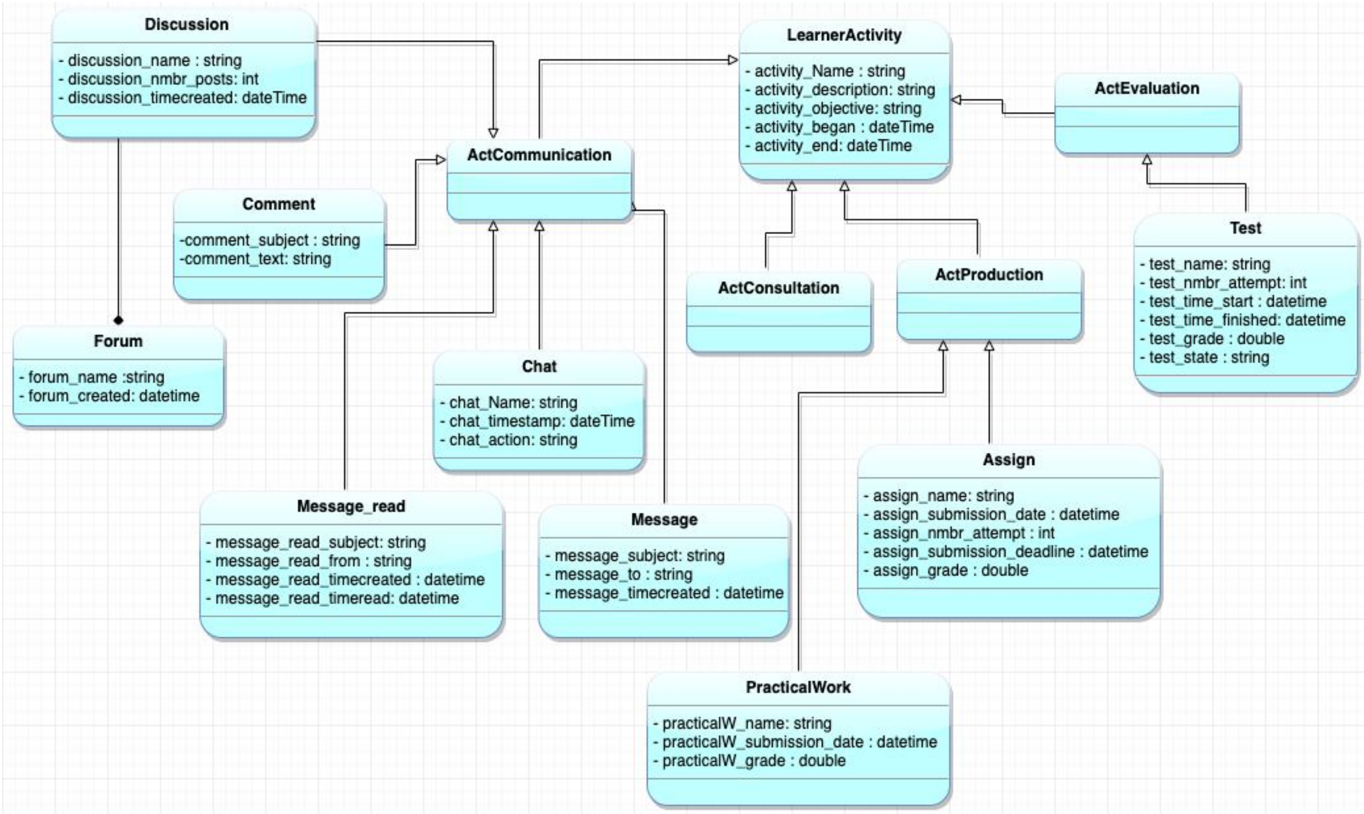

Figure 2: Classification of Learner Activities

current region, etc. In our view, these details are very important in trying to provide an adapted learning content to the particular environment in which the learner is located; (2) *Device* class outlines features of the learning device or equipment witch learner uses. In order to adapt the educational content to the learning device used to display this content, it is necessary to know the properties of this device. These devices are characterized with device type (i.e. Computer, Mobile, iPad, etc.), CPU characteristics, screen resolution, Operating system, browser used, etc. In the literature, there are Several works[41]-[43]-[44] that refer to standard specifications for description devices in different systems. In our proposed model we have inspired by FIPA device ontology [45]; (3) *Access* class describes any information related to the learner accessibility to the learning system, for example, the date and time of first and last accesses, access frequency, the available time that the learner can devote for studying, and session information retrieved each time the learner logs into the learning system; (4) *Network* class presents information about the learner connectivity and the network capacity. An adaptive system needs to have good visibility of learner connectivity. So, the presented learning materials must be customized according to network performance. For example, the learner sometimes can have a bad connection; In this case, it is better to provide a course within textual form instead of audio-visual one, or just to decrease automatically the quality of displayed content in order to be appropriate to the learner network features; and finally (5) The *CollaborativeContext* class provides information about the communication and the interaction between learners as well as the interaction between learner and tutor. This class is in general related to learner activities, particularly to communication activities. Among represented information: enrolled forums and consulted subject by the learner, his posts, his feedbacks. Through the collected information in *CollaborativeContext* class, our proposition aims to answer the following questions: What kind of subject can interest the learner? Does he initiate a discussion? Is he reactive in forums (e.g. makes sure if he expresses his feedback or just consulting without any reaction)? Which are learners with whom he communicates more? And finally, does he solicit tutors or not?

6 CONCLUSION AND FUTURE WORK

Technology-Enhanced learning systems are constantly progressing. Therefore, nowadays, there is a variety of systems such as adaptive, recommender and personalized learning system which aims to enhance the learning process in terms of quality. Adaptation, recommendation, and even personalization prosses require careful management of relevant information about the learner, and it is why the learner model is considered as the core of those systems. In this paper, we have proposed an ontology-based context-dependent learner model for technology-enhanced learning systems. The starting point for producing this learner model ontology was to identify specific information needed to describe a learner. We have presented a literature review related to our research work, justifying the need for integrating specific contextual information into the learner model such as the learner devices, the location, the connectivity, the accessibility, the learning environment, the

interaction between learners, etc. One of the main objectives of our proposal is, therefore, to present a domain-independent model that can be implemented in different domains and environments, and gives a complete description of the learner including both learner characteristics (e.g. personal data, performance, preferences, learner activities, competency, skills, etc.) and contextual information.
To achieve this goal our proposal is based on the ontological approach to taking advantage of the use of this technology. At the beginning of our research work, we have set four stages for the modeling process: the definition of learner model ontology then the initialization and validation stages and finally the exploitation of this model. Currently, we are in the initialization and validation stage. To initialize our ontology, we first need collecting data. We did not want to use simulation data, so we have dealt with a real case. Therefore, we set up an experiment to evaluate a real case in which we hosted a course in the Moodle platform. This experiment was performed on 116 learners who take a course for 8 weeks. Interactions between learners and the learning environment generate several traces in different forms. The collected traces will allow us to instantiate our ontology. To this end, we have developed a mapping-engine for establishing suitable mappings between the different collected data and data represented in L-MONTO. This initialization is the first validation for our ontology. The current research work does not stop at this point; we plan to focus on our future research to develop a system for exploiting the proposed ontology.

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