Towards an Ontology for Representing a Student's Profile in Adaptive Gamified Learning System

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Abstract: Learner and learning content are the key factors contributing towards the success of any adaptive learning system. Each learner searches for an adequate environment to his needs which offers personalized and adaptive content that provides a learning experience to be more successful and more useful to him. Moreover, he likes to study in a fun and entertaining environment that gives them a sense of engagement and motivation. Education research shows that considering student profile is effective in adapting courses and profile modeling is an important process that aims to give as complete representation as possible of all the aspects related to the user's features. With regard to motivation, some studies have approved that gamification is a good solution to enhance student engagement and that there is a strong link between it and motivation. Therefore, this article presents our contribution through a SPOnto ontology for representation of students profile, by combining the two concepts "adaptive learning" and "gamification" to provide a personalized gamified experience. We propose a student profile ontology, to benefit from semantic web technologies, which presents a global model of the student based on many important characteristics in order to help decision-making in the different academic contexts and to motivate him to achieve his learning goals.

1 INTRODUCTION

Online learning platforms, educational systems and continuing education programs are all based on a uniform approach that may be inappropriate to the profile of the learners, where a large number of students are educated without taking into account their preferences, their cognitive abilities, their learning style, their behaviors and their very particular personalities typical to each one of them. In fact, a new concept appeared called adaptive learning connected to artificial intelligence and cognitive science research, which provides learning appropriate to a learner's ability and takes into account his profile and his preferences. This concept has been introduced by many researchers as a solution for students' engagement but it is not as effective as anticipated. The lack of motivation is one of the main reasons for this issue. However, motivation is a decisive factor in students' learning that determines how much effort and commitment they have put into learning a particular topic (Brophy, 2013) and the human being only carries out any activity taking into account the reward obtained once this activity is successfully completed. In this regard, many researchs have shown a link between motivation and gamification. This latter is the use of game metaphors, game elements and ideas in a different context than games to increase motivation and engagement, as well as to influence user behavior (Marczewski, 2013). Several researchs approved that the integration of gamification has great potential to engage students and facilitate learning but it is complicated to implement it properly and it is not a simple process of adding game elements. Most gamified systems follow the "one size fits all" approach when integrating elements of the game, without taking into account differences between learners. So, to target these problems, we have proposed "SPOnto": an ontology of representation of student profile where we combined

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the two concepts "adaptive learning" and "gamification" to provide an adaptive gamified learning appropriate to student's profile which is based on many important characteristics to more motivate and engage them.

The comparative study of (Hamim et al, 2019) shows that the ontology approaches are the most recently used to model the profile of student. This latter was applied for the purpose of modeling the student profile, as being a technique that can give as complete a representation as possible of the student profile. Ontology has been commonly used as a useful knowledge engineering technique to reduce ambiguity and help with information sharing. It characterizes several domains' purposes' description through structured and formalized languages.

2 RELATED WORK

The use of ontologies in student profiling has gained considerable attention in recent years since it is suitable to tackle interoperability and information sharing challenges. Several ontological models have been proposed in the literature to overcome these issues.

(Munassar and Ali, 2019) proposed a Framework for adaptive e-learning (PALO) which is based on semantic web technology and offers students personal materials. They modeled learning objects and the learner's profiles according to different learning styles and knowledge levels by integrating the OWL ontology and the SWRL rules. The work presented by (Abyaa et al, 2017) based on modeling the learner's knowledge using ontologies and rule reasoning. They take into consideration in their adult learner's knowledge model the different knowledge types and categories, learner's prior knowledge, previously learned but forgotten knowledge, misconception and errors. (Ameen et al, 2012) proposed student profile ontology to personalize the content learning, based on the academic information. (Sarwar et al, 2019) concentrated on different attributes to profile the learner such as learning style, knowledge, age, locale/origin, professional experience and qualification. They proposed a semantic e-learning framework not only for profiles learners through ontology but also for categorizing them based on their profiles for recommending the suitable learning content. The work presented by (Bouihi and Bahaj, 2019) proposes a revised version of the classical 3-tiers architecture for a semantic web based recommender system, by adding a semantic layer hosting on ontology and semantic rules. This layer contains a learning management system ontology that comprises two interdependent sub ontologies: learning content ontology and learning context ontology. (Hamim et al, 2019) presented, after performing a comparative study under two main criteria: the profile modeling approach and the characteristics used taxonomy of student characteristics that might be used for profile modeling and that encompasses different point of view from the student. Their study shows also that the machine learning and ontology approaches are the most recently used to model the profile of student. (Hassan et al, 2019) proposed a framework in which each student is presented with adaptive gamification experience (activities and elements) according to his learning dimensions that have been identified from the interactions that a student performs with the system using a mathematical formula. (Rezgui et al, 2014) proposed a learner profile ontology, which presented a general view of the different learner's characteristics, to improve the learner model with semantic in order to provide a personalized content and learning paths according to specific student's needs. For the personalization of game design elements in collaborative learning contexts, (Challco et al, 2014) created gamification ontology, representing some gamification concepts and they focused on the definition of player roles and gameplay strategies. They demonstrate its use through a case study. (Dermeval et al, 2019) connect theories of both concepts "gamification" and "Intelligent Tutoring Systems (ITS)" using the ontology to allow automated reasoning, to enable interoperability, and create awareness about theories and good practices for the designers of gamified ITS.

According of the description of existing studies related to student profile ontology in the previous section, we were allowed to highlight the major limit that was identified is that the most studies didn't give a complete representation of student profile in all the aspects related to the student features. The majority has concentrated in one or some characteristic of the student and didn't cover all the different aspects in the same time. According to the table1 which represents a comparison of studies dealing with the concept of student profile ontologies in the educational context, we can notice that the academic features are the most used. The majority of studies didn't focus enough on student motivation, engagement and how can use gamification features to more attract them, but they just focus of the improvement of the student academic performance and his learning process. The source of data varies from one study to another, and the majority of studies use questionnaires, academic

databases, and the interactions of learners for the e-learning systems.

Table 1: Comparison of related works.

Article	Use academic features	Use psychological features	Use gamification features
(Ameen et al, 2012)	X		
(Rezgui et al, 2014)	X		
(Challco et al, 2014)			X
(Abyaa et al, 2017)	X		
(Munassar and Ali, 2019)	X		
(Sarwar et al, 2019)	X		
(Bouihi and Bahaj, 2019)	X		
(Hassan et al, 2019)		X	X
(Dermeval et al, 2019)			X

The added value of our work in comparison with the previous mentioned works is that we propose a student profile ontology that captures the full details and aspects related to the student features, to give as complete a representation as possible of the student profile, which containing both implicit and explicit information about him. As shown in the figure1, we defined a taxonomy inspired by (Hamim et al, 2019) to represent the different characteristics and categorize them in three categories: academic, psychological and gamification features. This taxonomy can aid the design of a student profile that covered the different point of view from the student.

3 SPOnto ONTOLOGY DEVELOPMENT

Ontologies can be built from scratch or can be reused an existing ontologies. There are many methodologies for ontology development. Among them we were inspired by a METHONTOLOGY (Fernández-López et al, 1997) to develop our SPOnto ontology from scratch, simplifying the process of five main steps that can be described as follow: (1) Scope and requirements definition, (2) Knowledge acquisition, (3) Conceptualization, (4) Design & Implementation, (5) Evaluation.

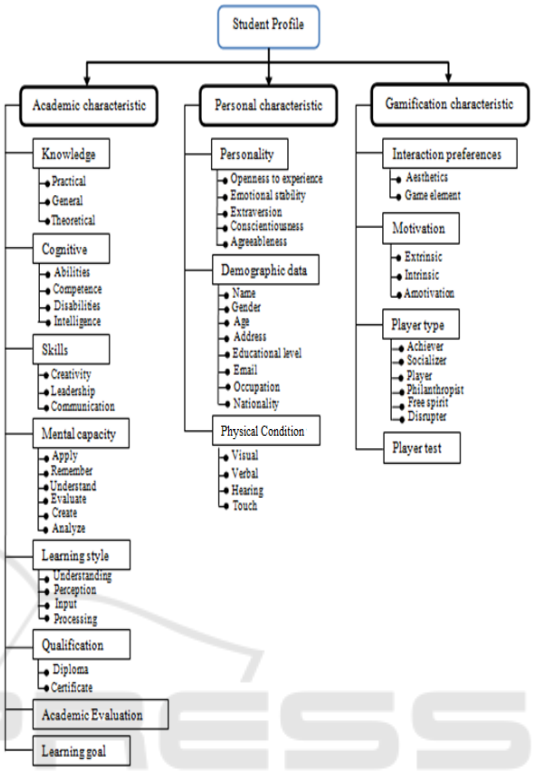

Figure 1: Student's characteristic taxonomy.

We choose this methodology because it is listed as one of the most mature ontology engineering methodologies existing in literature. Moreover, it includes activities to support most activities of the ontology development lifecycle (Dermeval et al, 2019). Our ontology's process phases are described in detail in the following subsection.

3.1 Scope and Objectives Specification

The scope of our ontology is the learner's profiling. The main users of our ontology are schools and e-learning systems.

The main objectives of our ontology are:

- Offering an efficient description of students in various aspects (behavior, knowledge, learning style etc.) in order to help decision-making in the different academic context and to be to act in case of problems such as failure, drop out. While, ontology technique is the best technique that can give as complete a profile representation as possible.

- Define the most adaptive learning resources depending on their profiles. Therefore, a profile model allows the detection of profile patterns which can be applied in similar cases which leads to facilitate the research, accelerate the decision and make it more efficient and make the system centered on the user.

3.2 Knowledge Acquisition

Once we have established the scope and the objectives of our ontology, we move to the second step of the pre-development stage which is "knowledge acquisition". This step comprises exploration, extraction and derivation of knowledge from the domain of interest. Many resources have been used to gather domain knowledge. In our case learner's profiling, we have acquired the domain knowledge and key concepts and elements from domain experts and researchers working in this field. We used terminologies from prominent existing ontologies from literature, as depicted in table 2.

Table 2: List of extracted student profile concepts from literature.

Concept	Description	Source
Personal Information	Describes biographic and demographic data.	(Rezgui et al, 2014)
Personality	As an internal factor that gives consistency over time for an individual's behavior.	(Rezgui et al, 2014)
Transcript	Describes an institutionally-based summary of academic achievement.	(Rezgui et al, 2014)
Motivation	Is the desire to do something. It could be intrinsic and extrinsic.	(Challco et al, 2014)
Performance	Describes the learner's measured performance, e.g. grades.	(Rezgui et al, 2014)
Competency	Describes the set of knowledge, skills and abilities the learner has acquired during learning.	(Rezgui et al, 2014)
Learning style	Describes the learner's preferred method of learning and acquiring knowledge, and also of having physical and sociological needs.	(Munassar and Ali, 2019), (Sarwar et al, 2019)
Cognitive	Refers to a variety of mental processes related to information manipulation, it includes: intelligence, competence, experience, abilities.	Hamim et al, 2019)
Skills/ interest	Refers to the talents and interests centers which include talents that enabled the student to succeed, it encompasses: creativity, interpersonal, communication, leadership, understanding (speed and logic).	Hamim et al, 2019)
Knowledge	Refers to the information acquired through experience or education, it can be: general, theoretical, and practical on a particular topic	(Rezgui et al, 2014)
Qualification	Describes any qualifications, certifications, licenses or degrees awarded to the learner.	(Rezgui et al, 2014)
Player type	Refers to classify users and identify the differences between them as a player in front of a gamified system	(Rezgui et al, 2014)
Game element	Refers to any kind of type from games and apply them to gamification as concept, mechanics etc.	(Challco et al, 2014)

3.3 Conceptualization

Next phase, following the METHONTOLOGY process, is to perform the conceptualization of our ontology. This step takes as input the list of concept resulting from the knowledge acquisition. It includes defining the core concepts, a glossary of terms, a tree of concepts, and the relations between the concepts in the ontology. Based on our sources of knowledge, we defined the following core concepts, which are represented in the class diagram in figure 2:

- **Profile**, which represents all the basic information relating to student's background, goals, interest and preferences.
- **Personal Information**, which represents the biographic and demographic data.
- **Academic Information**, which represents all information related to the student learning, such as the information acquired through experience or education, thinking abilities and skills etc.
- **Player Information**, which represents all information related to the player such as player type and game elements preferences etc.

Figure 2 represents the class diagram, which is a graphical representation of the concepts of our student profile ontology and the relationships between them. The glossary of terms contains the definitions of all terms related to the domain (concepts, attributes, relations). Table 3 provides a list of some concepts used in our ontology which we

specify, for every concept, the following information: the properties, the parent, and the relationships.

Table 3: List of concepts of the SPOnto ontology.

Concept	Role	Parent	Attributes
Profile	-	Thing	-
Learning style	hasLearning_Style, hasInput_LearningStyle, hasPerception_LearningStyle, hasProcessing_LearningStyle, hasUnderstanding_LearningStyle	Learner_information	Learning_style_value
Player type	hasPlayerType	Player_information	Player_type_value
Cognitive	hasDisabilities, has Abilities, hasCompetences, hasIntelligence	Learner_information	Cognitive_Type, Cognitive_Value
Interaction preference	hasAestheticPreferences, hasAestheticPreferences_Color, hasAestheticPreferences_Font	Player_information	Color_value, Font_value
Skills	hasCommunication_Skills, hasCreativity_Skills, hasLeadership_Skills	Learner_information	Skills_type, Skills_value
Physical condition	hasPhysicalCondition	Personal_information	Physical_Condition_type
(…)	(…)	(…)	(…)

3.4 Design and Implementation

Our ontology is implemented with protégé 5.2 ontology editor, which is by far the most widely used ontology editing environment, and is saved as an OWL (Web Ontology Language) file (Protégé, 2013). OWL is a common ontology language which defines and describes classes, subclasses and properties i.e., object properties, datatype properties and annotation properties. In the following subsections, we present our ontology model with regard to the main aspects of profiling domain knowledge.

The student profile is created using all students' information. Student information was commonly divided into three major categories:

Learner Information, which represents the academic information. It concerns all information related to the student learning, such as the information acquired through experience or education, thinking abilities and skills etc. Students' academic details are collected in "*Learner_information*" class which is in turn divided into several subclasses such as "*Learning_style", "Mental_capacity", "Knowledge",* "*Skills*", "*Cognitive*" and "*Learning_goals*". Among these subclasses we find:

- Learning style, which describes the learner's preferred method of learning and acquiring knowledge. There are several models of learning style, but we used in our work "Felder Silverman Learning Style Model which contains a four-dimensional: Dimensions Perception (sensing / intuitive), Dimensions Processing (active / reflective), Input measurement (visual/ verbal), and Understanding (sequential / global) (Munassar and Ali, 2019).
- Mental capacity, which represents a hierarchy of educational objectives such as cognitive, sensory and affective domains. For this criterion we used the bloom taxonomy, which helps the instructors to analyze the level of each student under six categories of cognitive domains such as remembering, understanding, applying, analyzing, evaluating and creating (Sami & Arumugam, 2019). This taxonomy not only helps student to evolve thinking abilities but also to identify the skills they are lacking with.

Figure 3 shows the instances of the "Profile" class, among these we found the instance "*Profile 1*" which has some properties related to learner information. An example, "*Profile1*" has some abilities like Reading and writing, has video as learning style, has some disabilities in math calculation but has a good memory as competence.

Personal Information, which represents the biographic and demographic data. This includes data such as: name, age and address etc. All of these data are collected in "*Personal_information*" class which is in turn divided into several subclasses such as "*Physical_Condition"*, "*Personality*" and "*Demographic_data*". For the personality criteria, we followed the FFM model (Denden et al, 2018), which categorizes personality traits in five dimensions: (1) Extraversion; (2) Agreeableness; (3) Conscientiousness; (4) Neuroticism; and, (5) Openness.

Player Information, which represents all information related to the player such as player type, game elements preferences etc. These information are collected in "*Player_information*" class which is in

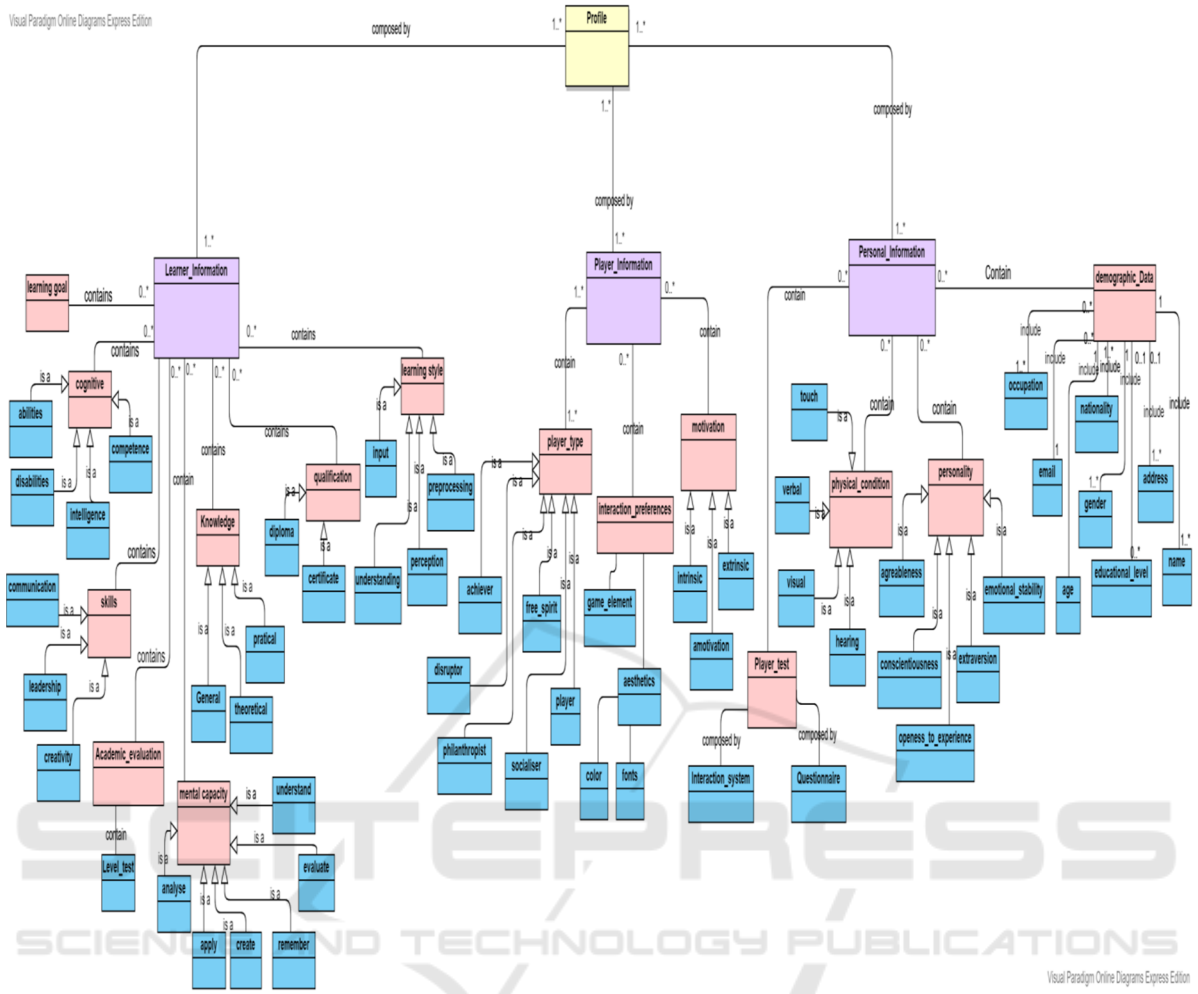

Figure 2: Conceptual Model of SPOnto ontology.

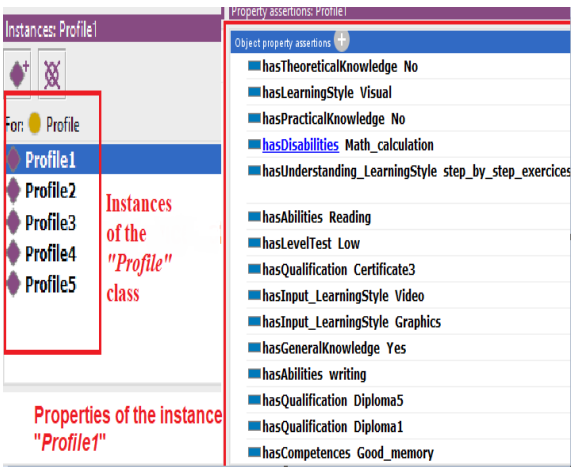

Figure 3: An example of properties and instances to "*Learner_information*" and "*Profile*" classes.

turn divided into several sub classes such as "*Interaction_preferences*", "*Motivation*" and "*Player_type*", as shown in figure 4. For the player type classification, we used a Hexad typology (Lopez & Tucker, 2019), which contains six types of players: (i) Philanthropists, (ii) disruptors, (iii) Socializers, (iv) Free Spirits, (v) Achievers and (vi) Players. This typology user preferences for game elements in gamified applications.

3.5 Evaluation

In the literature, many approaches of ontology evaluation have been suggested to assess whether ontology accurately and properly represented such domain information. We have reviewed the most common evaluation approaches and we have chosen the criteria-based evaluation approach (Yu et al, 2005).

Figure 4: OwlViz view of "*Player_information*" subclasses.

We selected a list of criteria among those such as clarity, consistency, conciseness and correctness. Each criterion is explained in the following subsection.

- **Clarity**, Gruber (Gruber, 1993) sets out clarity requirements which include: The described ontology terms "should communicate effectively the intended meaning" removing any aspects of subjectivity or ambiguity. The ontology should be documented with a natural language. In our context, the feedback of the interviewed domain experts has helped us to verify ontology clarity and more specifically to omit or replace any ambiguous term. For instance, we had "*Student_information*" as a concept which represents all information related to the student learning. During an interview with experts of the domain, they agreed that the term "Student" does not deliver its intended meaning because it's very general term which can represent any detail of student and should be replaced with the term "Learner" that is more significant and refers specifically to learning information of the student. As for the formal description of ontology terms, most SPOnto ontology terms are formally defined as they have been extracted from literature and government manuals. For example, the term "*Profile*" is defined as representation of all the basic information relating to the student features such as student's background, goals, interest and preferences.
- **Consistency**, or coherence (Haghighi et al, 2013) requires the logical coherence of ontology concepts and elements and avoids contradiction or ambiguities. Any contradiction between explicit or inferred axioms and their definitions makes the ontology incoherent. As an example, the class "*verbal*" and the class "*visual*" were subclasses of both "*Learning_style*" and "*Physical_condition*". In one hand, these classes are defined as a learning style and in another hand; these are defined as a type of physical condition. However, the inferences were inconsistent. So, we removed these classes from "*Physical_condition*".
- **Conciseness**, means that there should be no unnecessary concepts or explicit redundancies between definitions in the ontology. In our ontological development and validation this aspect has been carefully considered. For instance, regarding SPOnto ontology, it included 2 classes "*Mental_capacity*" and "*Cognitive*" as subclasses of the class "*Learner_information*". "*Mental_capacity*" represented educational objectives such as cognitive, sensory and affective domains, based on the six cognitive categories of bloom taxonomy and "Cognitive" described some of mental processes such as intelligence and competence etc. Since we realized that categorizing cognitive is unnecessary and useless for our ontology, we have melted "*Mental_capacity*" and "*Cognitive*" classes into one class "*Cognitive_capacity*".
- **Correctness**, means that the ontology represents the correct modeling of the real-world concepts (Yu et al, 2005). This criterion has been carefully considered in SPOnto ontology development and validation. As an example, domain experts' feedback has led us to add the concepts "*Teacher feedback*" and "*Parent feedback*" since they constitute a key factor in student profile identification and validation of his predicted characteristics.

4 CONCLUSIONS

In the learning system, the major problem facing students is that they cannot obtain pertinent information based on their requirements which in turn produces a feeling of boredom and reluctance in the students and decreases their sense of motivation and

engagement. Among the solutions associated with content personalization in learning systems, dealing with the heterogeneity of student profile in different aspects is a complex task. But modeling an efficient student profile describes the best way a student prefers to learn and reflects his true needs which in turn would enhance the usage. Besides, in order to deal with the problem of motivation, we used gamification techniques. The paper proposes "SPOnto": an ontology of representation of student profile in a learning system which connects two concepts "gamification" and "adaptive learning". The study is carried out under two main criteria: the profile modeling approach and the characteristics used. The representation of a student profile is achieved using ontology. Our ontology allows to build a global model of the student based on many important characteristics in order to help to predict their intentions and preferences and the decision-making to personalize the learning scenario. The resulting ontology was evaluated by virtue of a criteria-based approach to check its design and content.

In future work, we intend to apply our model in an existing e-learning system, called "class-quiz", to analyze it in a real system and approve the efficiency of the student profile model on the basis of all these characteristics.

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