An Ontology for Smart Learning Environments in Music Education

Konstantinos Sofianos, Michail Stefanidakis

***Abstract*—**Nowadays, despite the great advances in technology, most educational frameworks lack a strong educational design basis. E-learning has become prevalent, but it faces various challenges such as student isolation and lack of quality in the learning process. An intelligent learning system provides a student with educational material according to their learning background and learning preferences. It records full information about the student, such as demographic information, learning styles, and academic performance. This information allows the system to be fully adapted to the student's needs. In this paper, we propose a framework and an ontology for music education, consisting of the learner model and all elements of the learning process (learning objects, teaching methods, learning activities, assessment). This framework can be integrated into an intelligent learning system and used for music education in schools for the development of professional skills and beyond.

***Keywords*—**Intelligent learning systems, e-learning, music education, ontology, semantic web.

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I. Introduction

NOWADAYS technology is used extensively in all aspects of education. The new terminology in today's digital world is: any learning, at any time, with any device. Traditional teaching methods with teachers in front of a blackboard lecturing and students watching are now ineffective. The need to adapt student teaching to new technological developments to ensure digital skills is now imperative [1].

Learning is a process that leads to a permanent change in an individual's behavior, it takes place socially but has a personal and individual character. Each individual learns in their own unique way within the society in which he or she lives. The changes of the individual through learning take place in the field of knowledge, skills and attitudes. Knowledge can be found in people, organizations, libraries, websites, books, journals, databases or any other source of information. Learning is enabled and facilitated by technology [2].

Smart communication devices and the computer are an integral part of students' everyday life and it is inevitable that new methods of teaching and learning through the Internet will come to the fore and, with the computer as the axis, contribute to the proper preparation of students for the 21st century. In addition, the use of the Internet enables e-learning, brings to the fore new methods of teaching and learning and enables students to interact with other students, collaborate with each other, sharpen their thinking and communicate with their teachers [3].

E-learning is now a mature learning model and has changed the educational design from an instructor-centered learning model to a learner-centered approach. It is also a promising field that is slowly emerging and promises many educational resources and tools as well as a variety of research and methodology tools. With the rapid developments in this field, personalization and adaptability have now become important features in educational technology [4].

The use of the World Wide Web has made it possible for teachers to use new educational tools, to have access to a wealth of educational material and to be able to easily and quickly obtain information and formulate teaching scenarios for their students during the educational process. Students can now search for information on the Web and form knowledge about a subject [5].

The constant growth of the web creates a problem of information overload. This problem is increased when a large number of irrelevant search results are produced by search engines based on keyword matching. To correct this problem, the learner can use an intelligent learning environment and technologies such as ontologies [6].

An intelligent learning environment is a learning environment that adapts to the learning needs of the users and provides the appropriate support (guidance, feedback, advice, digital tools) at the right time, analyzing the learning behavior of the learners, their performance and the environment (online or real) in which they find themselves [7]. Such an environment can help students acquire knowledge even when they are doing leisure activities. It plays the role of a wise friend who looks for opportunities to advise students in their daily life, taking into account their needs and preferences [8]. It is an improved ubiquitous context-aware learning system that leverages social technologies, sensors and wireless communication for inputs to determine the character of learners for a personalized learning experience. It includes innovative features and capabilities that improve students' understanding of concepts and performance based on their learning goals and preferences [9].

Smart devices and new technologies such as: cloud computing, fog computing, swarm computing, computer vision (Augmented Reality, speech recognition and speech synthesis, Big Data, Internet of Things (IoT), etc.) [10] play a key role in the deployment of intelligent learning environments. On the other hand, ontologies offer a new way of learning adapted to the different preferences and needs of learners, supporting the learning process and improving the capabilities of an e-learning system [11]. Also, ontologies represent knowledge in an

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accurate way and present the educational material to learners in an appropriate way [12].

This article proposes an intelligent learning framework that uses an ontology for music education. Each element in the framework performs a specific task and in this way the learning process becomes smarter and more efficient. The proposed framework combines learning objects and an ontology to enable the delivery of a personalized lesson plan for each individual learner [13].

The use of ontology improves the learning process, supports interoperability between different objects, achieves effective personalization and supports different elements of the learning process (learning objects, teaching methods, learning activities). It addresses learners with different learning styles and different levels of knowledge [14]

In this article, we focus on modeling the scale and diversity of knowledge of instructional design that includes context, goals, process, content, assessment, and learning environment.

Finally, this paper is structured as follows: in Section II, we provide an adequate background on the history of the e-learning ecosystem and related work analysis with ontologies, learning objects, the semantic web and content management systems for personalizing the learning environment. In Section III, we present the proposed framework with an appropriate systematic literature review on the application of an ontology to e-learning. Section IV provides a discussion on the proposed framework. Finally in Section V, conclusions and future work are presented.

II. Related Work and Research Methodology

The concept of e-learning is quite general and encompasses any form of distance learning, where the Internet resources or the capabilities of computers in general are used as a platform. It is a process of Web-Based Training (WBT) and requires the development of new skills and competences for course design, online assessment and interaction between learners and teachers [15].

Current technology has the potential to create e-learning environments that reflect learners' preferences and personal characteristics. Researchers confirm that such environments can be used in any learning situation and use ontologies [16], [17].

The term ontology was first used and defined by Tom Gruber in the 1990s. In his view an ontology "is an explicit specification of a conceptualization". It also provides a fertile ground for understanding, capturing, representing and interpreting the concepts of a domain [18].

Since the early 1990s, ontologies have been a popular research topic in the artificial intelligence community. In the last decade, with the introduction of the Semantic Web, ontologies have grown in popularity and more recently, the concept of ontology is now prevalent in the field of e-learning, enabling a richer description and retrieval of learning content, facilitating personalization and recommendation of learning content, curriculum design and learning assessment [19], [20].

Ontologies can be used successfully in education because they allow the representation of a learning domain to be shaped and support the creation of a new generation of intelligent learning systems that are personalized and tailored to the preferences and needs of learners [21]-[26].

Looking at the literature, we find that there are a large number of researchers who propose e-learning educational systems based on ontologies and semantic web technologies [27]-[35].

Nowadays, the constant exposure of students to the Internet and digital media (Smartphones, Tablets, and Laptops) has shaped a new way of learning and receiving information. The advent of Semantic Web in the field of music education comes to facilitate the integration of new technologies into the educational knowledge bases and bring innovation in the way teachers and students manage information [36]. Moreover, the use of ontologies in different areas of music education offers a higher quality learning and helps to search for data and information about music [37].

One ontology that has been developed and can be used in the field of music education is the Music Ontology [38]. Music ontology is a formal framework that defines concepts and relationships in the field of music. It is used to represent and publish information about music, help create music websites, integrate music-related data across multiple sources, and enrich search engines around music tracks, artists, musical works, etc.

Another ontology that utilizes Semantic Web technologies in the field of music education is the Music Theory Ontology which extends existing work by including theoretical concepts and basic elements necessary for the understanding and analysis of music [39]. The Studio Ontology includes standard procedures in audio as well as signal processing [40], while the Musical Instrument Ontology provides an ontological model for encoding and classifying musical instruments based on their sound or excitation production mechanisms [41].

Also, educational ontologies have been created in e-learning for learning musical instruments and for music performance and assessment of students [42], [43]. Other ontologies have been proposed for the domains of sound, music production, sound effects and aim to describe and retrieve sound sources on the Internet [44].

In this paper, the ontology is used to personalize an intelligent learning environment for music education and provides students with a learning package consisting of different components of the learning process.

In the literature, there are many differences in the way ontologies are developed and there is no single integrated methodology for constructing ontologies [45]-[47].

For the research, the descriptive method was chosen and articles on ontologies and the role they can play in a learning environment were searched. Protégé 5.5 was used to develop the ontology and the research questions for the development of an intelligent learning system include:

(i) knowledge modeling to facilitate the design and development of a smart learning framework in music education,
(ii) extraction of knowledge flows from theory to practice for appropriate adaptation to flexible training plans.

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III. Description of the Ontology

As we have seen in the previous section, research work focuses on how to personalize the learning process in order to meet the needs and requirements of students, but also to adapt it to their specific characteristics. In addition, researchers propose various learning frameworks that address the concept of personalization by using appropriate learning objects.

An educational package contains various components of the learning process such as teaching methods, learning objects, assignments and assessments. To achieve this goal, we propose an intelligent ontology-based learning system. The architecture of the proposed system consists of four levels as shown in Fig. 1.

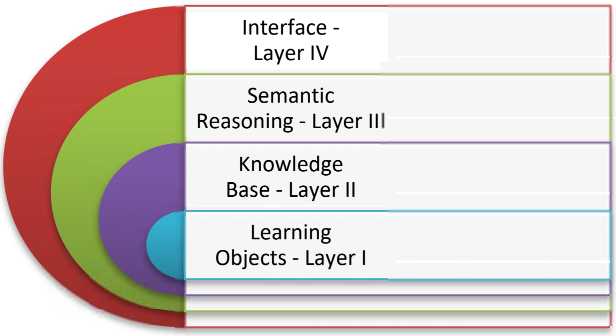

Fig. 1 Architecture of an intelligent learning system

The first layer of learning objects is the heart of the intelligent learning system and includes courses with information about them linked to the ontology.

The second level, the semantic level, contains the semantic representations of the overall learning process. It incorporates the ontology of the learner, the teacher, the teaching methods and the learning activities, using the Web Ontology Language (OWL). It also annotates concepts and the relationships between them (metadata - description of knowledge representation) [48].

The third layer, the semantic reasoning layer, is a piece of software where the Semantic Web Rule Language (SWRL) is used to provide the learner with a personalized learning package that meets their needs and requirements, as well as their specific characteristics.

The fourth layer, the interface layer displays the retrieved complete learning package which consists of learning objects, learning activities and teaching methods. The elements of this layer implement the functionality required for the learner to be able to use the intelligent learning environment.

A. Student Model

The evolution of technology is introducing new solutions to improve the learning environment and facilitate learning. Today's learning environment must be more flexible and adaptable to the preferences, interests and different characteristics of learners [49].

The elements that form the basis of an e-learning system are the learner model, the learning objects, the learning activities and the teaching methods. The Learner Model is considered the most important element and also the most necessary for the personalization of an intelligent e-learning system [50].

Learner modeling is the process in which an intelligent learning system creates and updates a learner model by collecting information from various sources by observing the learner's behavior or through the input of information directly from the learner [51]. It stores and represents information about the learner's personal preferences, prior knowledge, learning performance, interests, learning styles and learning goals [52]. The personalized learning path defined by the learner model contains the different preferences and needs for a learner [53].

B. Learning Style

Each learner has his or her own way of learning and prefers to receive information in a specific format to achieve a learning goal. Individualizing the learning process according to the learning style, make students able to learn in a more effective way, improve student performance and enable the learner to achieve their goals [54].

Learning style can be defined as a specific way in which the learner thinks, processes information and is the best and appropriate method by which the learner acquires skills and knowledge. The Felder Silverman learning model has become the most appropriate model for computer-based educational systems and is the most widely used [55], [56]. The Felder-Silverman model defines learning style as “the characteristic strengths and preferences in ways that individuals undertake to process information”. The model posits that individuals have preferences among five bipolar continuums: Active-Reflective, Sensing-Intuitive, Verbal-Visual, Sequential-Global and Inductive-Deductive [57]. Nevertheless, Dr. Felder later dropped the bipolar continuum Inductive-Deductive in 2002 [58].

We rely on this model to identify the student's learning style and recommend the appropriate learning objects.

C. The Proposed Ontology

The ontology of the proposed model includes five classes that cover various characteristics for each user (learner or instructor), but also learning objects, teaching methods, educational activities, student assessment and feedback, (Fig. 2).

Fig. 2 The proposed ontology

The User class includes two subclasses (student and instructor) where information about a user, student or instructor, is collected (Fig. 3).

The student's information includes the user's learning background, learning goals, learning style, difficulty level and time spent studying. The personality category stores the learner's personal information, preferences, interests, language spoken, social style and means of communication. Of the

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previous characteristics, personal information is a key feature when describing a learner model, while basic knowledge, learner performance, preferences, learning goal and interests [57].

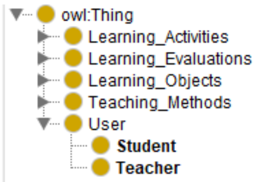

Fig. 3 The User class

D. Learning Objects

There are many standards about learning object metadata; but, in fact, metadata is not enough because there is often a lack of reasoning and reusability [58]. Moreover, access to a learning object is an important issue and requires very good design and organization.

In our ontology, the learning object class consists of different courses, where each course consists of different modules. Each module introduces information about the content of the course and includes a set of domains. Each domain consists of one or more topics that include the knowledge that each learner needs to successfully complete the module (Fig. 4).

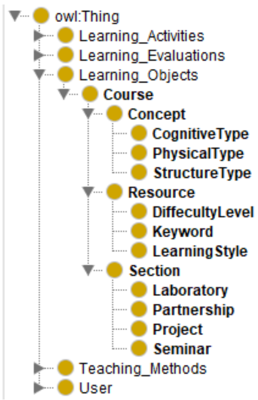

Fig. 4 The class of learning objects

Learning objects have a cognitive type, a physical type (video, sound, shapes, text, image), a structure (hierarchical or serial), a level of difficulty, a keyword, a learning type and a module (workshop, collaboration, project, seminar) [59].

E. Learning Activities

Learning activities are defined as any activities of a learner to enhance their knowledge, skills and abilities. There are a variety of learning activities that help students learn better.

Felder and Silverman (1988) suggest a range of teaching approaches that are consistent with learning preferences [60]. For active learners, group work and trial and error activities are suggested; for reflective learners, time for thinking, individual work and taking notes are suggested.

For sensory learners, facts, problem solving, working with details and connections to the real world are suggested; for intuitive learners, the possibility of discovering and realizing new concepts and working with abstract concepts is suggested; for visual learners, pictures, diagrams, films and demonstrations.

For verbal learners, listening to information, discussion and recording lectures are suggested; for sequential learners a gradual approach to the material is suggested; for global learners a holistic presentation of the big picture and intuitive work is suggested.

Learning activities are categorized according to Felder Silverman as shown in Fig. 5 [60].

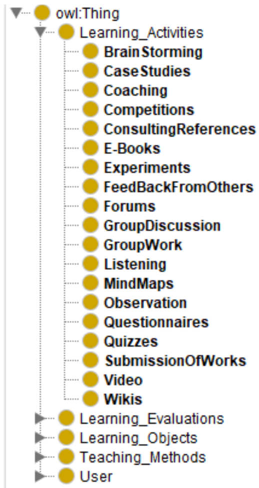

Fig. 5 The class of learning activities

F. Teaching Methods

The emergence of teaching methods in the learning pathway enhances the learning experience of learners tailored to their needs. An effective teaching method engages learners in the learning process and enables them to improve critical thinking skills, blunt their imagination and develop analytical skills. There is a set of teaching methods that help students to choose their own way of learning and thereby improve the learning process (Fig. 6) [60].

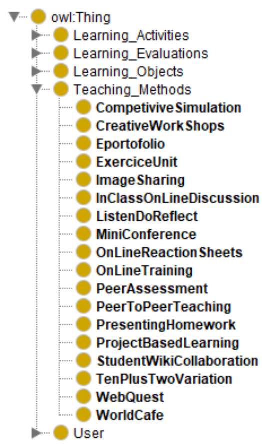

Fig. 6 The class of teaching methods

According to iCOPER D3.1 [61], [62], there exist many

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teaching methods such as: creative workshops, project presentations, listening, reflection, e-portfolio, web-quest, world cafe, concept maps, use of images, online discussion, online discussion, student collaboration through wikis, online class discussion, and brainstorming.

G. Evaluation

Assessment is a very important part of a smart learning system. Especially in the field of music education, assessment is particularly difficult and often requires feedback (Fig. 7).

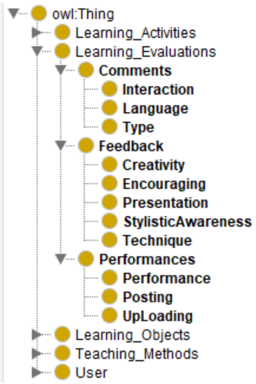

Fig. 7 The Evaluation class

Our ontology includes data properties that have to do with the assessment of students in the context of music education, which is a very challenging task. The Comments family includes the properties Criticize, Mood, Opinion, Practice, Praise, ProvidingFeedForward, Question, Reply, Request, and Smileys.

Regarding the skill and stage presence of the students a number of properties have been incorporated, such as: MovemeDexlelerity MovemeEase, MovemeIndependence, SenseofBreathing, PresenCommunication, PresenEffectiveness, PresenStagePersona, PresenStagePresence, Sound_Balance, Sound_Cohesion, SoundDynamicChange, StylisArticulation, SoundDynamicControl, SoundTimbreControl, StylisDynamicChange, StylisTempoChange, StylisTexture, StylisTimbre.

Giving feedback to students is a quite difficult task and at the heart of learning a musical instrument. It provides vital information about student performance and can come from a variety of sources, both physical and social [63].

When feedback is given correctly it has a positive effect on student performance and learning. For this reason, we have incorporated in the ontology a Feedback family which includes properties related to rhythm, skill and encouragement of students, such as: AccuraArticulation, AccuraNote, AccuraPulse, AccuraMetr, AccuraPiction, AccuraRhythme, AccuraExpressiveMarkings, AccuraFingering, Drive, Flexibility, EncourModels EncourCompontes, EncourStrategies, etc.

The ontology we have developed can be used for feedback and assessment of students in the context of music education, but it can also contribute decisively to the positive impact on students' learning and final performance.

Finally, based on research from the international literature and after discussions with music education teachers, we concluded that the evaluation of students can be based on a Likert-type scale (1 = Poorly, 2 = Moderate, 3 = Good, 4 = Very Good, 5 = Excellent) [64]-[67].

H. Data and Object Properties

The object properties we have added to the ontology (hasLearningActivities, hasLearnningObjects, hasTeacher, hasTeachingMethods, tutorOf) represent the relationships between objects in the ontology.

The data properties referring to the student's personal information, aesthetic factors, interests that make up the student's profile, learning goals, and learning style are presented based on the Felder-Silverman model in Table I.

TABLE I
DATA PROPERTIES

Data Property Name	Description
Personal information	
Demographic data	Personal information (Address, date of birth, e-mail address, etc.) (First name, last name, gender, name of institute, institute URL, phone)
Preferences	
Aesthetics	Aesthetic factors (color, font) for aesthetic and visual communication
Interests	Interests (activities, hobbies)
Language	Students' preferences for the language of the learning objects (preferred language, spoken language)
MediaType	Means of communication
SocializationStyle	Social press
UserProfile	
Identification	Student registration number
Security	User name and password
UserEducation	
BackgroundKnowledge	Previous knowledge, experience, qualifications
LearningGoals	Objectives set by the student
LearningStyle	Student learning style based on the Felder-Silverman model
LevelDegree	Level of difficulty
StudyofTime	Average study time daily

The properties at Table I contribute to the formation of the student's profile, which will guide an intelligent learning system to adapt to a student's learning needs and learning goals.

IV. Evaluation and Validation

To evaluate and validate our proposed ontology we used the Hermit 1.3.8.413 software. It is a reasoning tool that offers a set of functions to identify conflicting axioms through the consistency function and offers data type verification, model evaluation, anomaly detection and correction.

The evaluation verifies the syntax and semantics of the ontology taking into account the scenario and the end-users, in order to integrate the learner model into the smart e-learning system. The check performed with the help of the software showed that there is no contradiction between the axioms and this means that the designed model is in accordance with the

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OWL language specifications. Finally, the elements of the ontology are presented in Table II.

TABLE II
ONTOLOGY METRICS

Metrics	Value
Axiom	864
Logical axiom count	591
Declaration axioms count	261
Class count	72
Object property count	55
Data property count	133
Individual count	25
Annotation property count	1

A. Semantic Rules

Ontologies as a key component of the semantic web can be used in the field of e-learning to represent the knowledge of a domain. However, the use of ontologies is severely limited by the processing mechanisms that are an important part in this form of representation.

In order to be able to test an ontology against the logical level of Semantic Reasoning, ontology creators use the SWRL which is a proposal for a language for representing knowledge in the form of rules. It combines the sublanguages of the OWL web ontology language (OWL DL and Lite) with those of the rule markup language (unitary/dual Datalog RuleML).

The proposed rules are in the form of an inference:

$$B_1... Bn \text{ --> } A_1... A_m$$

where $A_1... A_m$, $B_1... B_n$ may be of the form C(x), P(x, y), same as (x, y), or different from (x, y) where C is a description of OWL, P is an OWL property, and x, y are variables, OWL constants or data values.

Each rule consists of a body and a head and is stored as an OWL instance within the ontological model. Writing a rule may seem simple, but in reality, its design and configuration is a complex process and should take into account every possible personalization scenario [68].

This proposed ontology includes a set of rules that relate to three different aspects of the educational process and are used:

- First, to determine the student's level of knowledge,
- Second, to encourage students to study appropriate learning objects and,
- Thirdly, to suggest appropriate tests for the student's assessment.

In their general form, the rules take the following form as shown in Table III.

B. Integration in an Intelligent Learning System

The Internet as a technology provides students with various tools according to their needs and preferences. It offers new and more effective methods for students to use these tools, to communicate, collaborate, carry out research, interact with the learning environment and receive the appropriate educational package (learning objects, learning activities) [69]. This ontology can be used by an intelligent learning environment and Fig. 8 illustrates a use case scenario showing the actions and reactions between the system and the learner.

TABLE III
SWRL RULE

# General Rule	SWRL Rule
IF (Student has education level "secondary") THEN (Student has Computer Literacy "beginner")	Student(?x)^EducationLevel(?x, "secondary") → ComputerLiteracy (?x, "beginner")
IF (Student has knowledge level of Concept_1 "good") THEN (Student should study Concept_2)	Student (?x) ^ is_Concept (?y, "Concept_1")^ConceptKnowledgeLevel(?y, "good") → Study(?x, "Concept_2)
IF (Student has knowledge level "poor" AND Access Material > 30) THEN (Student should do Exercise Difficult Level "1")	Student(?x)^ConceptKnowLevel(?x, poor")^AccessMaterial(?x, ?m1)^greater Than(?m1,30)→ DiffultyLevelofExercises(?x, 1)

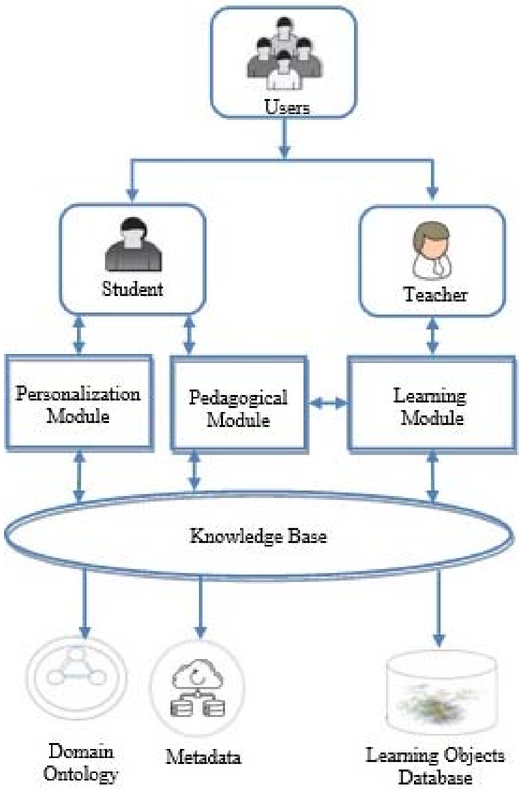

Fig. 8 System Architecture

When a student accesses the platform for the first time, they are asked to register and fill in a form with personal details (name, demographic data, contact details), password, qualifications and interests, all of which constitute their personal data.

The student is then asked to answer a set of psychologically concerned with questions designed according to the Felder-Silverman model in order to identify his psychological characteristics such as his learning style, cognitive abilities and preferences through a menu of options, where these constitute the cognitive data. For example, if the student is a sensory

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learner, facts, problem solving, working with details and making connections with the real world are suggested, while for visual learners, pictures, diagrams, films and demonstrations are suggested, and for verbal learners, listening to information, discussion and video lectures.

Once the student has completed the registration process or already has an account they can log in, they are asked to define their learning objective and answer a series of questions to assess their level of knowledge before accessing the course. The system initializes the learner's knowledge of this field and assigns an appropriate learning objective.

Based on the previously collected information, the system continues to suggest the appropriate course through the selection and combination of relevant learning concepts and their presentation in a tailored way to create the learning activity that will help him/her to acquire appropriate skills for the successful outcome of a Conservatoire examination or national qualification examinations.

Finally, when the learning activities of the course are completed and all the individual objectives have been achieved, the student is assessed and the educational process is completed.

V. Conclusion and Future Work

In an e-learning context, ontologies allow semantic annotation of data (e.g., student profiles, educational content) and offer a better organization of the data, better ways of searching and management, in order to suggest to the learner, the appropriate educational material based on the profile stored in the ontology [70], [71].

An intelligent learning environment is envisioned to make learning more accessible to everyone, regardless of location, learning status and preferences. Students and teachers now use smart devices and this contributes to learning and transforms the way they solve problems, acquire skills and knowledge [72].

The review of the literature shows that there are many studies that use ontologies in a learning environment. Most of them focus on personalization and provide students with appropriate learning objects based on their particular characteristics and preferences, ignoring some key elements of the learning process.

This article reflects the important role that an ontology plays in an intelligent learning environment. It facilitates finding and plotting a learning path, while ensuring at the same time the effectiveness of an intelligent learning environment making it more flexible and efficient.

In this paper, we have presented an ontology oriented to music education which can be used as an embedded module in an intelligent learning system and can be easily accessible through a web-based application. The ontology consists of five classes (users, learning objects, teaching methods, learning activities, assessment) and appropriate object and instance properties. Moreover, as one of the main advantages of the proposed model, the ontology has been enriched with a set of semantic rules (SWRL) which enable the personalization of the learning environment and the classification of students into different categories according to their learning profile and interests.

For the design and implementation of the ontology we used Protégé software and for the validation of the ontology the Hermit software. Finally, for the visualization of the ontology data we used GraphDBFree software which helped us to get a real sense of the power of the RDF model and the relationships between the data [73]-[75].

Within the process of designing and building an ontological adaptive model, we intend future work to search and analyze in detail all aspects of the "psychological state" dealing with learning styles, students' interests, social skills, discussion groups, emotional characteristics and cognitive abilities to enrich the proposed ontology.

We plan to take advantage of the semantics contained in the users' metadata to implement a clustering method of students with common characteristics. This will help in the creation of more precise learning activities based on collaborative learning, where we can have a group moderator, but also the distribution of students with common interests and characteristics in different discussion and sharing groups.

Furthermore, the most challenging part of our research was the selection of the characteristics of a learner to be included in the ontology that would be compatible with existing learner modeling standards. We plan to add more rules in order to cover as many student profiles as possible. The same goes for the assessment-feedback cycles in the field of music education since this is a critical and continuous process too.

Finally, we intend to connect the proposed ontology with the help of a Moodle platform to a set of Massive Open Online Courses (MOOCs) through appropriate plugins to implement an intelligent learning system and provide a set of learning objects and learning activities to students in the field of music education.

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