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Providing pervasive Learning eXperiences by Combining Internet of Things and e-Learning standards

Proporcionar experiencias de aprendizaje ubicuo mediante la combinación de Internet de las Cosas y los estándares de e-Learning

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Abstract

Nowadays, learning is more and more taking place anywhere and anytime. This implies that e-learning environments are expanded from only virtual learning environments to both virtual and physical ones. Thanks to the evolution of Internet, ICT (Information and Communication Technology) and Internet of Things, new learning scenarios could be experienced by learners either individually or collaboratively. These learning scenarios are Pervasive in such a way that they allow to mix virtual and physical learning environments as well. They are therefore characterized by possible interactions of the learner with the physical environment, the Learner's contextual data detection as well as the adaptation of pedagogical strategies and services according to this context. This paper aims to take advantage of this trend and keep up also with existing e-Learning standards such as IMS LD and LOM. The solution proposed is therefore to extend these standards models with that of Internet of Things and to provide an adaptation approach of learning activities based on learner's context and her/his track using the eXperience API. In this context and in order to allow both reasoning capabilities and interoperability between the proposed models Ontological representations and implementation are therefore proposed. Moreover a technical architecture highlighting the required *software* components and their interactions is provided. And finally, a relevant pervasive learning scenario is implemented and experimented.

Resumen

Actualmente, el aprendizaje está teniendo lugar con mayor frecuencia en cualquier lugar y en cualquier momento. Esto implica que los ambientes del aprendizaje electrónico se expandan desde los entornos de aprendizaje solo virtuales a entornos que implican espacios físicos. Gracias a la evolución de Internet, las TIC (Tecnologías de la Información y Comunicación) y a la Internet de las Cosas, se pueden experimentar nuevos escenarios de aprendizaje por parte de los estudiantes, ya sea individualmente o en colaboración. Estos escenarios de aprendizaje ubicuos, permiten compaginar tanto ambientes virtuales como ambientes físicos. Por tanto, estas experiencias se caracterizan por las interacciones posibles del estudiante con el entorno físico, la detección de los datos contextuales, y también la adaptación de las estrategias pedagógicas y de los servicios según el contexto. Este artículo pretende aprovechar esta tendencia y sustentarla en las normas existentes de aprendizaje electrónico como IMS LD y LOM. La solución propuesta es extender los modelos de normas de aprendizaje electrónico como IMS LD y LOM para soportar Internet de las Cosas y para aportar un enfoque de adaptación de las actividades de aprendizaje según el contexto del estudiante y su huella digital utilizando la API eXperience. En este contexto y con el fin de permitir las capacidades de razonamiento y la interoperabilidad entre los modelos propuestos se proponen representaciones ontológicas y una implementación de la solución. Además, se plantea una arquitectura técnica que resalta los componentes de software necesarios y sus interacciones. Y, por último, se implementa y se evalúa un escenario de aprendizaje ubicuo.

Keywords:

IMS LD; LOM; Experience API; Internet of Things; smart objects; smart learning objects; smart learning environment.

Palabras Clave:

IMS LD; LOM; Experience API; Internet de las cosas; objetos inteligentes de aprendizaje; ambiente inteligente de aprendizaje.

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1. Introduction

In the past, learning was classroom based. Students come to school and have face-to-face interactions with their teachers. With the advent of Internet, the e-Learning concept appears and continues to progress as in (García-Peñalvo, 2008; García-Peñalvo & Seoane-Pardo, 2015). Instructional designers create courses to be packaged and delivered to the learners within a Learning Management System (LMS). An LMS provides the learner with relevant Learning Objects (LO) and activities, which results on learning processes to follow and the learning objectives to achieve. In this context, learners' tracking were provided when possible by standards such as SCORM (Chandra *et al.*, 2014) allowing later teachers as well as LMS administrators to analyze learners' data and make relevant pedagogical decisions. This allows offering multiple services including the learner guidance during the learning process. But it has also many drawbacks like (a) The lack of pervasive learning activities, (b) Learners could only use learning objects provided by the LMS, (c) Resources allocation at design-time makes difficult reusability across different learning contexts and metadata standards. In addition, whenever, the learner uses physical or tangible learning objects, there is no means for keeping track of those actions. Nowadays, mobile and pervasive devices impact more and more everyday lives of individuals. Specifically, those devices are increasingly integrated into learning scenarios, in such a manner that learning environments become equipped with smart objects including smart LOs integrating ubiquitous things like sensors, NFC, RFID, etc. These devices are context-aware and adapt their behavior accordingly to the learner's needs and current context. Additionally, the Internet of Things (IoT) provides new opportunities for instructional designers and teachers especially those interested by experimental learning. Thus, they could take advantages of these new capabilities by developing pedagogical approaches that leverage the technologies emerging in environments around us (Watson *et al.*, 2013). However, designing these complex scenarios requires (a) the use of standards that allow on one hand to structure learning activities and to assign roles and on the other hand to overcome reusability and interoperability of these designs (b) tracking one's learner's learning experience from any environment be it digital or physical to be later used for other purposes like assessment or learning scenarios adaptation.

The main contribution of the present paper is therefore to extend IMS LD (Learning Design) and IEEE LOM (Learning Object Metadata) standards with Internet of Things to model context aware scenarios based on semantics of learning resources and smart objects and taking into account learner's previous interactions and achievements. Our ultimate aim is to keep track of the learning experience using eXperience API then adapt the learning scenarios based on this track.

Therefore, the rest of the paper is structured as follows:

In section 2, we describe a motivating scenario and its research issues and challenges. In section 3, we present e-Learning standards that we consider relevant in the context of the present work. In section 4 research work related to approaches that have combined in a certain manner the IoT, the semantic Web, e-Learning and standards as the IMS LD are presented. A comparison and a synthesis will allow us to make a check list of limits and drawbacks of those approaches.

In section 5, we will describe our proposal that consists mainly on a combination of IMS LD, IoT and xAPI. In section 6, we use ontological models and NFC technology for the implementation and the experimentation. Finally, in section 7, we conclude and outline our future works.

2. Motivating scenario description and analysis

To introduce the work depicted in this paper, we present in this section a motivating learning scenario and its related research issues and challenges.

2.1. Scenario description

Bob is a natural science teacher interested by technology. He attempts to create a smart learning environment by using social, mobile and ubiquitous learning aspects. He proposes to his students an environment for learning Human anatomy systems including 3D human body puzzle where learners could interact with each other to acquire skills related to those anatomy systems, their components and functioning modes. At the beginning, Bob introduces the course. Then, he proposes a collaborative activity where learners could interact with a 3D human body puzzle by the use of Near Field Communication (NFC) technology. Students are equipped with NFC enabled active devices to store information about a specific part of the 3D human body puzzle. This collaborative activity aims to test the students' comprehension level.

2.2. Issues and challenges

IoT provides a diversity of connected objects and several interactions' possibilities with the physical environment. This provides opportunities to explore its advantages using physical and virtual objects. These things interact between them and with users

including learners, teachers and instructional designers.
The main challenges here are:
(1) How to integrate physical learning objects with e-Learning objects and activities?
(2) How to keep track of individual or group learning activities and achievements?
(3) How to adapt learning scenarios accordingly to user's or group's context based on the historical stores?

3. Useful e-learning standards

3.1. IMS Learning Design (IMS-LD)

The IMS LD specification is developed by IMS GLC (IMS Global Learning Consortium) in 2003. It is the only available interoperability specification in the area of technology enhanced learning that allows the definition and orchestration of complex activity flows and resource environments in a multi-role setting (Derntl *et al.*, 2012; Berlanga & García-Peñalvo, 2005; Berlanga *et al.*, 2006). The IMS LD is based on the principle that considers a Learning process as a play metaphor (IMS LD, 2015). Each person has a role and performs a set of activities. A method is the main element of an LD scenario. It helps coordinating the activities of each role. It consists of one or more play(s), acts and role-parts. A role-part contains a reference to a role and a reference to a particular structured activity. An activity is either simple or composed. It has a learning or a supporting purpose.

3.2. IEEE Learning Object Metadata (IEEE LOM)

Learning Object Metadata (LOM, 2002) is an e-Learning standard published in 2002. It is considered as the most adopted content tagging specification. It is used for learning object annotation using metadata. LOM proposes classification of metadata elements into nine groups: General, lifecycle, meta-metadata, technical, educational, rights, etc. The advantages of adding metadata to learning objects aim to ensure interoperability and re-use of LOs, adaptability as well as sustainability.

3.3. Experience API (xAPI)

The Experience API (xAPI, 2013) is a new specification arising from the Tin Can project. It allows collecting data from an LMS or any other learning environment (an Intelligent Tutoring System or a game or also a classroom, etc.) and storing it in a repository called Learning Record Store (LRS). The information is structured into statements. These are formed at least by three components: an actor (e.g., John), a verb (e.g., plays) and an object (e.g., a game). There are also other components that add more information to statements like the context element. Statements are delivered by the hosting LRS on demand by an LMS, another LRS or also a reporting tool.

4. Related works

4.1. Works related to e-Learning standards

Authors in (Chikh, 2014) present a learning design objects' general model for the description of LD Objects (LDO). This model uses the LOM concepts and adapts them to establish taxonomy for learning scenarios.

Work in (Vidal-Castro, 2012) proposes an IMS LD ontology composed of 3 sub-ontologies: the first one represents concepts and relationships related to the elements of an LD accordingly to the IMS LD standard, the second one organizes concepts related to the LD resources and the final one represents learning objects metadata.

LOM is used to target the IMS LD learning objects by giving specific information on them. Pervasive LOM (PLOM) is an extension of the IEEE LOM for pervasive environments. It is used to augment context-awareness of learning sources and resources (Atif & Mathew, 2013). PLOM concepts add useful information to learning objects like location which provides a record of how an object is traced from its virtual location to its physical one, its capability to know the functionalities and services and its friends to find quickly with which other objects it could communicate and finally to facilitate composition of LOs.

IMS LD and LOM are used in ontological approaches but not for pervasive purposes. Only authors in (Atif & Mathew, 2013) use LOM in the context of pervasive environments. But, none of these works have included xAPI in order to keep track of learners' activities and achievements.

4.2. IoT and semantic Web

The W3C semantic sensor network incubator group develops an ontology that describes concepts used for sensing like sensors, sensor devices and sensor measurement capabilities. This ontology is named Semantic Sensor Networks (SSN) ontology. Authors in (Compton *et al.*, 2012) describe this ontology and give examples of use cases.

SENSEI [1] is an example of project that uses the SSN ontology. It aims at developing a framework of universal services interfaces for Wireless Sensor Networks (WSN) to realize the future of Ambient Intelligence while work depicted in (Presser *et al.*, 2009) establishes a model of sensors, actuators and processors as resources.

Authors in (De *et al.*, 2011) present an information model defining main concepts and components of the IoT domain and providing a formal representation of them. It is composed of an entity, a resource as well as an IoT services models. The main concepts are device, entity, resource and service. A device is attached to an entity that is associated with a resource. This resource controls the device and gives information about the entity. The service concept provides the required functionalities for interaction between entities and their related processes.

An overview of a service-oriented middleware using semantic technologies is presented on (Hachem *et al.*, 2011). This work focuses on modeling a set of ontologies describing devices, their functionalities and hardware devices that may exist in a network.

Finally, the approach presented in (Christophe, 2011) consists on modeling the Web of things paradigm using semantic profiles. This model allows the representation of a real world object as a virtual one. A proposed framework permits the discovery of any connected object and its use in a Web application.

4.3. Learning scenarios including IoT

Authors in (Gómez *et al.*, 2013) propose a system that allows students to interact with physical objects, which are virtually associated with a learning subject. The Unit of Learning (UoL) presented deals with Systems Engineering. It includes a practical activity to identify the function of each hardware element and computer operation. The learning objective is to know the function of each hardware device of a computer system. Before engaging learners into practical activities, the system provides learning objects about the computer hardware. Students have to work on those LOs. In practice, the laboratory labeled with Near Field Communication (NFC) tags insure communication with learners' mobile devices. Each learner interacts with physical objects and the corresponding augmented objects explaining the operation of each hardware component. Results analysis of this work proves improvement of students' learning outcomes.

Authors in (Chin &Callaghan, 2013) propose a hierarchical smart box used as a living lab. A living lab is a living environment housing people and technology in a semi experimental setting. Within this environment, an example of scenario of community of things takes place using the Pervasive Interactive Programming (PiP) Language. This latter is used for teaching computer programming and allows learners to easily create their own programs. Learners are asked to program coordinated activities: for example when the phone rings, the lamp raises and the media player stops. The learner logs into the system and translates the description written into a program thanks to PiP and its graphical representations of Things. The system converts the smart things behavior into rules and then the learner executes the program. This work's advantage is that it combines PiP, IoT and Living Labs.

Authors in (Domingo, 2012) provide an overview of IoT intended for people with disabilities including children. An example of school scenario includes the use of IoT for deaf children. They scan the RFID tags embedded into books; the text is translated into videos and launched in a computer. This scenario can be used not only for children but also for other categories of people with small modifications but keeping the same idea.

4.4. Learning scenarios including IMS LD and IoT

University of Things (UoT) (Luque *et al.*, 2011) is a novel paradigm that brings university and its services close to students and society in general, thanks to IoT technologies anytime, anywhere. To fulfill this paradigm, authors in (Borrego *et al.*, 2013) create a system named Pinakes based on IMS LD ontology and NFC technology. Equipped with a mobile phone with NFC tags, the learner scans bibliographic resources to pick up information related to books existing in the library, teachers' notes strewn at their offices or classrooms to pick up information, their suggested books' titles or their advices and finally their email addresses to communicate with them.

The approach presented in (Anasol *et al.*, 2012) proposes the creation then the use of a virtual laboratory by the combination of xReality, virtual objects and learning activities in a mixed reality learning environment. The mixed reality activities that are structured as a sequence of learning activities based on IMS LD standard aim to help geographically dispersed learners to produce IoT projects. These activities are performed using Fortito's Buzz Board Educational Toolkit (Callaghan, 2012). This toolkit is composed by a variety of hardware components that form xReality Objects and software modules and used to create IoT objects.

In a previous work, (Taamallah & Khemaja, 2014) have proposed models that combine IMS LD and IoT in learning scenarios. The work in the present paper constitutes an extension to those models, by also extending the LOM

standard to pervasive learning environments. The main focus of this paper is to adapt learning scenarios based on the learner's historical data, his preferences, his learning and environmental context by making use of the xAPI and a suitable architectural model for learning scenarios execution.

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5. El instrumento

We highlight again the challenging issues that the solution we propose will address. These issues are the following:

(1) How to integrate physical learning objects with e-Learning objects and activities?

(2) How to keep track of individual or group

learning activities and achievements?

(3) How to adapt this scenario accordingly to user's or group's context based on the historical stores?

To answer to question (1), we propose to extend IMS LD and LOM with IoT. Exploring IoT technologies such as NFC, RFID and sensors in educational environments offers many benefits such as providing context aware activities and associating learning and smart objects to the corresponding activities.

To answer to question (2), we use eXperience API model.

To answer to question (3), we explore the historical data, learner's preferences and actual context to adapt the scenario.

5.1. IMS LD model and its extension

To adapt IMS LD and allow its use in the context of new educational issues, we consider four LD extension points (figure 1):

1) The LD environment concept could represent either a physical environment like a classroom or a virtual environment like an Intelligent Tutoring System or an LMS.

2) A physical environment is an environment where the learner interacts with tangible objects and performs physical activities. Compared to a physical environment, a virtual environment is an environment where the learner performs virtual activities and use digital resources.

The physical environment concept is therefore extended with tangible and intelligent objects. These objects could be IoT objects or physical learning objects. This extension is explained in details with the IoT model in figure 2.

3) The learning object concept is extended with that of physical learning object.

4) According to IMS LD specification, an activity could be either a learning activity or a support activity. We extend the activity concept with other types of activities like physical activity or virtual activity.

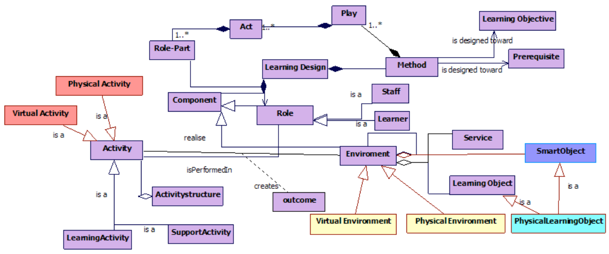

Figure 1. IMS LD extension

5.2. The IoT model

A smart object contains a hardware and software components. But each of these kinds of components is self-contained and can exist without the other. IoT devices can be classified into four types: a) Sensor device which is capable of measuring a physical property of the real world. b) Actuator that is capable of performing an operation on or controlling a system or a physical entity in the real world. c) Processor that performs computation operations on data. d) Composite that is composed by at least two of the devices types (Hachem *et al.*, 2011). (Latorre García *et al.*, 2013) categorizes smart devices in a remote laboratory context according to their services like authentication and authorization, discovery, learning analytics, metadata, etc. But these services could be applied to any smart device. Each physical device has a virtual representation that allows the communication with other devices and/or with Web resources. The IoT model illustrated in figure 2 describes the previous concepts.

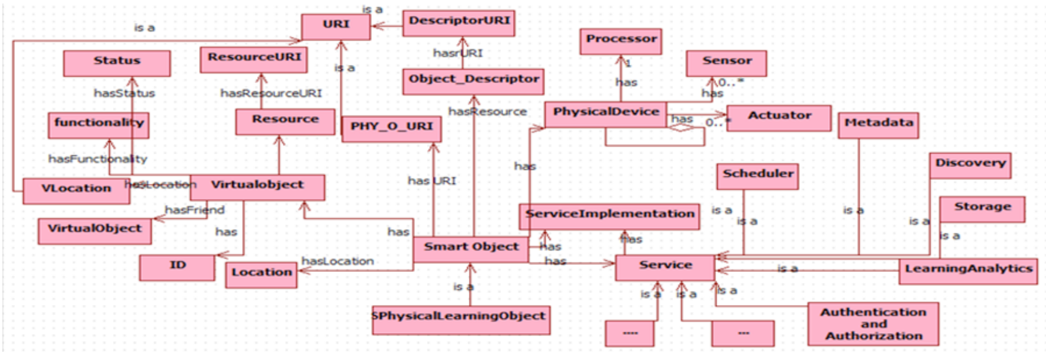

Figure 2. IoT model

5.3. PLOM model

According to IMS LD, Learning Objects (LO) are defined as reproducible and addressable digital or non-digital resources for learning purposes. LOM is used to target the IMS LD learning objects by giving specific information on the object. We extend IEEE LOM to pervasive environment (figure 3). The identifier and the location are some learning object's characteristics.

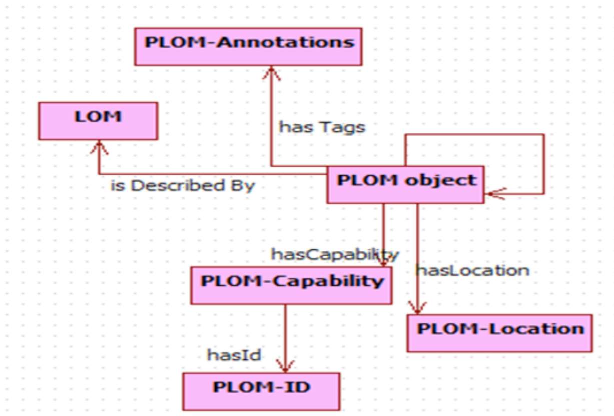

Figure 3. PLOM model

5.4. xAPI model

The xAPI model presented in figure 4 is formed by the important concepts of the xAPI specification, which are described in table1. The xAPI is helpful for a) a learner to know his previous performed activity b) a learner's colleagues to know the learner previous activity in the case of collaborative learning c) a learning scenario monitoring and adaptation.

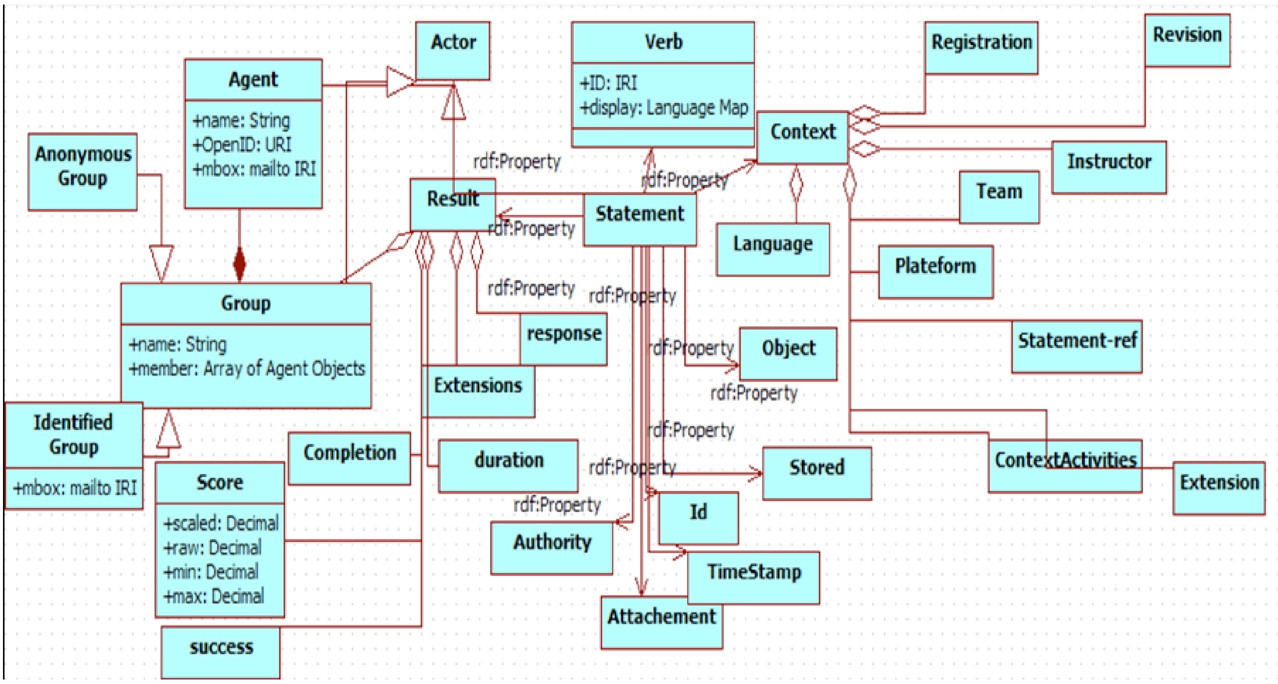

Figure 4. xAPI model

Concept	Description
Unique Identifier	identifies a statement. It is generated by an activity provider. If the statement is received without an id, the LRS generates one.
Actor	is an identity or a persona of an individual (an agent or a group) tracked using statements as doing an action within an activity.
Verb	defines the action between Actor and Activity.
Object	is the subject of an activity realized by an actor.
Result	represents a measured outcome related to the statement.
Context	defines the setting in which an activity occurs.
Timestamp	is the time at which the experience occurred.
Stored	is the time at which a statement is stored by the LRS.
Authority	verifies the validity of a statement by providing information about whom or what has asserted that this statement is true. It also observes and verifies the performance and the context that defines the setting.
Version	represents the statement associated xAPI version.
Attachment	is a digital artifact providing evidence of a learning experience.

Table 1. xAPI concepts

5.5. Toward a global model

This global model (figure 5) presented in this sub-section defines appropriate associations between concepts. Tables 2 and 3 highlight mappings between concepts, which allow interoperability between models.

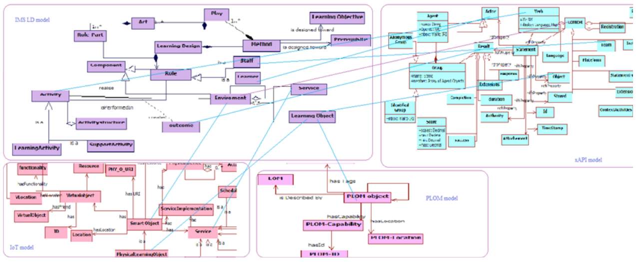

Figure 5. Toward a global model

IoT concepts	IMS LD concepts	PLOM concepts
Learner	Learner	
S Physical Learning Object	Learning Object	PLOM object
Service	Service	

Table 2. Mapping between IoT concepts, IMS LD concepts and PLOM concepts

IMS LD concepts	xAPI concepts
Learner	Actor
Activity	Verb
Learning Object	Object
Outcome	Result
Environment	Context
Staff	Team

Table 3. Mapping between IMS LD concepts and xAPI concepts

5.6. The proposed architecture

The execution of the proposed solution requires the creation of a relevant environment. This environment should be pervasive and give back track of learners' experiences. The figure 6 illustrates the proposed architectural model. This model is service oriented and contains flexible and modular components. When the learner is interacting with smart learning components, which represent 3D human body puzzles, and using services such

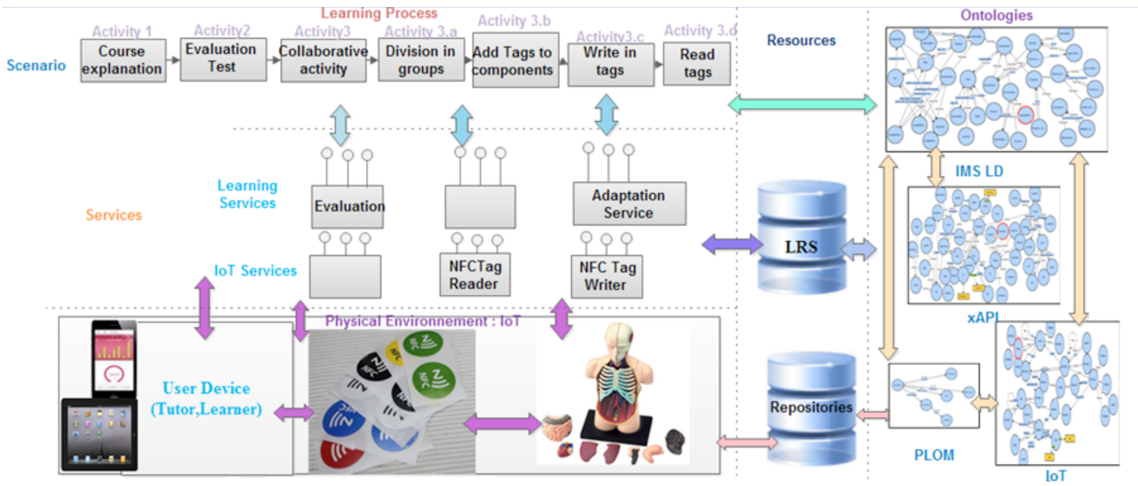

Figure 6. Architectural model

as Evaluation service, he uses repositories to store smart objects and learning objects. The PLOM and IoT ontologies describe semantically this information. Learning Record Store stores the learner's activities and the xAPI ontology describes semantically this historical data. The instructional designer explores this track to adapt the learning scenario by using the IMS LD ontology.

6. Proposed implementation

In this section, we will implement two parts of the presented architecture, which are the ontologies and the physical learning environment. Each concept of the proposed model uses its unique vocabulary and its different language. To grant the interoperability between these models, we choose the use of ontologies. We also use SWRL (Semantic Web Rule language) and the corresponding JESS reasoning engine to add and then execute semantic. In addition, we use the SQWRL (Semantic Query Enhanced Web Rule Language) as a query language.

6.1.IMS LD ontology

IMS LD ontology (figure 7) describes formally and semantically the IMS LD concepts. IMS LD extension aims to extend IMS LD to new learning needs such as the use of the IoT in the learning environment. Table 4 adds SWRL rules to IMS LD ontology.

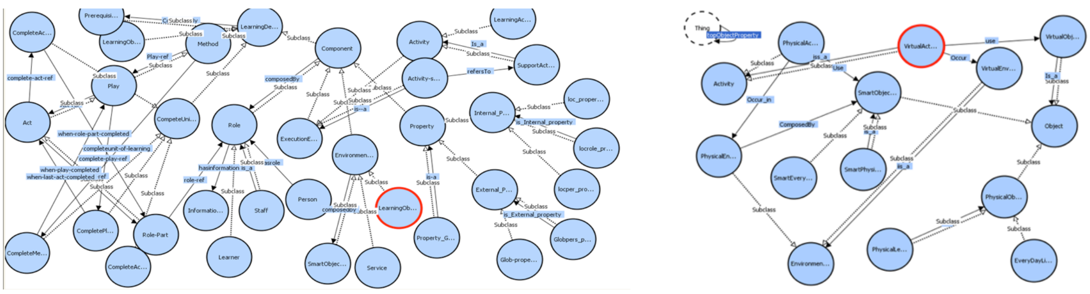

Figure 7. IMS LD ontology and its extension

IMS LD Specification	« AnUoL is completed when the referenced play(s) is (are) completed. More than one play can be selected, meaning that all the referenced play(s) must be completed before the UoL is completed » (page 38)
SWRL rule 1	→ Method(?x) ∧ Play(?y) ∧ CompleteMethod(?z) ∧ completeUoL(?z, ?x) ∧ when-play-completed(?y, ?z) → Play-ref(?y, ?x)
IMS LD Specification	« A play is completed when the last act is completed » (page 40).
Explanation	When the last act is accomplished, the related play is completed.
SWRL rule 2	→ Play(?x) ∧ CompetePlay(?y) ∧ complete-play-ref(?y, ?x) ∧ Act(?z) ∧ when-last-act-completed(?z, ?y) → Act-ref(?z, ?x)
IMS LD Specification	« An act is completed when the referenced role-part is completed. More than one role-part can be selected, meaning that all the referenced role-parts must be completed before the act is completed » (voir page 42).
Explanation	The role-parts are completed before the related act is.
SWRL rule 3	→ Act(?x) ∧ CompleteAct(?y) ∧ complete-act-ref(?y, ?x) ∧ Role-Part(?z) ∧ when-role-part-completed(?z, ?y) → Role-Part-ref(?z, ?x)

Rules	**Explanation**
→ PhysicalEnvironment(?x) ∧ PhysicalActivity(?y) → Occur_in(?y, ?x)	A physical activity occurs in a physical environment.
→ VirtualEnvironment(?x) ∧ VirtualActivity(?y) → Occur(?y, ?x)	A virtual activity occurs in a virtual environment.
→ PhysicalActivity(?x) ∧ PhysicalObject(?y) ∧ SmartObject(?z) → Use(?x, ?y) → PhysicalActivity(?x) ∧ PhysicalObject(?y) ∧ SmartObject(?z) → Use(?x, ?z)	The tangible object used in a physical activity may be either smart or not.
→ VirtualActivity(?x) ∧ VirtualObject(?y) → use(?x, ?y)	A virtual activity uses a virtual object.

Table 4. SWRL rules related to IMS LD ontology.

6.1.IMS LD ontology

The IoT ontology illustrated with figure 8, describes semantically the concepts presented in the IoT model. The table 5 presents the SWRL rules related to the ontology.

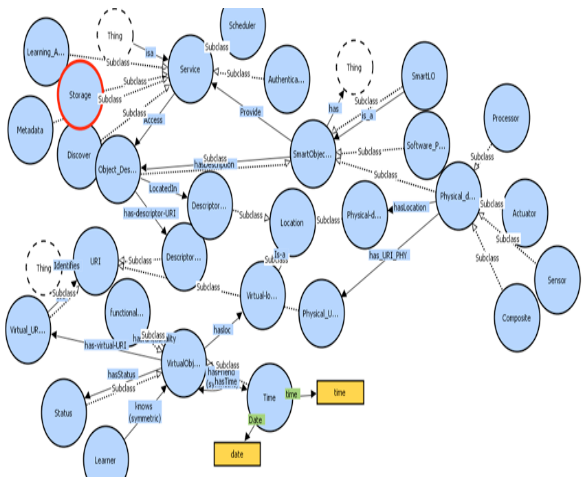

Figure 8. IoT ontology

Règle SWRL1	→ Physical device(Projector) ∧ Sensor(Capteur) ∧ has-S(Projecteur, Capteur) ∧ Physical device(Lampe) → Communicate with (Projecteur, lampe)
Explication	Smart objects are projector and 2 lamps. With its sensor, the projector detects the states of the 2 lamps.
Règle SWRL2	→ Physical_device(Projector) ∧ (hasstate(Projector,on)) ∧ VirtualObject(Lamp1) ∧ VirtualObject(Lamp2) ∧ hasFriend(Lamp1,Lamp2) ∧ hasStatus(Lamp1, On) → hasStatus(Lamp2, OFF)
Explication	When the projector is on, one of the 2 lamps changes its state to off.

Table 5. SWRL rules related to IoT ontology

6.3. PLOM ontology

The PLOM ontology illustrated with figure 9, describes semantically the concepts presented in the PLOM model.

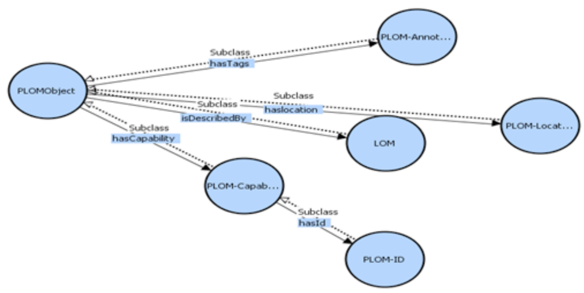

Figure 9. PLOM ontology

6.4. xAPI ontology

The xAPI ontology illustrated with figure 10 aims to collect the useful information. The information is stored in form of statements. These statements represent the list of activities done by a learner or by a group of learners it depends of the user.

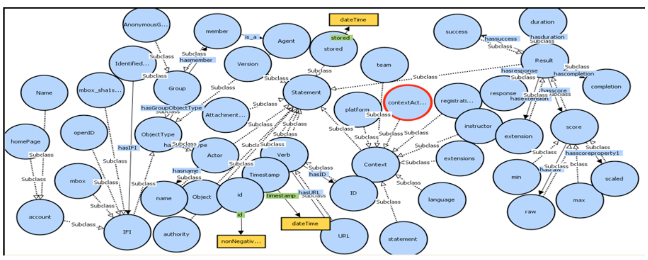

Figure 9. PLOM ontology

Specification	An agent should not use inverse functional identifiers that are used as a group identifier (page 10).
Explanation	An agent should not use the same identifier as a group identifier.
SWRLrule 1	→ Agent(?x) ∧ Group(?y) ∧ IFI(?z) ∧ IFI(?a) → hasIFI(?x, ?z) ∧ hasIFI(?y, ?a) ∧ differentFrom(?a, ?z)
Specification	Scaled is a decimal number between -1 and 1 (page 22)
Explanation	The score » should be between -1 and 1.
SWRLrule 2	→ score(?x) ∧ scaled(?y) → Scaled(?x, ?y) ∧ swrlb:greaterThan(?y, -1) ∧ swrlb:lessThan(?y, 1)
Specification	Max is a decimal number greater than min (if present) (page 22).
SWRLrule 3	→ score(?x) ∧ max(?y) ∧ min(?z) → hasmin(?x, ?y) ∧ hasmax(?x, ?z) ∧ swrlb:greaterThan(?y, ?z)

Specification	An agent MUST be identified by one of the four types of Inverse Functional Identifiers(IFI). An agent MUST Not include more than one Inverse Functional Identifier (page 10)
Explanation	An agent must be identified by only one of the 4 IFI types (account, mbox, mbox_sha1sum or openID).
SWRLrule 4	Agent(?x) ∧ account(?a) ∧ mbox(?b) ∧ mbox_sha1sum(?c) ∧ openID(?d) → hasIFI(?x, ?a) Agent(?x) ∧ account(?a) ∧ mbox(?b) ∧ mbox_sha1sum(?c) ∧ openID(?d) → hasIFI(?x, ?b) Agent(?x) ∧ account(?a) ∧ mbox(?b) ∧ mbox_sha1sum(?c) ∧ openID(?d) → hasIFI(?x, ?c) Agent(?x) ∧ account(?a) ∧ mbox(?b) ∧ mbox_sha1sum(?c) ∧ openID(?d) → hasIFI(?x, ?d)
Specification	An anonymous group Must include a member property listing constituent Agents (page 10).
Explanation	Member propert of an anonymous group lists the agents of this group.
SWRLrule 5	AnonymousGroup(?x) ∧ member(?y) → hasmember(?x, ?y)

Table 6. SWRL rules related to xAPI ontology

The figure 11 illustrates the jess execution of SWRL rules and the figure 12 an example of SWRL Query that lists the learner of group 1.

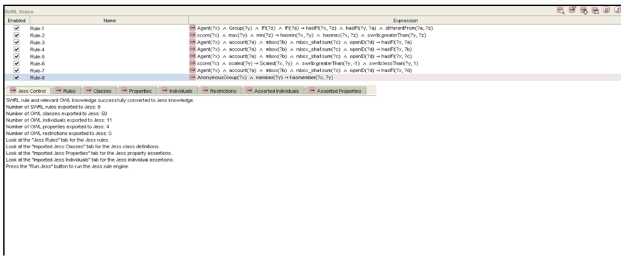

Figure 11. Jess execution of SWRL rules

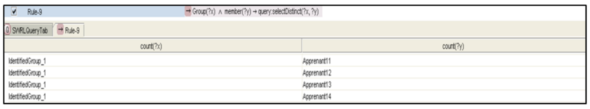

Figure 12. An example of SWRL query

6.5. Examples of learners' activities

The figure 13 illustrates the activity of writing/ reading activity using NFC tags, Smart phones equipped with NFC module and an android application named NFC Tag Writer.

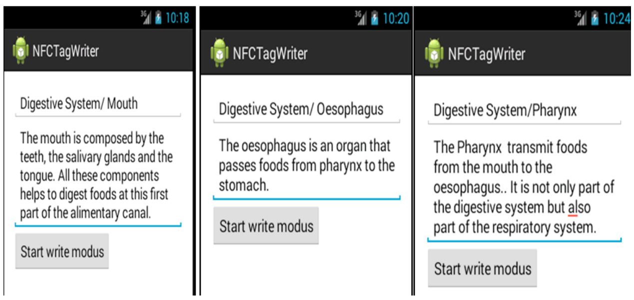

Figure 13. Writing on NFC tags

6.5. Examples of learners' activities

We use SQWRL queries to retrieve the learner's historical data from the xAPI ontology. Then we adapt the learning process if necessary using the IMS LD ontology, the IoT ontology and the PLOM ontology exploring the xAPI ontology.

The activity A1 illustrated by the figure 14 is: The learner Alain uses a Samsung Galaxy S4 Smartphone and a Mifare 1k NFC tag.

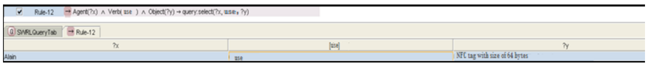
Figure 15. Activity A2

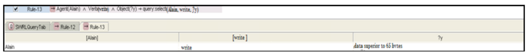
Figure 16. Activity A3

The activity A2 and A3 illustrated by the figure 15 and the figure 16 Alain wants to write data with size of 130 bytes using a tag with a size of 64 bytes which is impossible.

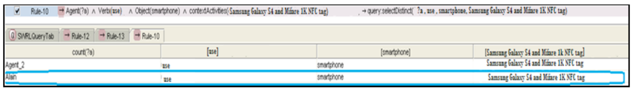
Figure 14. Activity A1

6.7. Activity adaptation

When a learner wants to scan an NFC tag with her Smartphone, we provide a list of names of the compatible NFC tags (figure 17).This list is attributed by using the environment context. It means that we adapt the activity with reference to the NFC tags that exist in the learning environment.

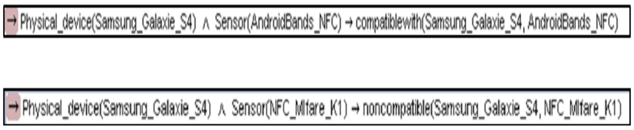

Figure 17. SWRL rules

To adapt the activities A2, A3, the tutor proposes the use of a URL (Uniform Resource Locator) for recording the enormous information in the tag (figure 18). So the learner chooses the URL. Then the user scans the NFC tag and accesses to the web page containing the related information.

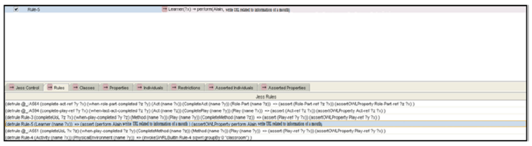
Figure 18. SQWRL rule

7. Conclusions and future works

Combining virtual learning scenarios to physical ones showed new interesting opportunities for both learners and teachers. It highlighted however the need to combine and/or extend existing e-Learning standards to those of IoT. A specific need to keep track of the learners' activities and achievements showed the relevance of using the xAPI standard.

So, in this paper, our aim was to use e-Learning standards with smart objects to design complex learning scenarios and keep track of the learner's learning experience. For that we have used ontologies to grant interoperability between standards and to provide context-aware activities to learners. We have also experienced the NFC technology in a collaborative learning experience.

Currently, we are developing the present work by providing a virtualization solution for physical smart learning objects in order to grant their access from a Cloud Computing based solution. This brings advantages of sharing physical smart learning objects between several Educational communities as it was the case for common digital learning objects or resources.

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Notes

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