Processes Reference Model for Interoperability in Learning Object Environments

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***Abstract*—In the e-learning there are efforts to use interoperable learning environments, nevertheless there are significant limitations that make it difficult to achieve. In this paper it is proposed a Process Reference Model for Interoperability in e-learning that describes the activities that universities could follow to implement interoperable learning environments. The foundations of this research are the Mexican Standard for Interoperability between Learning Objects and the findings of interviews with Mexican Universities with experience in the learning technologies. A total of 106 activities were identified and described from different processes and approaches. We consider that this proposal could guide to the universities in implementing interoperable environments for e-learning.**

Keywords- Interoperability, e-Learning, Learning Object, Learning Object Repository, Learning Environment, Process Reference Model Interoperability.

I. INTRODUCTION

The concept of e-learning had its origins in the XIX century from the offer of correspondence education to cover educational demands in areas of difficult coverage, while marketing didactic resources, this being the environment that promotes distance education [1]. The term e-learning is used as a synonym for distance education, Web-based education, computer-based education, virtual learning, distributed learning, online or mobile learning [2]. Currently e-learning is based on educational technology that is described as an intellectual pedagogical space where the object of study are media and Information Technology (IT) in terms of representation, diffusion and access to knowledge and culture in different educational contexts: distance education, formal education, non-formal education and higher education [3].

The educational offer in the distance modality in universities has grown because it is seen as an alternative to expand equity, coverage, democracy and justice in education, while it is an option of international cooperation, flexibility in educational systems and quality standards regulated by common standards [4]. In this sense, e-learning market has shown a rapid and significant growth in recent years, with an annual growth rate of 7.9% from 2012 to 2016, including Asia, Eastern Europe, Africa and Latin America with an above average growth of 17.3%, 16.9%, 15.2% and 14.2% respectively [5].

In Mexico, there are several initiatives from the public and private sectors to enhance the use of IT in support of education. One example is that the academic and scientific communities create research and working groups for the development of Learning Object (LO) for e-learning. However there are difficulties in implementing these initiatives, since it is possible to find within a university that its own teachers do not want to share the resources they develop, either because there are no guidelines for the recognition of authorship, or, if they exist, they need to be clarified with legal advice [6], there is no guide for the design of resources and they are forced to venture to develop them by the urgency of the school periods, hence limiting their quality; or other technical aspects that may be due to the platforms used to give access to LO, which includes, among other reasons, LO cannot be visualized, they are not legible or do not consider them adequate according to their educational planning. Also, the results of these initiatives are not accessible to all teachers and students in the country. For example, materials are available through the Internet on public access sites and when a user launches a search he finds a large volume of results from which to choose, where which it is not possible to distinguish between those that were developed according to quality standards and clear, specific and well-prepared educational objectives of those who do not meet these criteria.

Achieving the sharing of educational resources between different institutions becomes a complex situation, since various technical, organizational and cultural aspects are involved. In order to solve this problem, interoperability seeks to promote the ability of diverse and disparate organizations to interact following common objectives of mutual benefit, involving the exchange of data, information and knowledge, through business processes, between their respective systems of information and communication technologies [7]. To achieve interoperability in an educational environment, it is important to standardize the development and implementation processes of the entities that intervene in it [8], such as LO, Learning Object Repositories (LOR) and Learning Environments (LE). In this sense, a relevant contribution is the document called Mexican Standard for Interoperability between Learning Object Environments [9]. That document presents a Framework for Interoperability between Learning Object Environments (MRI-EOA) that describes 31 processes related to the development, search, retrieval and reuse of LO through LOR and LE [9]. However, these processes are described in a generic way, lacking a method for their implementation. Due to this, we have worked on the development of an extension for MRI-EOA. The objective of

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this article is to present the Process Reference Model for Interoperability in Learning Object Environments, which extends to the MRI-EOA. In this Model Processes entities are defined in greater detail such as activities, work products, roles, techniques [10] that are involved in order to comply with a desired interoperability grade and thus formalize the processes and propose good practices [11]; promoting he adoption of standards and specifications that allow the interoperability of systems in Mexican universities [9].

The present article is structured as follows: Section 2 presents a theoretical background related to the interoperability between Learning Object Environments, the processes defined in the MRI-EOA[9] and the software process entities selected for the implementation of the Process Reference Model. Subsequently, Section 3 presents the methodology. Section 4 describes the results achieved and the validation of the results through a case study. Finally, Section 5 describes the conclusions and future work.

II. BACKGROUND

A. Interoperability

Interoperability is the ability of software to exchange data with fidelity so that diverse organizations can interact freely generating mutual benefits from sharing their information and knowledge [12]. As related work on the implementation of interoperability we identify interoperability in large scale systems [13], the development of a framework for interoperability of European services [14] and interoperability under an approach in e-learning [15].

According to [16] some of the benefits of standardization in e-learning are: to establish learning strategies to reuse in various contents, to ensure interoperability between learning systems, to facilitate the scalability of the technologies used and to ensure cultural diversity. Also, some authors have characterized interoperability as technical, syntactic, semantic and organizational [17], and others relate it to educational and cultural approaches [15]. Table I presents the description of the characteristics and approaches mentioned by the authors [15, 17].

On the other hand, in [18] it is exposed the existence of the interoperability of processes as the capacity to align the processes of different institutions in order to exchange data and business processes in a transparent way.

Under the emphasis on the process and its management as the main justification for standardization initiatives, as well as efforts to measure the capacity of the process [18].

B. Software Process Management

Software processes are a set of coherent activities that lead to the creation of a software product [19]. The ISO/IEC standard TR 24774 describes that the minimum entities necessary to describe a software process are the title, purpose, activities and outputs [20]. Activities, such as software process entities, are performed by the roles that are responsible for the use of input resources or products and the generation and storage of output artifacts or products. In this way, in a project the roles establish, update, correct, verify and/or validate procedures, methods and work products according to the purpose of the process.

TABLE I. DESCRIPTION OF INTEROPERABILITY CHARACTERISTICS

Interoperability Features and Approaches	Description
Technique	It focuses on the communication protocols and the infrastructure required for them to work [12].
Syntactic	It is related to the format of the exchanged data [12].
Semantics	It seeks to make the meaning of the information exchanged understandable by any other application [12].
Organizational	It refers to the effective communication that is given in organizations to transfer information [12].
Educational	It relates to how resources are used didactically [11].
Cultural	It addresses aspects of linguistic, cultural and social education in different contexts [11].

C. Processes and capacity reference models for interoperability

A Software Processes Reference Model describes which activities are recognized as the best and good practices that an organization must implement for software production [21]. On the other hand, a Process Capability Evaluation Model reflects how effective an organization is by managing the skills, training, and experience of staff in the organization [19]. They also support institutions in selecting strategies to improve their processes by determining their maturity and identifying findings in current processes [22]. With the purpose of obtaining a national and international panorama on Processes Reference Models and capacity for interoperability in a national and international context, some related work presented in Table II were identified in the literature.

The presented models help in the understanding of the characteristics and approaches of interoperability, since they are practical cases where they exemplify the different approaches of the interoperability. For example, in [29] a framework is presented to evaluate the results produced by the use of IT in federal institutions and the maturity with which they administer and apply IT for the performance of their functions. The joint review of these works facilitates the obtaining of an integrated idea on the application of interoperability in the different contexts mentioned and promoted the definition for the proposal for an e-learning context.

D. Mexican Standard for Interoperability between Learning Object Environments

The Mexican Standard for Interoperability among Learning Object Environments [9] presents the Framework for Interoperability between Learning Object Environments (MRI-EOA) that takes into account the practices (activities) of the Mexican universities: Autonomous University of Aguascalientes through its Learning Objects research group, the High Technology Center for Distance Education of the National Autonomous University of Mexico, the Virtual University System of the University of Guadalajara and the Direction for Continuing and Distance Education of The Autonomous University of the State of Mexico. Among these practices are the methodologies followed for the development of LO, roles involved in the development of LO, technologies

used, schemes for LO labeling and packaging, characteristics of their LE and LOR, and standards and specifications used.

The MRI-EOA proposes 31 processes that must be implemented around LO, LE and LOR to achieve interoperability (Table III).

Each MRI-EOA process is generally described omitting the definition of work products, procedures and specific interinstitutional agreements that enable LO sharing [9]. In this sense, it is emphasized the need for a Processes Reference Model for interoperability between Learning Object Environments, thus providing a formal specification of the elements involved in each of the 31 processes.

TABLE II. MODELS OF MOST REPRESENTATIVE PROCESSES ABOUT CAPACITY FOR INTEROPERABILITY

Model	Characteristics
LISI, Levels of Information Systems Interoperability [23].	It evaluates technical aspects of interoperability, such as the connection between systems.
LCIM, Levels of Conceptual Interoperability Model [24].	Proposes conceptual levels for interoperability
GIMM, Maturity Model of Government Interoperability [15].	Evaluate processes at the government level.
MMIE, Maturity Model of Business Interoperability [26].	Evaluate processes in the business environment.
Interoperability and Open Data Framework (EIDA) of the Mexican government [27].	Work plan focused on defining platforms for interoperability in the social domain, health, housing, education, science and technology.
Model of Maturity and Capacity for Implementation of Electronic Government in Public Institutions in Chile [28].	It integrates the evaluation of the technological, organizational, operational and human capital capacities that are necessary to consider in the electronic government.
OIM, Maturity Model of Organizational Interoperability [25].	It presents criteria to evaluate organizational aspects of interoperability.
Large-scale systems [13].	It evaluates systems in different platforms taking into account the previous models.
Model of Value and Maturity of Digital Government in Mexico [29].	It provides a framework for assessing the maturity with which ICT resources are managed.

TABLE III. PROCESSES DEFINED FOR MRI-EOA

Id	Processes for interoperability		
P1	Development of LO	**P16**	LO internal search
P2	Labeling of LO	**P17**	Search by keywords
P3	Packaging of LO	**P18**	Search by metadata
P4	Aggregation of LO	**P19**	Retrieval of LO metadata
P5	Implementation of LOR	**P20**	Location of LO
P6	Implementation of LE	**P21**	Arming courses
P7	Access to environments	**P22**	Deployment of LO
P8	Manual import of LO	**P23**	Use of LO
P9	LO storage	**P24**	Reuse of LO
P10	LO Registration	**P25**	LO application
P11	Metadata publishing	**P26**	Recovery of LO
P12	LO evaluation	**P27**	Communication with federated LOR
P13	LO publication	**P28**	Federated search for LO (To external environments)
P14	Communication between internal environments	**P29**	Federated search for LO(From external environments)
P15	Search for OA in LOR	**P30**	Export of LO via environments
		P31	Import of LO via environments

III. METHODOLOGY

This work was realized under a qualitative perspective, taking into consideration the premises of the action-research method [30] with the objective of discovering in Mexican universities the experience in e-learning through structured interviews according to the MRI-EOA. The type of sampling used is accidental probabilistic, since the objective of the study is not to generalize results, but to understand the reality of 6 universities in validating the advantages, benefits and disadvantages of the proposed Process Reference Model. Therefore, the sample is represented by a group of subjects selected on the basis of being accessible or suitable [31]. Based on related work on process models, interoperability capacity models and government initiatives on interoperability in Mexico, Chile and the European Union; the following phases were defined: 1) define the Process Reference Model for Interoperability in Learning Object Environments considering the minimum elements defined by ISO/IEC TR 24774; 2) validate participatory and empirical the proposed Process Reference Model; and 3) update the activities of a pattern based on feedback from the participants.

IV. RESULTS

A. *Process Reference Model for Interoperability in Learning Object Environments*

For the formal definition of the Process Reference Model, which includes a process pattern for each of the 31 MRI-EOA processes, the entities and their relationship to each other were modeled. Fig. 1 shows the role entities and/or actors involved, activities, input resources, input and output work products. We used the metamodel for SPEM 2.0 software engineering processes. The modeling base in SPEM defines a set of work items that are classified as definitions or work products and the process roles performed by activities that are contained in packet diagrams [32].

According to [9], each process is associated to a category of processes for interoperability, which are processes for the implementation of LE, processes for the implementation of LOR, processes for the development of LO and common processes between LE and LOR, whereby the activities of Fig. 1 and 2 were represented with a packet diagram. Likewise, it is represented that LOR processes and LE processes require the realization of LO processes.

The structure of the Process Reference Model for interoperability was defined as: name and purpose of the process, roles and/or roles involved, input resources, input and output work products and activities to be performed. In Fig. 1 activities were classified as Technical Activities (TA), Syntactic Activities (SA), Semantic Activities (SMA), Organizational Activities (OA), Cultural Activities (CA) and Educational Activities (EA).

The nomenclature for naming interoperability processes is, P_C n. Process name, where:

P = {Interoperability processes}
C = {OA, A, R, A R}
LO = {LO processes}
E = {LE processes}
R = {LOR processes}
E_R = {Common processes between LE and LOR}

1≤ n ≤31 processes

For example, from Fig. 3 E P 1. Implementation of LE is related to process 1 of the category of Learning Environments called LE Implementation.

Of the 31 processes, the following were identified as main processes E P 1 Implementation of LE, R P 2. Implementation of LOR and LO P 3. Development of LO, as there are other processes that, in order to be implemented, require one of these 3 processes to be implemented first.

20 of the 31 processes in the MRI-EOA are modeled, because they are the main processes that depend on them and their relationship, and they have been detailed for the moment in their software processes entities after the validation done to the process pattern (Fig. 3, 4 and 5).

The case study protocol is based on a simple design proposed by [33]. Due to the strategy of validating the 46 activities of the process standard for interoperability [34], during March 2016, the criterion for selecting participants in the case study was that Mexican universities were recognized for their experience in the field of distance education.

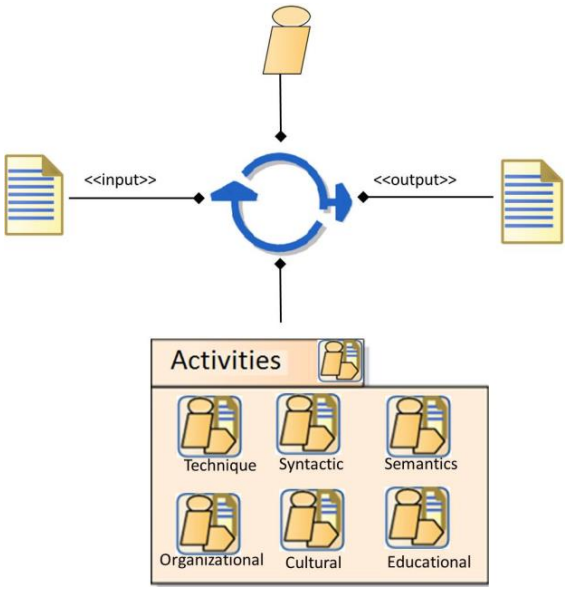

Fig. 1 Representation of the process pattern for interoperability

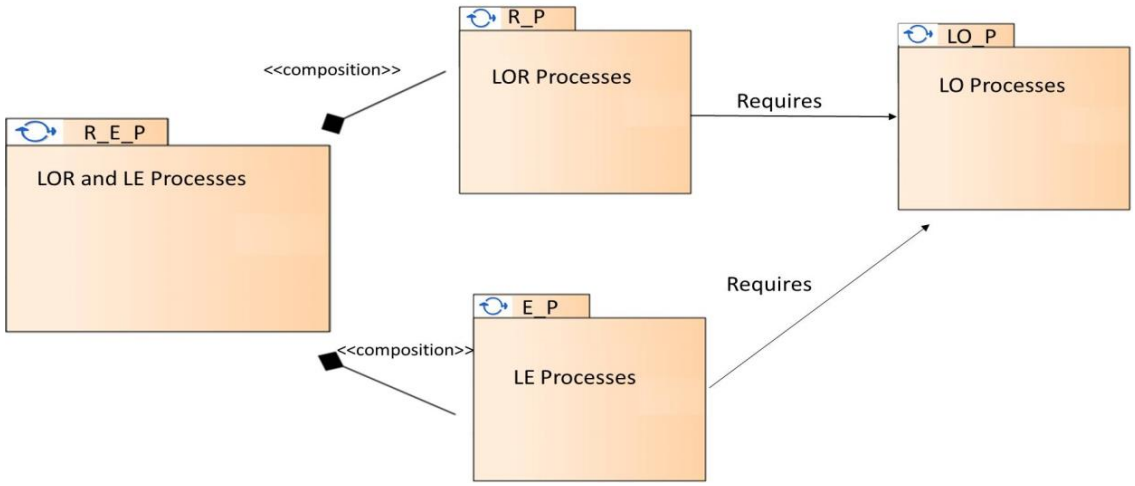

Fig. 2 Categories of processes for interoperability

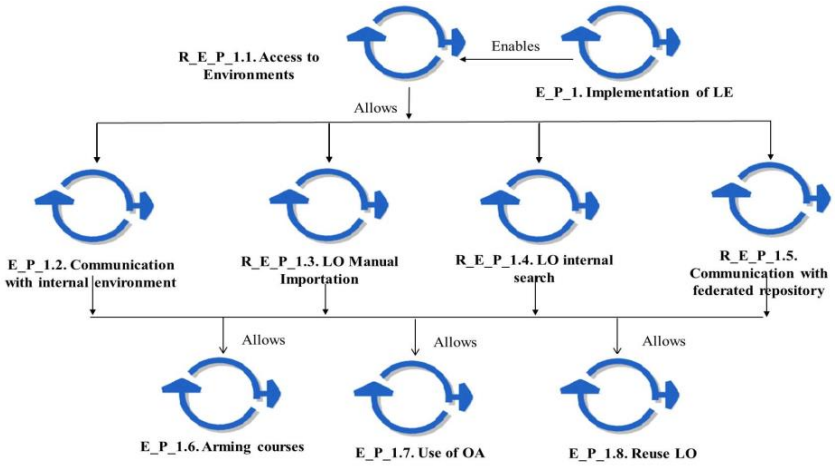

Fig. 3 Processes for the implementation of LE. Based on [9]

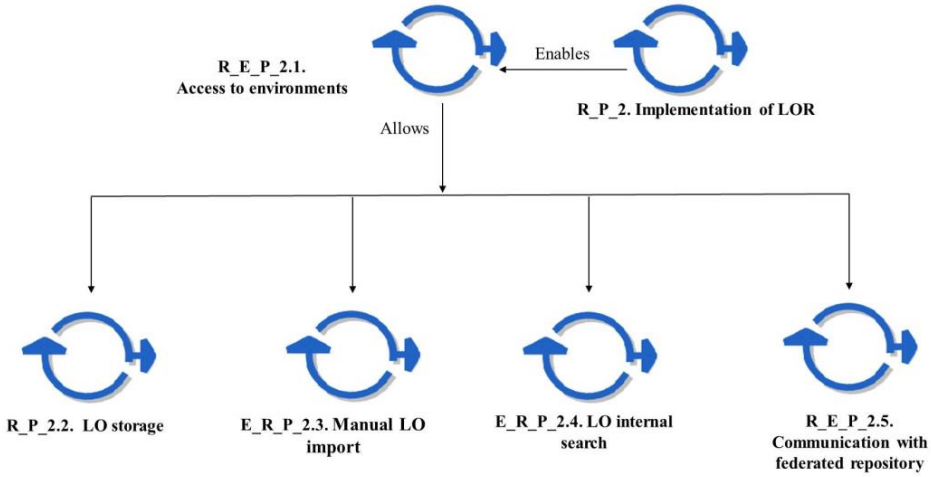

Fig. 4 Processes for the implementation of LOR. Based on [9]

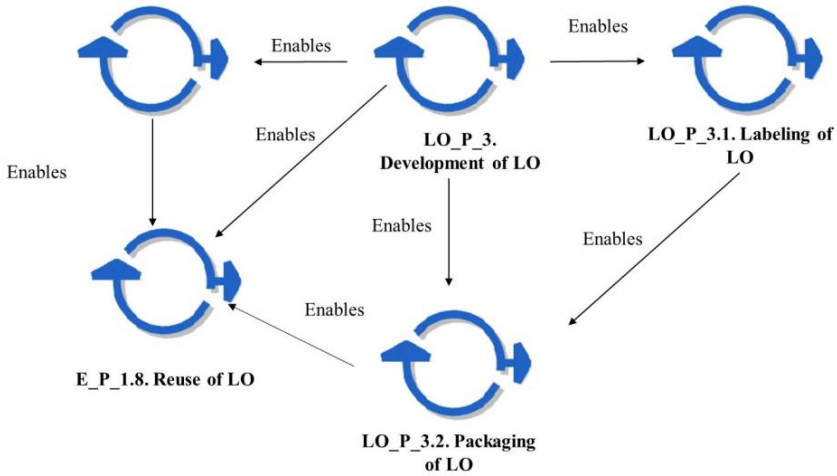

Fig. 5 Processes for the implementation of LO. Based on [9]

Table IV presents the characteristics of the 6 participating universities in the validation process. From the context of applying a questionnaire, two types of variants were considered: participatory and empirical. The participatory variable is due to the participants accessing a Web application that presented the 46 activities. They were asked to evaluate to which extent these activities are realized at their respective universities. It should be clarified that the participants have multiple roles as rector, coordinator, manager and teacher who represent a diverse experience in the various activities that have dominion and are responsible.

The activities were classified according to the LOR and LE processes and the LO processes. Their answers were found in the following scale of capacity: (0) Not performed, (1) Partially performed, (2) Performed, (3) Mostly performed and (4) Completely performed. They also gave a comment explaining their answer.

The empirical variable is reflected in how the information obtained in this validation was used to detail the software process elements of the processes pattern through the intervention of the participant to analyze the way in which the activities of the interoperability processes are executed according to the framework.

In the context of interoperability, a model includes advantages, definitions, analysis of key areas and interoperability parameters; defines and determines interoperability maturity levels and creates common methodologies and structures for interoperability of software systems [17]. Table V shows the capacity of each university to perform the activities evaluated. Considering the highest percentages, it is observed that in the UDG 28% of the activities are Performed (2), in the UAA 33% are Completely Performed (4), in the UAG 60% are Predominantly Performed (3), in Colima 36% are Predominantly Performed (3), in the UAEM 13 % are Partially Performed (1) and in the UABC 10% are Partially Performed (1). This expresses the measure to which each institution performs activities for the interoperability of the processes pattern, reflecting the profile of each institution in terms of its tendency to interoperate. For example, it is observed that the UAG performs 100% the activities of the processes pattern and Colima performs 98% in a capacity level Predominantly Performed, which could mean that its systems are highly interoperable, whereas in the case of UAA, UAEM and UABC where the porcentages of capacity for the activities No realized (0) is over 50% reflects that despite having implemented processes for distance education, these do not favor and are insufficient for the interoperability. In UDG its activities has a capacity Performed, which means that they has implemented processes for e-learning but need to formalized them, to achieve the interoperability. Based on the results of the evaluation, it was possible to define more activities in the pattern of processes that extend each one of the approaches of interoperability, with which it is likely to obtain results that reflect to a greater extent the reality of the universities and its interoperability capacity, so that by reviewing the information collected, 106 activities classified in the various MRI-EOA processes from a Technical, Semantic, Syntactic, Organizational, Cultural and Educational point of view were defined.

B. Example of Process Pattern Content for Interoperability Between Learning Object Environments

According to the evidence, the activities identified take into account aspects such as: 1) the analysis that could be realized by universities when deciding whether to develop LO, LOR and LE; 2) the planning processes that this entails; 3) the training processes of both teachers and technical personnel that should be executed; 4) the evaluation and monitoring recommended to ensure the quality of educational resources; 5) the communication agreements that must be made between the universities that wish to interoperate; and 6) IT that can be used, design and safety recommended for educational platforms, among others

TABLE IV. MEXICAN UNIVERSITIES PARTICIPATING IN THE EVALUATION OF ACTIVITIES RELATED TO INTEROPERABILITY

University	Role	Experience
University of Guadalajara. Virtual University System (UDG)	Rector of the Virtual University System	Research and teaching in distance education
Autonomous University of Aguascalientes (UAA)	In charge of the Section of Design of Strategies of Teaching and Learning of the General Direction of Teaching of Undergraduate in the department of Educational Innovation	Design of teaching and learning strategies.
Autonomous University of Guadalajara (UAG)	Distance Learning Coordinator	Diagnosis and Evaluation of Interoperable Open Institutional Repositories
COLIMA	Full-Time Research Professor	Research and teaching in distance education
UAEM	Responsible for the Area of Professional Studies	Research and teaching in distance education
Autonomous University of Baja California (UABC)	Head of the Open Education Center (CEA)	Construction of online courses.

TABLE V. PERCENTAGE OF ANSWERS ISSUED BY EACH UNIVERSITY ON THE CAPACITY

University	Capacity				
	4	3	2	1	0
UDG	5%	5%	28%	24%	39%
UAA	33%	9%	2%	0%	56%
UAG	19%	60%	13%	8%	0%
COLIMA	24%	36%	33%	6%	2%
UAEM	5%	11%	6%	13%	65%
UABC	5%	2%	8%	10%	75%

Table VI shows, by way of example, the process pattern LO P 3 Learning Object Development, specifying as entities software processes roles, input and output resources, expected results, the activities AT for the configuration, security and access to the system, AO related to management, planning and improvement, AE they which have to do with the evaluation, monitoring and quality of the teaching and learning processes and AC they which refer to the preparation to the personnel involved in the implementation of learning environments, the beliefs and custom of the people involved in the process must possess. It is important to clarify that only 10 activities of the 106 are shown, because the objective of the article is to present the extensions made to the model and not its content

TABLE VI. P_LO_3 DEVELOPMENT OF LEARNING OBJECTS

Process Name	Development of Learning Objects
Nomenclature	P_LO_3
Acronyms	Learning Object (LO)
Purpose	Analyze, design and develop digital elements that are part of an LO.
Input Resources	Author tools, LO storage space, satisfaction assessments of LO use, documentation of other practices for the development of LO.
Expected results	LO, LO licensing procedures, promotion strategies, institutional indicators, budget analysis, project prototypes and training plan.
Roles involved	Programmer, Pedagogical expert, Instructional designer, Graphic designer Institutional authority.
Technical Activities (TA)	
AT1. Have a space for the storage of the LO, either in own repository or in the CPU of a computer. Space where LO will be housed.	
AT2. Use authoring applications for the development of LO. Evaluate different authoring applications in the market that allow LO to be developed according to its objectives.	
AT3. Have the tools that are needed to develop the digital elements that will be part of the LO, i.e software, videos, presentations, etc. Identify the tools needed to develop the digital elements that will be part of the LO, for example software, video, presentations.	
Organizational Activities (OA)	
AO1. Define and manage the budget necessary for the development of LO. Consider the expenses involved in the development of LO, both software, equipment and personnel.	
AO2. Build a team to develop LO. The team can be made up of a pedagogue, a software development expert, a multimedia designer.	
AO3. It consists of defining strategies to organize the staff that participate in the development of OA. For example an announcement for the teachers and / or departments dedicated to this activity.	
Educational Activities. (EA)	
AE1. Validate LO by experts before being published for use. It involves managing and establishing communication relationships with experts who realized the evaluation. It implies that staff developing the LO accept that their work undergo an evaluation, with the objective of monitor quality in LE. When seeking better results in the teaching and learning processes, ensure that educational materials are efficient.	
AE2. Develop LO that seek to support the teaching processes. When developing LO do this by implementing strategies that promote an agile and better quality teaching process.	
AE3. Develop LO that seek to support learning processes. When developing LO do this by implementing strategies that promote learning in students.	
Cultural Activities (CA)	
AC1. Train the personnel involved in the department that promotes the development of educational materials, on licensing. Knowledge in the area of copyright can facilitate the registration process of LO.	
AC2. To take into consideration the practices developed in other universities for the development of LO to improve their own. Define communication mechanisms with other universities so that information can be obtained to guide their own development. It implies having initiative to review for practices of other universities and share their own.	

V. CONCLUSIONS AND FUTURE WORK

As a summary, under the emphasis on the process and its management as the main justification for the initiatives of standardization of interoperability processes, as well as the efforts to measure the capacity of the process [18], in this paper was defined a Processes Reference Model for Interoperability between LO Environments including the main entities software processes based on an e-learning Interoperability Framework (MRI-EOA). The Process Model provides the description of 106 activities in 31 processes for interoperability and their relationship between them in order to promote the adoption of standards and specifications that allow the interoperability of educational platforms. In this sense, from the MRI-EOA processes, the SPEM software process metamodel was used for the formal description. Activities were defined that extend each process, they describe from a Technical, Syntactic, Semantic, Organizational, Cultural and Educational approach the actions that could be realized in each process, based on the good practices that certain Mexican universities do. In order to define the activities of each process, a participatory and empirical validation of the process pattern and of the 46 activities that had been identified from a previous experiment was performed [34]. With the evidence gathered, it was possible to define a total of 106 activities, although it was not possible to define activities for each of the processes and for each approach of interoperability. It is expected that the definition of all activities will be finished in a subsequent study in which the sample of participating universities will be expanded to obtain other data that will help complement the activities of the process standard.

The specification of a Process Reference Model for the interoperability based in a processes pattern, such as the one presented here, will allow universities interested in interoperating the creation of validation mechanisms for their current processes through any of their capabilities: showing them their interoperability; serve as a guide in the adoption of processes for interoperability; define the level of interoperability they have; as well as the identification of the level of interoperability that can be achieved by performing the activities of the process pattern in accordance with their vocation, interests, goals and capabilities. This could be observed from the self-evaluation carried out by the six participating institutions, which answered the measure of their capacity to perform the activities of the pattern of processes proposed, and whose results reflected their trend towards interoperability, showing that Institutions recognized in Mexico due to their distance education programs perform the activities of the processes pattern, at a level of capacity according to their own possibilities. Being the MRI-EOA a Mexican initiative, the processes pattern was also defined as consulted Mexican universities with experience in e-learning. However, for being a Mexican

initiative does not imply that it can only be applied in this context, since the processes it deals with and the activities it describes take into account aspects related to the operation of educational platforms, the establishment of collaboration agreements between universities, the development of LO, the use of international standards for interoperability; all these aspects are not exclusive to a nation, but an extension of the research will be necessary to evaluate its applicability in a Latin American and international context, investigating the level of priority of the approaches involved.

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