Analysis Framework for Tailored Selection of Learning Objects Methodologies

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Abstract— This article described the process used for developing and validating an analysis framework that allows comparing design methodologies for the design creation of Learning Objects (LO) and selecting the one that best meets the needs of teachers based on the needs of a specific educational context. This framework is called MASMDOA (Analysis Framework for the Selection of a Learning Object Design and Deployment Methodology), and it has been applied to a case study where, from a compilation of LO design methodologies used in Ibero-America, one of these methodologies is selected to work in the context of a LO design and production workshop. MASMDOA proved useful for selecting a LO design and deployment methodology that is appropriate for the requirements of an educator in a specific context. To achieve this, MASMDOA proposes a set of criteria that are useful for recommending and characterizing the methodologies to be analyzed and, following a two-phase process, it recommends the methodology that is better suited for the educator's needs. In this paper, we present MASMDOA, the case study to which it was applied, and the results obtained.

Keywords – learning objects, analysis framework, digital educational materials

I. Introduction

Nowadays, educational processes are enriched by the variety of materials and resources available for the teaching and learning processes. Audiovisual media, such as videos and multimedia presentations, are found today on a very prominent place in countless educational experiences. The increased use of Teaching and Learning Virtual Environments (TLVE) in higher education spaces has defined new learning scenarios for the students, where educators are required to incorporate digital content to traditional study materials and/or to adapt existing materials to these new languages. Studies have been carried out that indicate that the use of digital educational material (DEM) in the teaching and learning processes help achieve a better motivation and learning in the students (computer-based instruction) versus the traditional learning materials [1]. This type of studies supports the significance of using Information and Communication Technologies (ICTs) with the teaching and learning processes and state that, when successfully adopted, these technologies are helpful for achieving a teaching methodology that favors student learning. The discussion of DEM design involves considering the process used for making decisions pertaining to aspects linked to educational (subject-matter knowledge combined with pedagogical knowledge) and technological (technological knowledge) characteristics [2]. LOs are a type of digital educational material that proposes certain design characteristics.

The origin of the term “Learning Object“ is attributed to Wayne Hodgins who, in 1992, proposed building the DEM from standalone, reusable modules that could be coupled to create modules of increasing complexity, very much like the LEGO block sets work [3]. A LO can be understood as a “digital didactic unit designed to achieve a simple learning goal, and to be reused in different Teaching and Learning Virtual Environments, as well as in various learning contexts. It must also include metadata that allow locating and contextualizing it” [4]. However, the concept of LO is not a unified one because there is no consensus on the authors in relation to its definition. Therefore, there is a wide variety of interpretations, which has in turn led to the emergence of a series of LO design methodologies created from various conceptual standpoints [5, 6, 7, 8, 9, 10, 11, 12, 13]. In the last two decades, there have been significant efforts in the development of LO design methodologies [14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 37, 44, 45]. These allow, for instance, optimizing the time invested in the production of DEM, minimizing content adaptation tasks and yielding technologically efficient systems for knowledge distribution. There have also been breakthroughs in the development of tools to support LO design, as well as for the creation of the necessary conditions to enable access and reutilization through

LO repositories as support for the educational processes. Some of these design methodologies arise from model content standards such as Netg [24], Learnativity [25], SCORM [26], CISCO RLO [27], and so forth, which propose a certain set of levels of increasing granularity, from small educational units that can be paired and group to create large, contextualized units with a specific educational purpose.

However, no advanced benchmark studies have been found comparing the various existing methodologies for designing LO, which would allow classifying them, or comparing the LOs generated using such methodologies, stored in digital repositories, which would allow analyzing the flexibility for adoption of these design methodologies. Basically, a LO design and deployment methodology is primarily aimed at generating high-quality, systemic learning objects with the necessary conditions to be easily added to other educational contexts that may be relevant [19]. This leads to some questions that are presented as context for this article, namely: ¿What type of proposals and methodologies have been used so far for the design and creation of LOs? ¿Is it possible to know what the orientation of a proposal or methodology is (i.e., technological, educational, or both) without implementing it? **¿How can an educator select a methodology that is suitable for designing and creating LOs for a given context?**

The purpose of this article is presenting an analysis framework, called MASMDOA, which will allow comparing a set of LO design methodologies and selecting the most appropriate for a specific educational context. The analysis framework has been applied to a preselected set of methodologies that was specifically compiled in the Ibero-American context. The article is organized as follows: Section 2 presents the theoretical foundations, Section 3 describes the construction of the analysis framework MASMDOA for comparing and selecting LO design methodologies, Section 4 discusses the validation of the criteria used in MASMDOA based on expert analysis, Section 5 analyzes a case study of the application of the analysis framework to a set of methodologies, with the selection of a methodology through MASMDOA, and then describes the assessment of such selection by post-grade university educators, and Section 6 presents the conclusions and future lines of work.

II. Theoretical Foundations

A. *Learning Object*

The concept of Learning Object (LO) is still subject of discussion and several definitions have already been proposed for it [4]; however, in this article we consider a LO to be an independent digital didactic unit formed by a specific learning goal, contents, activities and self-assessment that can be reused in various educational and technology contexts (repositories, teaching and learning virtual environments). It also has metadata that allow locating it within the repositories and tackle its contextualization. When talking about a "didactic unit" we refer to an integral, organized and sequential set of elements with their own meaning that allows students assess the results of their work after studying [28]. The inclusion of the term "digital" limits the conception of a LO as a digital resource of entity and, as such, it is classified as a software creation that can be conceived as a software unit with an educational purpose, with a given time and in relation to a teaching or learning process. By saying that it is "independent," it is implied that there is no need for any other material for the LO to have meaning and be used, i.e., it has within it everything that is required to achieve a specific educational goal. When saying that the LO "formed by a specific learning goal, contents, activities and self-assessment", the basic elements that should be included in the LO are described, such that the activities, contents and assessment allow achieving the specific learning goal. The "reuse" feature of LOs is one of the most significant characteristics that differentiate LOs from other didactic materials found on the Web. From an educational standpoint, the more contextualized the content in the LO, the fewer possibilities for reuse in different lessons, units, new modules or contexts. From a technological point of view, the possibility of a LO to be integrated into multiple Teaching and Learning Virtual Environments requires the use of standardized and compatible packaging that facilitate the exchange of LOs across different technology contexts.

Finally, from an economic viewpoint, the reuse of LOs is important for industrializing the production of digital educational materials, since content providers will reuse already created LOs to compose new DEM, building greater granularity "knowledge units" (such as topics, units, modules, etc.) based on the existing ones, thus reducing production costs. "Metadata" are a significant part of LOs, since they provide information about the object that facilitates the search and location process within the repository [4]. It is desirable that metadata are associated to the LO and are not lost upon download. This also favors reutilization.

The definition adopted for LO was the result of a systematic review on the conceptual evolution of LOs over the last 15 years. During this process, the definitions proposed by the various authors were collected, which in turn exposed the agreements and disagreements in relation to the distinctive features of what is considered to be a LO. The definition selected here is intended to be of a pragmatic nature and can be used as a guideline for designing LOs; it also offers a reference framework to identify what is and what is not a LO.

B. *Learning Object Features*

This section introduces the characteristics that are linked to the concept of LO. Table 1 summarizes the agreements and differences among various authors in relation to the characteristics of a LO [5, 6, 7, 8, 9, 12]. When analyzing each of the definitions, it can be seen how the authors use different names to refer to the same characteristic. For example, to express that a LO must be an "autonomous unit," the authors also used the terms "self-contained unit", "self-containing unit," and "independent unit." Based on the group of characteristics listed on Table 1, it can be observed that there is a subgroup on which the authors agree the most. These are: It favors learning, it has an internal structure or contents (objective, contents, activity, assessment), it is a digital material, entity or resource, it can be reused, it must have metadata, it can be assembled, it is independent, autonomous unit, it must be published in a repository, and it considers contextual needs. Other characteristics that are not less significant but for which the level of agreement is lower are: Didactic unit, based on technology, interoperable, locatable.

Some of the characteristics listed above are of a technological nature (material, digital entity or resource, publication, metadata, supported by technology, interoperable, locatable), others are of an educational nature (it favors learning, assembly possible, internal structure, didactic unit, independent), and others can be classified as general aspects (e.g., it considers contextual needs, author license, etc.). Several authors [29, 30, 31] have expressed that LOs should meet certain characteristics commonly agreed upon by the scientific community, namely: It can be published, interoperability, generativity, granularity, educational, reusable.

C. Content Models

Content models basically define the structure of the LOs at various granularity levels. They are based on the idea that learning content can be independent and autonomous, and that it can be used alone or dynamically assembled to other LOs. These learning components can be combined to form greater-granularity educational interactions or be reused in different learning contexts [32]. Either way, there are different content models and LO definitions that have been useful for developing LO design methodologies (LODMs). Content packaging models, such as CISCO [27], NCOM [33], SCORM [26], Netg [24], and so forth, describe how the educational content is packed in a standard manner. These have been used to build LOs with various aggregation levels, thus going from LOs to units, modules, courses or collections of LOs. Netg, Learnativity, CISCO, ALOCOM[1] and Dner & Lo Project models [34] all agree that the internal structure of a LO should have a simple learning goal, contents related to the teaching of a concept, a fact, a principle, a procedure or process, as well as activities and an assessment, all of which, combined, would make the objective of the LO viable. They have contributed significantly to the definition of a LO. These models that have been applied in practical contexts and have been used to create LOs allow validating the definition adopted in this article, identifying how large or small a LO should be and what its internal structure is, so that they are reusable and generative.

D. Design Methodologies of Learning Objects

This article focuses on the *de facto* methodologies that have been useful for creating LOs at several universities throughout Ibero-America, which is the geographical location chosen for this analysis. A bibliography search has been carried out in digital data bases and other primary and secondary sources of information to identify all those methodologies, methodological proposals, heuristics, and guides that provide the necessary guidelines for designing and creating LOs. As a result, 29 methodological proposals were found, but only 19 of those were considered for the analysis; these 19 proposals were selected based on their impact and specific details provided for LO design. On the other hand, a series of criteria were identified matching the characteristics of a LO; these criteria are based on a conceptual review that spanned the last 15 years, as well as on the definition adopted in this article. The criteria that should be considered when proposing methodologies for designing LOs are described below; these will later be used for MASMDOA:

- Locatable: this criterion refers to the use of a metadata standard recommended by the methodology so as to be able to use these metadata to search for the LO and locate it.
- Guidelines/Techniques: this criterion refers to the use of guidelines or techniques for designing the LO that are included in the methodology and allow creating and updating both the LO as well as its contents. The use of guidelines or techniques allow massively producing LOs, considered as software items, and reaching large audiences without a proportional increase in costs [36].
- Reusable: this criterion indicates whether the methodology in question considers the deployment of a LO over a TLVE (technological reutilization).
- Publication: this criterion indicates whether the methodology in question considers the storage of a LO over in a repository.
- Interoperable: this criterion indicates if the methodology recommends the use of any packaging standards (such as SCORM) or specification (such as IMS) to add interoperability features to the LO for use in various technology platforms.
- Educational Design: this criterion indicates the type of pedagogic and didactic strategy that the methodology has incorporated to the LO design and creation process. That is, it is related to the educational design of the LO.
- Generativity: this criterion refers the way in which the methodology determines the structure of the LOs and provides the necessary guidelines for building larger collections (such as units, lessons, modules, etc.) by assembling LOs. This criterion will be referred to as "assembly possible".
- Granularity: this criterion refers to the size a LO should have according to each methodology, i.e., the internal components that each LO has and the type of objective proposed for it. This criterion will be referred to as "LO component".

Some specific features that the methodologies to be analyzed may have should also be considered as analysis criteria.

[1] Abstract Learning Object Content Model, model that allows content interoperability [35].

TABLE I. COMMON FEATURES OF DIFFERENT AUTHORS ABOUT LEARNING OBJECTS

AUTHOR	L´Allier	CUDI	CISCO	IEEE LTSC	Wiley	Hodgins	Chan	Polsani	McGreal	Zapata	Aretio	MENC	Proyecto OdA	Chiappe	UPV	González & Anido	Sicilia & Sánchez Alonso	Astudillo *et. al.*	Sanz
YEAR	98	99		00			02	03	04	05		06		07		08	09	11	14
Features of Learning Object																			
Independent/ Autonomous Unit	x							x			x	x		x	x	x	x		
It favors learning	x	x	x	x	x	x	x			x		x	x	x	x			x	
Digital material, entity, resource		x		x	x		x		x	x	x	x	x	x	x		x		x
It considers contextual needs		x				x	x			x		x						x	
Didactic Unit																	x	x	
Assembly possible		x			x			x				x							
Internal Content/Structure	x		x					x		x		x	x	x		x	x	x	x
Objective	●		●							●		●		●			●	●	●
Contents			●					●				●	●	●		●	●	●	●
Activity	●		●									●		●			●	●	●
Assessment	●		●														●	●	●
Reusable			x		x			x	x	x	x	x	x	x	x	x	x	x	x
Based on Technology				x							x								
Metadata						x					x	x	x	x			x	x	x
Interoperable													x						x
Be published						x					x	x	x	x			x	x	x

Each LODM starts from a conceptual definition of LO and therefore, when selecting a methodology, such information is also relevant. Thus, this criterion is also considered when comparing methodologies for designing LOs. The intended target audience of the methodology (recipients) is also important. Finally, the use of author licenses in relation to the use of the LO is also relevant. Table 2 summarizes the criteria considered for analyzing the methodological proposals. After this analysis, the following questions arise: ¿What aspects, be it technological, educational and/or general, should a LO design and deployment methodology take into account? ¿What are the most relevant characteristics when designing and creating LOs? ¿How can a LODM be characterized so that the type of LO it produces can be known? The solution is not trivial, and it depends on factors that are linked to the context and its specific needs. In the following section, the analysis framework MASMDOA is discussed. This framework allows comparing and selecting LO design methodologies based on the specific needs of an educator in a given context. Besides, it can be used for an institution in order to decide which methodology is better to create LO according to their needs and conceptions.

III. ANALYSIS FRAMEWORK DEVELOPMENT

As a response to the concerns discussed above, in this section we propose a framework for analyzing LO design methodologies (MASMDOA). This framework will allow educators and institutions to select a LODM from a group of methodologies based on their needs in relation to LO design and creation. Even though MASMDOA can be applied to any set of LO design and creation methodologies, the framework is explained using the set of methodologies that were surveyed for this study, as an example of its intended use.

Figure 1. Analysis Framework Phases

TABLE II. CRITERIA FOR THE ANALYSIS OF METHODOLOGICAL PROPOSALS

Dimensions		
Technological	***Educational***	***General***
Locatable, Guidelines/Techniques, Reusable, Publication, Interoperable	Educational Design, Assembly Possible, LO Components	Definition Included, Methodology User, Author Licenses

Thus, the LODM that is ultimately selected will be a *de facto* methodology that has been used in Ibero-America for creating LOs, since the compilation carried out meets these requirements. The criteria for analyzing the methodological proposals are the starting point for creating MASMDOA, since they will allow, on the one hand, defining the educational context, and on the other, selecting the most appropriate LODM. Thus, MASMDOA can be subdivided into 2 phases, as shown in Figure 1.

1) Phase 1: Search for LODMs that are applicable to the educational context: During this phase, all LODMs that meet the educator's[2] needs based on contextual requirements are identified and recommended. All recommended LODMs will

[2] It could be an educator or an institution, but we use educator to simplify the drafting of methodological steps.

be relevant for the educational and technological aspects of that particular educational context; however, they should be assessed to refine and facilitate LODM selection (second phase). Phase 1 comprises the following steps:

a) Starting from the relevance criteria proposed by MASMDOA and related to the characteristics of a LO: In this phase, all criteria are listed on a table (see Table 2) each one has a series of associated values that describe their semantics.

b) Coding each criterion to be analyzed for each LODM: For this step, it is recommended that each criterion is coded so as to simplify making reference to them during the analysis stage (for example, A1-Locatable, A2-Guidelines/techniques, A3-Reusable…A11-Author Licenses).

c) Analyzing the presence of each criterion in the LODMs: Simply writing "Yes" or "No" to indicate if the criterion in question is present; this results in a list that indicates if each of the 11 criteria (A1, A2…, A11) is "met" for each of the "n" methodologies selected.

d) Coding the table of LODMs: For the next step, the values assigned to each criterion (A1, A2…, A11) is coded, using a binary representation, for each of the methodologies. Thus, every "yes" is replaced by a value of one (1), and every "no" is replaced by a zero (0).

e) Defining the criteria that are of interest for the educator: In this step, the criteria that were coded in step 4 above are listed, and those found to be relevant for the educational context are selected. A value of "1" is assigned to all criteria that the educator finds relevant, and a value of "0" if assigned to all criteria that are not relevant for the context.

Document Vector

Nro.	Methodology	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
1	Methodology 1	1	0	1	1	0	1	1	1	1	1	0
2	Methodology 2	1	0	0	1	0	1	0	1	1	1	0
3	Methodology 3	1	1	1	0	1	1	0	1	1	1	0
4	Methodology 4	1	1	1	1	1	1	0	1	1	1	0

Query Vector

Nro.	Methodology	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
1	Teacher Preferences	1	0	1	1	1	0	1	1	1	0	0

Figure 2. Document and query vectors

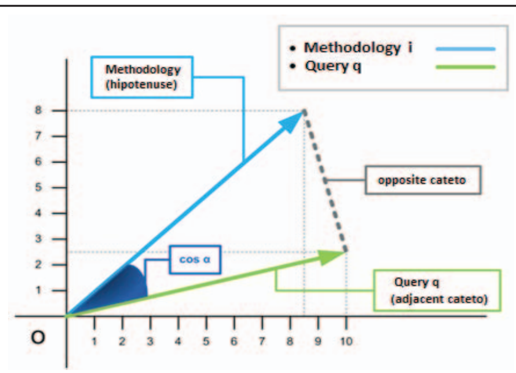

Figure 3. Cosine Angle

f) Recommending those LODMs that cover the criteria that are relevant for the educator: For this step, a formal mechanism should be defined to compare the criteria that the educator has selected and specified for that particular context to the criteria found in each of the LODMs. This will allow finding those methodologies that are closer to the context defined, i.e., those LODMs that cover those criteria that are relevant for the educator will be recommended, and those that are not appropriate for the context will be discarded. This will allow finding those methodologies that are closer to the context defined, i.e., those LODMs that cover those criteria that are relevant for the educator will be recommended, and those that are not appropriate for the context will be discarded. From this viewpoint, a valid mechanism to achieve the objective described is applying the Boolean Vectorial Model for Information Recovery proposed by Salton and Lesk (1968) [38]. This model allows representing educator needs based on a Boolean vector, the same as LODMs, aimed at matching educator needs with LODMs. The Boolean vectors that represent educator needs are referred to as "query vector," while the Boolean vectors that represent LODMs are referred to as "document vector". Figure 2 shows this representation. The idea behind this model is generating an accurate ranking of large collections, which makes it ideal for establishing the level of similarity between a given methodology "i" and a given query "q" (see Figure 3). The deviation of methodology "i" from query "q" can be measured by the degrees of the angle between them. This is possible because they create a triangular structure to which the calculation between the angle formed by the hypotenuse (in this case, the vector of methodology i) and the adjacent (vector q of the query given by the user), which is the cosine of the triangle, is applied. In the case of Figure 3, it can be seen that there is a certain distance between the query "q" vector from the methodology "i" one; when both vectors are close enough to overlap, it will mean that the angle between them is smaller and their level of similarity is higher. Thus, a cosine of 0º would represent the maximum possible similarity. The equation to calculate the cosine similarity coefficient is:

$$\mathrm{SimCos}(m_{(m)},q) = \frac{\sum_{n=1} \left(P_{(n,m)} \times P_{(n,q)}\right)}{\sqrt{\sum_{n=1} \left(P_{(n,m)}\right)^2 \times \sum_{n=1} \left(P_{(n,q)}\right)^2}} \qquad (1)$$

Where:

P – Weight of the term

n – Identifier of the term by vector position, term 1, term 2…

m – Document identifier

q - Query identifier

As LO design and deployment methodology recommendation criterion, the value of the median[3] can be used, which is

[3] The median is the figure at the center of the set when figures are sorted from lower to higher. If the set has an even number of integers, the median is given by the two figures at the center, which are added and divided by two.

obtained by calculating cosine similarity coefficients. Then, the value of the median is compared to the coefficients calculated for each of the methodologies. MASMDOA proposes the following rule for recommending methodologies:

If Coefficient > median, then:
"Recommendable"
Otherwise:
"Not Recommendable"
End If

Thus, a set of methodologies that can be recommended to the educator is obtained based on the criteria that the educator considers to be relevant for a specific context. Table 3 shows the result.

2) Phase 2: Refining the selection of LODMs based on weighted criteria: In this phase, after having the recommended LODMs, and in order to refine the selection, the educator is prompted to weigh a series of criteria that are related to educational and technological aspects of the LODMs. As a result, the recommended LODMs are assessed and their selection refined, and only a few of these methodologies are kept. It encompasses the following steps:

a) Determining the adequacy (weight) of each of the criteria of interest selected by the educator: It has been used an "adequacy (weight) scale" for rating each criteria selected by the educator (A1, A3, etc.) in the previous step. This "adequacy scale" allows refining the LODM recommendations to the educator.

TABLE III. CALCULATING THE COSINE SIMILARITY COEFFICIENT

Nro.	Methodology	Coefficient	Result
1	Methodology 1	0,802	Recommendable
2	Methodology 2	0,617	Not Recommendable
3	Methodology 3	0,668	Not Recommendable
4	Methodology 4	0,756	Recommendable

TABLE IV. APPLIED ADEQUACY LEVELS

Code	Criterion	Interest	Level (Weight)
A1	Locatable	1	3
A2	Guidelines/Techniques	0	Not selected
A3	Reusable	1	2
A4	Publication	1	2
A5	Interoperable	1	2
A6	Educational Design	0	Not selected
A7	Assembly Possible	1	2
A8	LO Components	1	3
A9	Definition Included	1	3
A10	Methodology User	0	Not selected
A11	Author Licenses	0	Not selected

An ordinal scale can be defined to determine the level of adequacy for each criterion that was considered to be of interest by the educator (A1, A2, etc.) in relation to the methodology. The values defined by the "level of adequacy" used to qualify and quantify each criterion are:

- High (3): the criterion analyzed is very adequate, it must be used by the methodology.
- Medium (2): the criterion analyzed is adequate, it must be used by the methodology.
- Low (1): the criterion analyzed is not very adequate, it may or may not be used by the methodology.

The adequacy level of each criterion will allow calculating an overall assessment metric that will in turn allow refining LODM selection. Table 4 shows an example of adequacy level applied to each criterion.

b) Calculating the overall assessment metric for the recommended methodologies to refine their ranking: From the set of recommended methodologies, an "Overall Assessment Metric" can be calculated to refine the ranking of recommended methodologies based on the "adequacy level (weight)" of all criteria of interest added up together. From the set of recommended methodologies, an "Overall Assessment Metric" can be calculated to refine the ranking of recommended methodologies based on the "adequacy level (weight)" of all criteria of interest added up together. The criteria of interest can be grouped from 3 perspectives: technological (A1, A2, A3, A4, A5), educational (A6, A7, A8), and general (A9, A10, A11). Thus, the following are defined:

- t: total number of criteria of interest of a given LODM belonging to the technological perspective and that the educator indicated that must be present.
- e: total number of criteria of interest of a given LODM belonging to the educational perspective and that the educator indicated that must be present.
- g: total number of criteria of interest of a given LODM belonging to the general perspective and that the educator indicated that must be present.

Assessment from the technological perspective:

$$T = \sum_{i=1}^{n} (ti * Level) \tag{2}$$

Where ti – is the criterion of interest "i" that belongs to a LODM. Where Level – is adequacy level defined for criterion of interest "ti".

Assessment from the educational perspective:

$$E = \sum_{i=1}^{n} (ei * Level) \tag{3}$$

Where ei – is the criterion of interest "i" that belongs to a LODM. Where Level – is adequacy level defined for criterion of interest "ei".

Assessment from the general perspective:

$$G = \sum_{i=1}^{n} (gi * Level) \quad (4)$$

Where gi – is the criterion of interest "i" that belongs to a LODM. Where Level – is adequacy level defined for criterion of interest "gi". The maximum values achieved in the assessment by the technological, educational, and general perspectives are when all criteria of interest are selected and their adequacy level is the maximum (3):

$$T_{max} = 3 * \sum_{i=1}^{n} (ti) \quad (5)$$

$$E_{max} = 3 * \sum_{i=1}^{n} (ei) \quad (6)$$

$$G_{max} = 3 * \sum_{i=1}^{n} (gi) \quad (7)$$

The weighing coefficients or relevance for each of the perspectives (technological, educational and general) are:

$$C_t = \frac{Tmax}{Tmax+Emax+Gmax} \quad (8)$$

$$C_e = \frac{Emax}{Tmax+Emax+Gmax} \quad (9)$$

$$C_g = \frac{Gmax}{Tmax+Emax+Gmax} \quad (10)$$

The Overall Assessment Metric is calculated as follows:

$$Total = (T \times Ct) + (E \times Ce) + (G \times Cg) \quad \mathbf{(11)}$$

This equation reaches a maximum value when all perspectives have the maximum possible value at the same time, i.e.:

$$Totalmax = Tmax\ Ct + Emax\ Ce + Gmax\ Cg \quad \mathbf{(12)}$$

c) Calculating the percentual value to establish the result of each methodology in the assessment scale: A percentual value can be calculated, which will be matched to the assessment scale. It is calculated as follows:

$$Percentual\ Value = (Total / Totalmax) * 100 \quad \mathbf{(13)}$$

Figure 4 shows an example for calculating the percentual value for the recommended methodologies.

d) Identifying each of the methodologies on the assessment scale based on their calculated percentual value: Once the percentual value has been calculated for all recommended LODMs, they can be catalogued in the following assessment scale, defined as:

- Greater than or equal to 80% – The methodology is Very Adequate
- Greater than or equal to 60% and lower than 80% – The methodology is Adequate
- Between 0% and 60% – The methodology is Not Very Adequate.

Figure 4 shows an example in which Methodology 1 and Methodology 4 are very adequate, but the percentual value for Methodology 4 is higher (91.3%) than the percentual value for Methodology 1 (84.35%), which means that MASMDOA will recommend Methodology 4 as the most suitable one (very adequate). It is worth mentioning that this process is completely transparent to the user. The educator should only: (1) select the criteria that are relevant to their educational context (in phase 1, step 5), and, (2) assigns a weight to each of these criteria (phase 2, step 1).

IV. ANALYSIS FRAMEWORK CASE STUDY

It is important to be aware of the feasibility of the analysis framework for selecting a LO design and deployment methodology for a given context. To this end, knowing which aspects (criteria) of MASMDOA are considered to be significant for the target audience, as well as which aspects have not been taken into account for the framework, could be useful in the future to improve the framework. To assess the validity of the analysis framework contents, the expert assessment technique [39, 40] was used, using a questionnaire as the tool selected to gather the opinion of participating experts in relation to the criteria that are presented in MASMDOA. The purpose of this was corroborating the significance of each criterion and detecting unforeseen errors. Expert opinion is defined as an informed opinion presented by individuals that are knowledgeable on the subject matter and that are acknowledged by other qualified experts in the subject matter, and who can provide information, evidence, judgment and assessments [40].

Nro.	Methodology	T	E	G	Ct	Ce	Cg	Total	Percentual Value %
		9	5	3	0,52	0,29	0,17	6,8	100,00
1	Methodology 1	7	5	3				5,7	84,35
4	Methodology 4	9	3	3				6,2	91,30

Figure 4. Percentual Value calculated

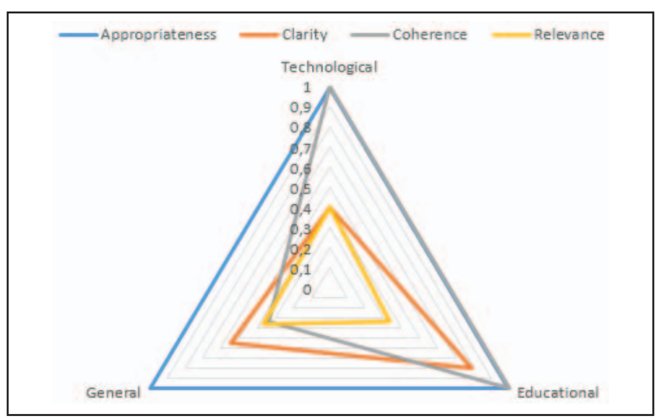

Figure 5. Agreement among judges

The following procedure was used to obtain the opinion of experts:

1) The purpose of the expert opinion was defined.

2) Judges were selected using the procedure known as biogram[4]: As a result, 7 expert judges were selected [41] distributed all over Ibero-America: 1 from Spain, 2 from Ecuador, 2 from Argentina, 1 from Venezuela, 1 from Colombia. The experts present different profiles, with background in either Educational Sciences (in particular, Educational Technology) or Computer Science with specialization and/or training in Educational Technology. Thus, both the educational and technological dimensions that are intertwined in the creation of LOs are covered. When selecting the judges, experience working with LOs and having a prior opinion on the subject were also considered. This will allow gathering the necessary expert opinion and also assessing the criteria corresponding to the general dimension proposed in the analysis framework. However, it is necessary to extend this analysis with more experts in order to obtain more accurate results.

3) The dimensions and the items to be assessed for each of the dimensions were detailed in relation to appropriateness, clarity, coherence and relevance of each item.

4) A template was designed and then sent to the judges for assessment: It is available at http://goo.gl/forms/yxCZJwvphw

5) Agreement among judges was assessed: To do so, Kendall's [42] W statistical coefficient was used. This coefficient is used to determine the association degree among k sets of ranges [43], and is therefore particularly useful when experts are asked to assign ranges to items, for example, from 1 to 4. The minimum value that the coefficient can have is 0, and the maximum value is 1. When the value of Kendall's W coefficient is between 0.0 and 0.2, it means that there is no consensus or that consensus is low; a value between 0.3 and 0.4 means moderate consensus; a value between 0.5 and 0.6 means relatively high consensus; and a value between 0.7 and 1.0 means very high consensus. In the case of MASMDOA, the values presented on Table 5 were obtained.

TABLE V. VALUES OF KENDALL'S W COEFFICIENT FOR MASMDOA

Dimension	Kendall's W			
	Appropriateness	Clarity	Coherence	Relevance
Technological	0,994	0,400	1,000	0,400
Educational	0,994	0,792	1,000	0,333
General	0,994	0,542	0,333	0,364

[4] The biogram consists in preparing a biography for the expert by adding aspects such as: place of work, years of professional experience, academic formation, research experience, etc.

6) Conclusions were drawn: These refer to the aspects that require improvement as well as those that received good scores from the participating experts. In general terms, in relation to MASMDOA, there is a very high agreement in relation to the appropriateness of the items included in all dimensions – technological, educational and general. However, the experts recommended including sub criteria or sub items to each of the items included in each of the dimensions of MASMDOA with the purpose of improving recommendations and the adequacy of LODMs recommended by the analysis framework. Expert agreement is relatively high in relation to clarity, very high in relation to coherence, and moderate in relation to relevance. This indicates that work has to be done to improve the clarity and relevance of the items in each dimension. Figure 5 shows the results.

V. ANALYSIS FRAMEWORK EXPERIENCE ASSESSMENT

To assess MASMDOA, a case study was used, since it is an empirical method that allows analyzing phenomena in their own context. This method is used when there is no marked boundary between phenomenon and context, or when there is a lack of experimental control and information is gathered from a few entities [43]. A main question was used as starting point to guide the entire design and execution process: *"¿Does the methodology recommended by the analysis framework meet the needs of the educator or the needs of the context?"* The case study was developed in the context of a post-grade course carried out at the National University of La Plata; attendees were educators from that University as well as from the University of Cuenca, Ecuador. Training was focused around the design and production of LOs, and the methodology used for designing and creating them was a methodology called "CROA". This methodology was recommended by MASMDOA based on a series of needs that were identified as aspects of interest for course participants (all of them educators). It should be noted that these educators had little to no experience in the design and creation of LOs. Among the needs that were identified and which the methodology in question should tackle, the following can be mentioned:

- N1: Using some metadata model or standard to describe the LO
- N2: Recommending the use of a standard to package the LO so that it could be deployed on various virtual environments that could interpret the package that was created
- N3: Considering how to store a LO in a LO repository
- N4: Specifying the structure that LOs should have to form larger collections
- N5: Indicating the minimum components that the LO should have
- N6: Offering a definition of LO to guide their design
- N7: Providing the LO with a license

- N8: Being able to design and develop the LO by themselves

After gathering the needs of both educators and context, MASMDOA was applied to the 19 methodologies being considered, whose geographical distribution is as follows: 6 methodologies from Mexico [15, 17, 37], 6 methodologies from Colombia [16, 20, 22], 2 methodologies from Venezuela [19, 21], and 1 methodology from Spain [14], Chile [44], Uruguay [45], Brazil [18] and Argentina [23] each.

The Venezuelan methodologies for the creation of LOs consider in their proposals the use of instructional design, the LOM metadata standard, and SCORM as packaging standard. The Mexican methodologies make use of pedagogic patterns, templates, prototype evolutionary templates and extreme programming, UML and case tools to guide the design of the LO. The Colombian methodologies follow the guidelines proposed by the National Ministry of Education of Colombia and adopt a common definition to work with the design of the LO. The Argentinean methodology considers several of the criteria mentioned above. It should be noted that most of the methodologies do not propose specific granularity levels for the design of LOs, whose use would then be useful for LO reutilization, so that LOs can be combined for creating collections of LO, such as modules, lessons, etc. After applying MASMDOA, 9 methodologies were recommended, with only 4 of them categorized as "very adequate" based on the needs that had been specified, and only one with the highest score among the 4 that were "very adequate". This methodology was CROA. After this, a protocol containing the activities listed below was designed: a) Case definition, b) Case design and planning, c) Preparation for data collection, d) Data collection, e) Analysis and interpretation of the data collected, f) Results report. To collect the data, a questionnaire was sent to 7 educators who passed the raining course. This tool provide 14 questions related with the dimensions defined in MASMDOA, with the purpose to answer to the question done at the beginning of this section, that let see if the LODM selected satisfice the teacher's needs. The questionnaire used to gather the data is available at: http://goo.gl/forms/TAKimcXdsK. Table 6 shows the results obtained.

TABLE VI. ANALYSIS FRAMEWORK EVALUATION

Queried Need	Strongly agree	%	Weight assigned to each need (criterion relevance)
N1	4	57	3
N2	4	57	2
N3	4	57	1
N4	3	43	2
N5	7	100	3
N6	6	86	3
N7	0	0	2
N8	6	86	2

As it can be seen in Table 6, educator needs N1, N5 and N6 are considered to be very important and that they should be covered by the methodology. Fifty-seven percent of the educators considered that N1 was met, 100% of the educators considered that N5 was met, and 86% of the educators considered that N6 was met. Needs N2, N4, N7, N8 were considered to be important and that they should be covered by the methodology. Fifty-seven percent of the educators considered that N2 was met, 86% of them considered that N8 was met. In the case of N4, only 43% of the educators considered that it was met, while everyone considered that N7 was not met. However, when checking the documentation available on the CROA methodology, it was found that it has a specific vocabulary and information to license LOs, with metadata fields that refer to the license used to share the LO. The reason why the educators responded that CROA does not provide information on the use of author licenses may be related to the way in which training sessions were developed, this being a variable that should be included in future assessments so as to isolate from the responses context the development of the training sessions as a variable that can affect the results. With the exception of N7, MASMDOA recommended CROA as the methodology that should be used for the design and creation of the LO, with an 87.5% coverage of the needs identified by the educators to be relevant for their specific context.

VI. CONCLUSIONS AND FUTURE WORK

Based on the general objective of this article, the most significant results obtained from the research work carried out are described below:

- A conceptual review of the LO paradigm has been presented, and a table summarizing the characteristics that LOs should have has been produced compiling the various views of authors over the last 15 years. By analyzing the conceptual definitions, the following pragmatic definition of LO was adopted: a LO is an independent digital didactic unit whose structure is formed by a specific learning goal, content, activities and self-assessment, and that can be reused in different technological (repositories, teaching and learning virtual environments) and educational contexts. It also has metadata that allow locating it within the repositories and tackle its contextualization.
- The Analysis Framework for LO Design Methodologies (MASMDOA) developed here is based on the characteristics of the LOs and is associated to a series of criteria that were extracted after a thorough review of LO definitions. MASMDOA includes criteria that cover technological and pedagogical aspects of the LO.
- Based on educator needs or a specific context, MASMDOA recommends a series of methodologies for designing LOs as first instance. After this first recommendation, and based on some relevance criteria that are assessed by the educator, an assessment metric

is calculated that allows refining the initial recommendation of methodologies and selecting the most suitable based on educator or application context needs.

- The validation of the criteria used in MASMDOA was carried out using the expert opinion method, and the level of agreement among all 7 participating experts was calculated. To do this, Kendall's statistical coefficient W was used, which is a representation of the agreement by the experts on the different criteria used in MASMDOA based on appropriateness, clarity, coherence and relevance of each of them within the 3 dimensions being considered (technological, educational and general).

- As a result of the assessment, it was concluded that there is a very high level of agreement in relation to the appropriateness of the items included in each of the three dimensions. However, the experts recommended adding sub criteria to each of the items within each of the dimensions in order to improve the final recommendation of the Analysis Framework and improve "sensitivity" for recommending a methodology. The agreement in relation to clarity is relatively high, it is very high in relation to coherence, and moderate in relation to relevance. This indicates that work has to be done to improve the clarity and relevance of the items in each dimension.

- As a result of the application of MASMDOA, it was inferred that the recommended methodology responded to 87.5% of the specific needs of context of the educator. However, the CROA methodology had a total value of 91%. This difference is attributable to the fact that the author license indicator was assessed as lacking by the educators that participated in the case study but it was afterwards corroborated that such indicator is indeed included in the recommended methodology.

- The case study developed for this article is merely a use case and does not prove the validity of the Analysis Framework. The development of other experiments to extend and corroborate the validity of MASMDOA deemed necessary. In this context, as future work, it is expected to expand the criteria used in each of the dimensions in MASMDOA, developing new sub criteria that provide a better "sensitivity" tool to improve recommendation and appropriateness of LODM. To achieve this, the other methodologies that were recommended (very adequate) have to be validated the same as CROA was, and then a comparison must be carried out to determine if the assessment by the educators matches the recommendations of the Analysis Framework. However, this case study has demonstrated the applicability and efficacy of the Framework.

It can be concluded that MASMDOA can be used as a guideline to help educators find a LODM that fits their own needs and/or those of their context. MASMDOA is ready for be used by people with a certain technical level, as OA developers, and can be used for institutional decision-making or in a project for the generation of OA. However, as future work is proposed to developed a user-friendly tool that hides the technical details to end users so it can be used by any teacher. Also, MASMDOA allows educators knowing the orientation of the LO design and deployment methodology without actually having to implement it, by providing relevant information about technological and educational aspects, showing their orientation, whether there are any trends for favoring technological aspects over educational ones or vice versa, or whether both aspects, i.e., the technological and the educational, are balanced. This directly affects the educators or those in charge of educational technology aspects at universities. With this tool (MASMDOA), educators have a feasible mechanism that helps them make good decisions to create appropriate digital educational materials but, above all, adapted to their needs.

In the future, the following lines of work will be explored:

- Expanding the survey of LO design methodologies to a global context, in order to collect a substantial amount of information that could potentially enrich MASMDOA.

- Researching the applicability of other models to replace the Boolean vectorial model for recovering information.

- Studying the suitability of the scale used to assess the adequacy level of each of the criteria included in MASMDOA.

- Developing other experiments that will allow corroborating the validity of MASMDOA.

- Expanding the criteria used within each of the LO dimensions in MASMDOA, developing new sub criteria that will provide a better "sensitivity" to the tool to improve the recommendation and adequacy of LO design methodologies.

- Developing a user-friendly tool to educators automatically use the MASMDOA analysis and selection procedure.

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