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Towards a holistic model for quality of learning object repositories: A practical application to the indicator of metadata compliance

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Abstract

Purpose – This paper aims to address the need to ensure the quality of metadata records describing learning resources. We propose improvements to a metadata-quality model, specifically for the compliance sub-feature of the functionality feature. Compliance is defined as adherence level of the learning object metadata content to the metadata standard used for its specification. The paper proposes metrics to assess the compliance, which are applied to a set of learning objects, showing their applicability and usefulness in activities related to resources management.

Design/methodology/approach – The methodology considers a first stage of metrics refinement to obtain the indicator of the sub-feature compliance. The next stage is the proposal evaluation, where it is determined if metrics can be used as a conformity indicator of learning object metadata with a standard (metadata compliance). The usefulness of this indicator in the information retrieval area is approached through an assessment of learning objects where the quality level of its metadata and the ranking in which they are retrieved by a repository are correlated.

Findings – This study confirmed that the best results for metrics of standardization, completeness, congruence, coherence, correctness and understandability, which determine the compliance indicator, were obtained for learning objects whose metadata were better labelled. Moreover, it was found that the learning objects with the highest level of compliance indicator have better positions in the ranking when a repository retrieves them through an exact search based on metadata.

Research limitations/implications – In this study, only a sub-feature of the quality model is detailed, specifically the compliance of learning object standard. Another limitation was the size of the learning objects set used in the experiment.

Practical implications – This proposal is independent from any metadata standard and can be applied to improve processes associated with the management of learning objects in a repository-like retrieval and recommendation.

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Originality/value – The originality and value of this proposal are related to quality of learning object metadata considered from a holistic point of view through six metrics. These metrics quantify both technical and pedagogical aspects through automatic evaluation and supported by experts. In addition, the applicability of the indicator in recovery systems is shown, by example to be incorporated as an additional criterion in the learning object ranking.

Keywords Metadata, Digital repositories, Quality, IEEE-LOM, Learning object

Paper type Research paper

Introduction

Quality assessment is a complex issue in any scope. In this paper, the focus is on the quality of the materials used in e-learning in order to support the teaching-learning process. In this sense, the notion of a learning resource has been formalized in the concept of a learning object (LO). In this research, the definition proposed by McGreal (2004, p. 21) is used: a learning object is "any reusable digital resource that is encapsulated in a lesson or assemblage of lessons grouped in units, modules, courses, and even programmes". Physically, a learning object can be considered as a package that contains a learning resource, a metadata and a manifest describing the package contents (IMS GLC, 2007).

Metadata standards are key elements in this context. Metadata standards are formal specifications used to describe educational resources (Al-Khalifa and Davis, 2006). IEEE-LOM (Learning Technology Standards Committee (LTSC), 2002) developed metadata standards designed specifically for learning objects, and defined the syntax and semantics of metadata. They consist of more than 60 descriptors grouped into a conceptual scheme of nine categories: general, life cycle, meta-metadata, technical, educational, rights, relation, annotation and classification. Using a standard or application profile for the labelling of learning objects is not necessarily an indicator of quality, although contributes to the objects correct description.

This paper proposes improvements to the model presented by Vidal *et al.* (2008), specifically the sub-characteristic for compliance belonging to the functionality characteristic. Compliance is defined as the adherence level of the learning object metadata content to the metadata standard used for its specification. Two research questions have been defined that guide this work:

RQ1. Does a learning object with metadata properly labelled according to standard get higher values in the proposed compliance metrics?

RQ2. Is a learning object with the highest level of quality more likely to be recovered in a repository by exact searching?

To answer both questions, two experiments are presented. The first one is designed with the aim of validating the metrics that make up the indicator of compliance quality. The second is designed with the aim of verifying, in a case study, that there is a correlation between the quality of the learning object metadata and the chances of recovering it in a repository.

As shown in Figure 1, the methodology is based on the model proposed by Vidal *et al.* (2008). First, a refining step is performed where the characteristics and sub-characteristics of the complete model are defined. In the next stage, metrics to gauge the compliance of sub-characteristic are defined. The next steps consider the evaluation of the proposal. In the first experiment, these indicators are calculated for a set of labelled learning objects. Then, the metadata quality levels of each object and the position in which they are recovered by an exact searching system are correlated.

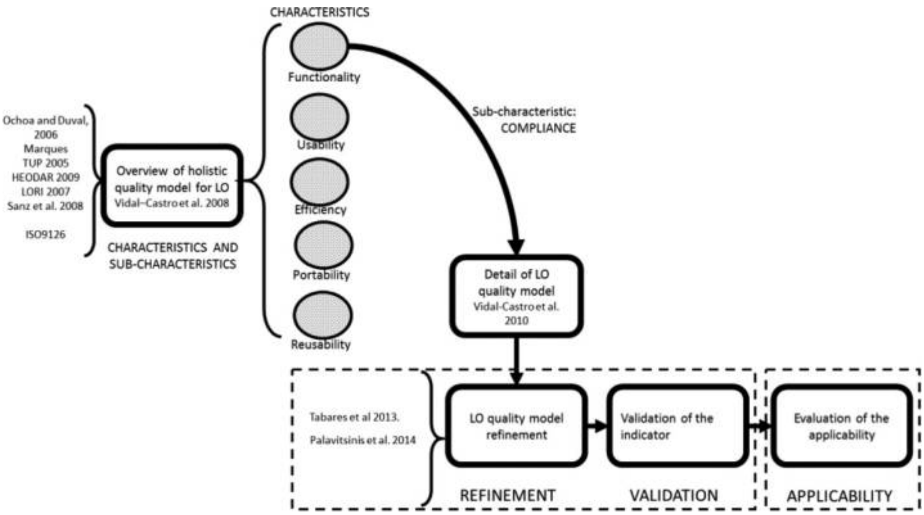

Figure 1.
Methodology

Background

Some studies focus on evaluating aspects, or on metrics for determining the quality level of the learning object, for example, the levels of reusability, accessibility, usability and portability, among others. Sanz *et al.* (2009) proposed to evaluate the reusability from a structural viewpoint, through the following features: self-contained, modular, properly grained, traceable, modifiable, usable and standardized. From a contextual viewpoint, a learning object which is more dependent and specific will be more limited in terms of its reusability. In Khoo *et al.* (2010), the evaluation is based on the learning object's content and the content characteristics associated with reusability. The assessed characteristics are topic, treatment type, treatment level, detail level, style and information type. In Currier and Campbell (2005), three factors are specified to determine the learning object's reusability. These factors are technical format and contextual and technical dependency. Cuadrado and Sicilia (2005) proposed an adaptation to software metrics for evaluating learning object characteristics, such as reusability. The adapted metrics are: weighted method per class, depth inheritance tree, coupling between object and lack cohesion of methods. These metrics focus on the evaluation of the content (interactive activity), structure (links between learning objects), metadata and goals of the learning object, respectively. They were tested in Noor *et al.* (2009) on a collection of 50 learning objects.

Other proposals treat the subject from a more global perspective. For example, the TUP model (Cuadrado and Sicilia, 2005), LORI (learning object review instrument) and HEODAR (Morales-Morgado *et al.*, 2009) include a broader set of quality characteristics. The LORI tool (Leacock and Nesbit, 2007) evaluated aspects such as content quality, objective fulfilment, feedback and adaptation capability, motivation, presentation, usability, accessibility, reusability and standards compliance. Ochoa and Duval (2006) defined a set of seven metadata-based metrics. These metrics are accuracy, completeness, provenance, compliance, consistency, currency, readability and learning object's linkage. Rovinskiy *et al.* (2003) proposed metrics to evaluate the completeness and compactness of a collection of learning objects. Most evaluations focused on assessing the level of individual quality of each learning object; however, it is also possible to assess the quality of collections of objects.

One line of research in studies is to use metadata as information to evaluate the quality of LOs. The model proposed by Vidal *et al.* (2008) is based on an adaptation from the ISO 9126 standard [ISO/IEC, 2001]. The model proposes that the quality of a learning object must consider its nature; that is, it assumes that a quality learning object has technical and instructional aspects that encourage its use, reuse and adaptation for meeting the learning needs of a student or target audience. This model defines characteristics and sub-characteristics. The quality characteristics described in the model, specifically functionality, ease of use and reuse, consider pedagogical aspects directly. The efficiency characteristic is more related to technical aspects of a learning object, as a digital resource. Some features are measurable on learning object content, metadata or as a whole. Moreover, the evaluation can be either quantitative or qualitative. In a later work, the authors detail the form as determining the compliance sub-characteristic (part of the functionality characteristic) through six indicators (Vidal *et al.*, 2010). The indicators are metadata standardization, completeness, correctness, clarity, congruence and pedagogical coherence. The proposal made by Tabares *et al.* (2013) defined the quality of the metadata by using completeness, consistency and coherence metrics. The first two metrics are similar to those proposed by Vidal *et al.* (2010), but coherence is defined from the correlation between metadata, which should be drawn from a well-labelled significant set of objects. Coherence is defined as an n-array relationship between the learning object metadata with a pedagogical sense.

The quality of a learning object has different dimensions, for example, pedagogical or technical; that is, a learning object must be regarded as a digital and educational resource simultaneously. Evaluations usually emphasize some dimensions.

For evaluation of quality learning objects, both manual and automatic mechanisms have been used. The manual form is based on the perception of experts gathered through surveys or questionnaires (Morales-Morgado *et al.*, 2009; Leacock and Nesbit, 2007). Automatic systems are based on technology from artificial intelligence and usually use the information included in the metadata itself or its contents (Sanz *et al.*, 2009). Mixed systems for evaluation could use both of the previous methods to provide a quality level indicator.

It is interesting that a small portion of the reviewed research refers to a software quality model or to any other standard (Segura *et al.*, 2008). It is important to note that software quality standards, such as ISO 9126 or ISO 25000, should not be directly applied to a learning object owing to their instructional purpose, but must be adapted for this kind of evaluation.

General proposals focused on content and presentation of a learning object (Leacock and Nesbit, 2007; Morales-Morgado *et al.*, 2009). Other proposals (Ochoa and Duval, 2006; Sanz Rodríguez, 2010) emphasized the evaluation of the metadata. In particular, the latter also includes the structure of a learning object. The proposal presented by Leacock and Nesbit (2007) emphasized the pedagogical dimension, while Ochoa and Duval (2006) and Sanz Rodríguez (2010) added the technical dimension.

From the standpoint of the learning object building process, Palavitsinis *et al.* (2011) proposed the metadata quality assurance certification process (MQACP). This process was applied to different repositories, generating improvements in the metadata quality level (Palavitsinis *et al.*, 2014). Table I shows how the revised proposals can be integrated and complemented with the model previously proposed in Vidal *et al.* (2008).

Improvements and changes performed to features of the compliance sub-characteristic

Improvements and changes performed for each feature of the compliance sub-characteristic using the work of Vidal *et al.* (2010) are presented. The improvements target the definition of the metric, the description of the variables or the form of

Table I. Analysis of evaluation quality models

Quality characteristics	Repository	Repository	Marqués (2000)	TUP (Bednarik, 2002)	Ochoa and Duval (2006)
Functionality					
Suitability					
Goal correction	X	X		X	
Pedagogical consistency between LO and audience	X	X		X	
Pedagogical consistency between LO and cognitive style		X		X	
Content sufficiency					
Content supplement		X	X		
Content granularity	X	X			
Content validity		X	X		
Trust in sources	X				
Media pertinence	X	X	X		
Accuracy					
Content accuracy	X	X			
Compliance					
Metadata standardization					X
Metadata completeness					X
Metadata correction					X
Metadata understandability					X
Metadata congruence					X
Metadata pedagogic coherence					X
Interoperability					
Software dependency				X	
Recoverability					
State recoverability				X	
Usability					
Understandability					
Content understandability	X	X	X		
Spelling and grammar correction		X	X		
Media contribution	X	X	X		
Learnability					
Content organization	X	X	X	X	
Design standardization	X	X	X	X	
Attractiveness					
Collaboration encouragement					
Interaction encouragement		X	X	X	
Creativity encouragement		X			
Motivation encouragement	X	X	X	X	
Uniformity		X	X		

(*continued*)

Quality characteristics	Repository	Repository	Marqués (2000)	TUP (Bednarik, 2002)	Ochoa and Duval (2006)
Operability					
Adaptability to learning styles	X		X		
Usability compliance	X				
Efficiency					
Time behaviour					
Client and server load			X	X	
Resource utilization					
Storage efficiency					
Installability			X	X	
Co-existence					
Hardware dependency				X	
Reusability					
Content reusability					
Independence from religious aspects					
Independence from geographical aspects					
Independence from ethnic aspects			X		
Independence from political aspects					
Design reusability					
Autonomy					
Goal dispersion					
Content-presentation division					

Table I.

calculation. The evaluation of the metrics of the compliance sub-characteristic is done mainly on the metadata fields.

Two distinctions are made between metadata fields, according to their status as a mandatory field and according to their content. Related to metadata fields, four types are identified (Figures 2 and 3):

(1) *Fields with vocabulary*: The fields with vocabulary are fields whose content is restricted by a finite set of possible values.

(2) *Fields without vocabulary*: These are divided into fields of free text content and limited text content.

(3) *Fields of free text content*: The fields of free text content are fields whose content is open (i.e. free-text).

(4) *Fields of limited text content*: These are fields that do not have a controlled vocabulary, but they are not open fields (i.e. they have constraints that limit their labelling).

According to the mandatory nature of the field, three categories are identified:

(1) *Mandatory fields*: These fields are prescribed by the standard or application profile (i.e. they cannot be empty). These fields are fundamental for the later use of the LO.

(2) *Recommended fields*: These are fields that are considered important but are not essential for the later use of the LO, so they may be empty.

(3) *Optional fields*: They are complementary fields and can be empty.

Feature: metadata standardization

To evaluate the feature of metadata standardization, all recommendations and constraints set out by the standard of labelling are transformed into IF-THEN-ELSE rules. Note that the mandatory nature of the field is not considered a rule because this aspect is evaluated in the metadata completeness metric.

When the fields related to a rule are empty, the rule evaluation could be non-applicable, except when the rule itself invalidates this possibility. For the second recommendation stated in Table II, if one of the three fields is empty, the rule cannot be evaluated and is considered not applicable (NA). The third recommendation, in addition to the mandatory constraint, indicates that the object should have at least an author. In this case, if the field role is empty, the rule is applicable and is considered unsatisfied.

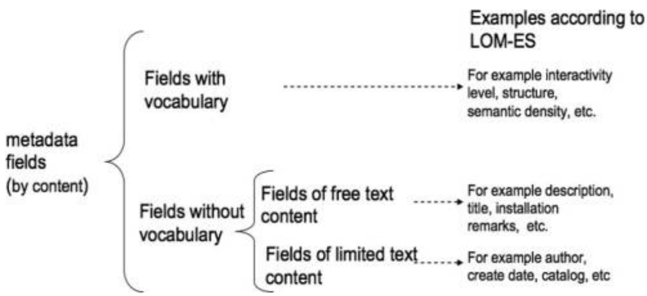

Figure 2. Types of metadata fields for evaluation according to the content

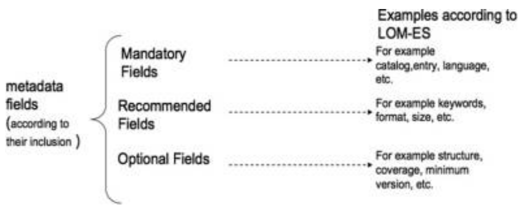

Figure 3. Types of metadata fields for evaluation according to their inclusion

This metric is evaluated as shown in equation (1), where value zero indicates that no rule is satisfied on the learning object metadata, and value one indicates that all defined rules are satisfied by the learning object metadata:

$$mStandardization = \frac{\text{Rules}_s}{\text{Rules}_d} \tag{1}$$

where: Rules_s: is the number of satisfied rules; Rules_d: is the total number of applicable rules defined from the standard.

Feature: metadata completeness

When the learning object metadata indicates the use of a standard of labelling, then all mandatory fields stated by the standard should be filled out. Otherwise, a minimum of three fields are considered as mandatory: title, localization and description.

This metric is defined as shown in equation (2), where the value of zero indicates that no mandatory field on metadata is filled out and one indicates that all mandatory fields on the metadata are filled out:

$$mCompleteness = \frac{\text{MF}_f}{\text{MF}_d} \tag{2}$$

where:

MF_f = the number of mandatory fields filled out;

MF_d = the total number of mandatory fields considered.

Feature: metadata correctness

Metadata correctness is evaluated in fields with vocabulary [equation (3) and Figure 3]; that is, fields that must be filled with valid domain values, as specified by the standard used, or according to a controlled vocabulary or thesaurus:

$$mCorrectness = \frac{\text{RF}_{cf}}{\text{RF}_d} \tag{3}$$

Metadata field*	Recommendation**	Metadata field included in the recommendation***
1.2 Language	Note 2: If the learning object had no lingual content (as in the case of a picture, for example), then the appropriate value for this data element would be "none"	1.2 Language
1.8 AggregationLevel	If the learning object is a digital picture, 1.7:General.Structure = Atomic and 1.8: General.AggregationLevel = 1	5.2 LearningResourceType 1.7 Structure 1.8 AggregationLevel
2.3.1 Role	Note 1: Minimally the author (s) of the learning object should be described.	2.3.1 Role

Notes: *Field of the standard or application-profile in which the recommendation is specified; **Textual recommendation specified in LOM-ES; ***Fields included in the rule evaluation

Table II. Examples of LOM-ES and recommendations for learning object labelling where:

RF$_{cf}$ = the number of correctly filled filed with vocabulary;

RF$_{d}$ = the number of fields with vocabulary and non-empty.

This metric is evaluated as shown in equation (3), where zero value indicates that no metadata fields with vocabulary are filled out according to the vocabulary or value space defined by the standard and value one indicates that all metadata fields with vocabulary are correctly filled out. When using labelling tools, this metric fails to be relevant, as the values should be controlled by these tools.

Feature: metadata understandability

As shown in Figure 3, standards for labelling consider fields without vocabulary, among which there are fields of free text content and fields of limited text content. The fields of free text content, such as the *title*, have no limitations on content. The assessment instrument for fields of free text content uses a five-level Likert scale questionnaire (Uebersax, 2006). Figure 4 shows an example questionnaire with three evaluation items.

The metadata understandability feature for fields of free text content is assessed as the ratio between the sum of the answers for each field of free text content of the learning objects (a$_{ij}$) and the total evaluation items defined in the instrument for fields of free text content:

$$\mathrm{mFText} = \frac{\sum_{i=1}^{n} \frac{\sum_{j=1}^{m} a_{ij}}{m}}{n} \quad (4)$$

where: a_{ij} = 1. . .5 corresponds to the answer for each item;i = 1 . . . n, where n is the total number of fields of free text content and not empty metadata fields; j = 1. . . m, where m is the number of evaluation items, and m = 3 in the example in Table IV. It is assumed that all items must be assessed.

This metric is assessed as shown in equation (4), where value = 1 indicates that fields of free text content of the learning objects have low understandability and the value = 5 indicates that fields of free text content can be easily understood. The assessment instrument for fields of limited text content uses a binary scale questionnaire (yes/no):

Figure 4. Example items proposed for evaluation of metadata understandability feature for fields of free text contents

$$\text{mLText} = \frac{\sum_{i=1}^{n} a_i}{n} \tag{5}$$

where:

a_{ij} = 0...1 corresponds to the answer for each item;

i = 1...*n*, is the total number of limited text content and not empty metadata fields.

This metric is assessed as shown in equation (5) where value = 0 indicates that fields of limited text content of the learning objects have low understandability and value = 5 indicates that fields of limited text content can be easily understood.

Finally, the metadata understandability feature is calculated:

$$\text{mUnderstandability} = \left(p_a \times 0.25 \times (\text{mFText} - 1)\right) + (p_b \times \text{mLText}) \tag{6}$$

where:

The constant 0.25 is used to convert the 1-5 scale 1-5 to 0-1 scale.

p_a y p_b= are the weights for fields of free text content and fields of limited text content. These values can be adjusted according to the perceived importance for each field type. Their values must be in the range [0-1], such that the sum is 1:

$$p_a + p_b = 1$$

This metric takes values between [0-1]. mUnderstandability = 1 indicates that all non-restricted fields or fields without vocabulary are easily understood by a user. mUnderstandability = 0 indicates that all fields without vocabulary are difficult to understand by the user.

Feature: metadata congruence with learning object content

The reliability of the metadata values is related to the congruence between information consigned in learning object metadata fields and the actual content of the learning objects. The assessment instrument can be defined as a yes/no checklist. It is important to note that there are fields where congruence cannot be evaluated with just content analysis of a learning object or its metadata. In such cases, the fields are not considered in the assessment of congruence. For example, the LearningResourceType field can be evaluated by looking at the learning object content:

$$mCongruence = \frac{F_c}{F_d} \tag{7}$$

where:

F_c: the number of metadata fields congruent with the learning object content;

F_d: the total number of non-empty metadata fields.

This metric is assessed as shown in equation (7), where value = 0 indicates that no metadata is congruent with the learning object content and value = 1 indicates that all metadata fields are congruent with the learning object content.

Feature: metadata pedagogical coherence

There must be a pedagogical coherence among education-related fields, such as interactivity level and learning resource type; interactivity type and learning resource type, to name a few. The assessment instrument may include an appreciation of the pedagogical value and the possibility of recommending the learning objects according to the education-related fields.

The assessment instrument can be defined as a five-level Likert scale questionnaire. Table III shows some educational-related fields used in the evaluation of the pedagogical coherence. Figure 5 shows an example questionnaire with items for pedagogical coherence evaluation. This evaluation is conducted by experts in view of their teaching experience and content of educational-related fields.

This metric is assessed as shown in equation (8), where value = 0 indicates that metadata fields of the learning object have low pedagogical coherence value = 5 indicates that metadata fields have high pedagogical coherence:

$$\text{mPedagogicalCoherence} = \frac{\sum_{j=1}^{m} a_i}{m} \qquad (8)$$

Metadata field	Metadata field	Metadata field
1.2 Title	5.1 InteractivityType	5.8 Difficulty
1.3 Language	5.2 LearningResourceType	5.9 TypicalLearningTime
1.4 Description	5.3 InteractivityLevel	5.10 Description
1.6 Coverage	5.4 SemanticDensity	5.11 Language
1.7 Structure	5.5 IntendedEndUserRole	5.12 CognitiveProcess
1.8 AggregationLevel	5.6 Context	9.1 Purpose
4.1 Format	5.7 TypicalAgeRange	9.2 TaxonPath
		9.3 Description

Table III. Example of LOM-ES metadata fields related with pedagogical coherence

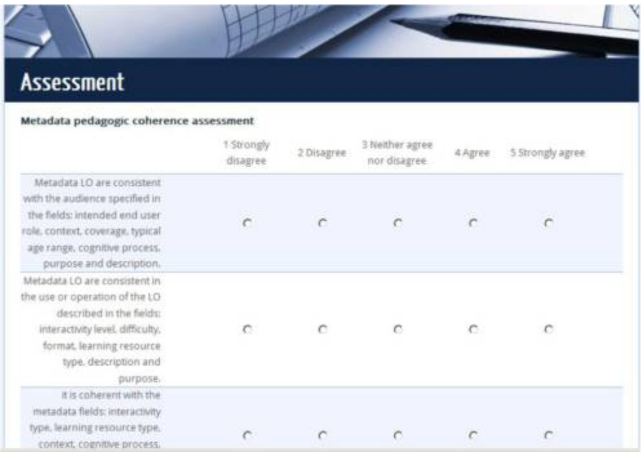

Figure 5. Extract of questionnaire for metadata pedagogical coherence assessment

where:

$a_i = 1 \ldots 5$ corresponds to the answer for each item;

$j = 1 \ldots m$, with m the number of evaluation items.

Compliance sub-characteristic global indicator

As mentioned earlier, the sub-characteristic compliance, part of the functionality characteristic, is defined according to the standardization, completeness, correctness, clarity, congruence, and pedagogical coherence of the metadata. The calculation of the compliance is expressed according to equation (9):

$$\begin{aligned} \text{mCompliance} = {} & \text{P}_1 \times \text{mStandardization} + \\ & \text{P}_2 \times \text{mCorrectness} + \\ & \text{P}_3 \times \text{mCompleteness} + \\ & \text{P}_4 \times \text{mUnderstandability} + \\ & \text{P}_5 \times (0.25\,\text{x}(\text{mPedagogicalCoherence} - 1)) + \\ & \text{P}_6 \times \text{mCongruence} \end{aligned} \tag{9}$$

where:

The constant 0.25 is used to convert the 1-5 scale to 0-1 scale.

$P_1 \ldots P_6$ = is the weight of each aspect weighted feature conformance. Their values must be in the range [0-1], such that the sum is 1:

$$\sum_{i=1}^{6} p_i = 1$$

i: 1 . . . 6 to each feature for evaluation.

The weight (p_i) for each feature of the compliance sub-characteristic, namely, mStandardization, mCorrectness, mCompleteness, mUnderstandability, mPedagogicalCoherence and mCongruence, allows adapting the quality assessment to the user needs or the community. For example, if you use a tool for automatic labelling of the weight of correctness feature, it could be reduced in favour of the weight of other features.

This indicator takes values between 0 and 1. The mCompliance = 0 indicates that metadata fields have no compliance. The mCompliance = 1 indicates that all metadata fields are in compliance.

The evaluation of the six quality features is made using expert criteria and automated procedures. Table IV summarizes the way each feature is evaluated.

Experiment 1: evaluating the compliance indicator

This section details an experiment to prove that a properly labelled learning object has better quality indicators than other mislabelled learning objects. The metric ones and proposed instruments are used to evaluate their applicability and pertinence.

Evaluation experiment description

To evaluate the proposal, an experiment has been designed where the test collection was a set of eight learning objects with its metadata extracted from the AGORA repository (Prieto *et al.*, 2008). The test collection has been labelled using the LOM-ES application profile [Asociación Española de Normalización (AENOR), 2016]. LOM-ES is the version of IEEE-LOM standard for the Spanish educational community. This application profile defines 80 fields (including varying repeating fields), organized into nine categories. LOM-ES includes several modifications over the standard IEEE-LOM, mainly in the form of new elements and extensions to the predefined vocabularies, especially in the educational category.

To select this set of learning objects, the topic and completeness of the fields were considered. Eight learning objects were extracted from the repository, one of them was considered as a control group, which was correctly labelled by an expert. Table V shows the collection of learning objects used in the experiment. This table represents the learning objects labelled in the repository.

Three experts participated in the experiment as raters. They were homogeneous in their background knowledge. All of them were educators with more than four years of experience in instructional design and with knowledge in metadata standards. To statistically validate the consistency of the experts' evaluations, the analysis of Kappa with quadratic weighting (κ) was used. If the raters are in complete agreement, then $\kappa = 1$. If there is no agreement among the raters, other than what would be expected by chance, then $\kappa \leq 0$ (Landis and Koch, 1977).

The total number of metadata fields that are involved in the proposed metrics changes depending on the standard or application profile used and for which the compliance sub-characteristic is evaluated. In this experiment, the LOM-ES application profile (with 61 fields without repetition) is used; therefore, the percentage of fields involved in the metric is:

- Metadata standardization involves 21 out of 61 fields (i.e. 34 per cent).
- Metadata completeness involves 22 out of 61 mandatory fields (i.e. 36 per cent).
- Metadata correctness involves 26 out of 61 fields (i.e. 43 per cent).
- Metadata understandability involves 35 out of 61 fields (i.e. 57 per cent).

Features	Mechanism of evaluation
Metadata standardization	Automatically with an application (which will be described in Section 4.1.1)
Metadata completeness	Automatically according to the mandatory fields and vocabulary specified in LOM-ES application profile
Metadata correctness	Automatically according to the mandatory fields and vocabulary specified in LOM-ES application profile
Metadata understandability	By experts
Metadata congruence with LO content	By experts
Metadata pedagogical coherence	By experts

Table IV. Mechanisms of evaluation for each feature of the compliance sub-characteristic

id	Name in Agora repository	Id in repository
LO1	IF, use by operators	331
LO2	Linux for novices	196
LO3	Programming basics	119
LO4	Definition of blog	67
LO5	What is a wiki?	84
LO6	Social networks	66
LO7	Syntax and semantics in ANSI C	332
LO8	Resource file emerging perspectives on learning, teaching and technology	584

Table V. Learning objects used in experiment

- Metadata pedagogical coherence involves 19 out of 61 fields (i.e. 31 per cent).
- Metadata congruence with LO content involves 45 out of 61 fields (i.e. 74 per cent).

Automatic evaluation of metadata standardization

The LOM-ES specification describes each of their fields in metadata. For each field, it specifies identifier, name, explanation, size, order, value spaces and some examples. In some cases, within the explanation of the fields, there is a note with constraints or filling recommendations. Table VI shows some examples of recommendations and constraints found in the LOM-ES application profile.

According to the specification of LOM-ES, the recommendations were transformed into IF–THEN rules and codified into a metalanguage of their own. These rule collections have been integrated into a tool (Menéndez *et al.*, 2012) to determine the metadata standard compliance level of a learning object. This application was developed as an Ajax service to be integrated easily in other e-learning systems. The client sends a XML LOM and indicates the rule collection to be used (IEEE-LOM, LOM-ES, own rules). The tool contrasts each rule with the XML structure and fetches a compliance level for the rules defined with the selected profile.

Results of metadata standardization

According to the LOM-ES application profile, ten rules are extracted. Table VII shows the results of the standardization metric for each learning object.

Table VI.
Rules in the LOM-ES application profile

LOM-ES recommendations	Fields included in the recommendation
A contribution should be described to at least the author of the learning object. The description includes the identification and date of the activity	2.3 Contribute 2.3.1 Role 2.3.2 Entity 2.3.3 Date
If the learning object type mixes active and passive elements, then its 5.1 InteractivityType is combined	5.2 LearningResourceType 5.1 InteractivityType
A learning object requires a license type in the catalogue	5.2 LearningResourceType 6.2 CopyrightAndOtherRestrictions
The 5.6 Context is prescribed for objects with 1.8 LevelOfAggregation = 2 or higher	1.8 LevelOfAggregation 5.6 Context

Table VII.
Results of standardization evaluation

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Evaluated rules*	7	5	5	6	7	7	7	5
Metadata Standardization metric	0.143	0	0.200	0.333	0.143	0.143	0.143	0.600

Note: *Quantity of rules which could evaluate the LO according to the ten rules extracted from the LOM-ES application profile

Results of metadata completeness

According to the LOM-ES application profile, there are 22 mandatory fields. Table VIII shows the results of the completeness metric for each learning object. The common value is 0.318 when the quantity of filled metadata fields are only seven from a total of 22 metadata fields evaluated.

Results of metadata correctness

According to the application profile LOM-ES, there are 26 metadata fields with vocabulary or values space, from this application profile or adapted from the IEEE-LOM standard. Table IX shows the results of the correctness metric for each learning object. The values are between 0.647 and 0.880, and the average is 0.735. Despite the use of an automatic labelling tool, the results are poor. One possible reason for this situation is related to the use of the vocabularies of the IEEE-LOM standard and not its adaptation with LOM-ES; that is, in the metadata field, it says 3.3 MetadataSchema "LOM-ES" but it should say "LOM". For example, the metadata field value 5.6 Context is "high education" which is incorrect because the LOM-ES adapted this vocabulary. In the majority of the learning objects, the quantity of the filled metadata fields is evaluated from 16 out of a total of 26 fields.

Results of metadata understandability

Understandability is evaluated in the metadata fields that do not have a controlled vocabulary. These unrestricted fields are divided into fields of free text content and limited text content. According to the application profile LOM-ES, there are 17 fields of limited text contents and 18 fields of free text contents.

Understandability in fields of free text contents

The experts' agreement is validated with Kappa analysis. Table X shows the Kappa coefficient of three experts. On average, the coefficient is 0.759; therefore, the agreement level is "substantial agreement".

The understandability metric for fields of free text content varies between 2.6 and 4.733 and the average is 3.75 (Table XI). In the majority of the learning objects, the quantity of filled metadata fields evaluated is only five of a total of 18 metadata fields.

Table VIII. Results of completeness evaluation

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Evaluated metadata fields*	7	7	7	7	7	7	7	13
Completeness metric**	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.591

Notes: *Total number of filled metadata fields; **The value = 0 indicates an empty field and value = 1 indicates a filled field

Table IX. Results of correctness evaluation

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Evaluated metadata fields*	17	17	17	17	17	17	17	25
Correctness metric*	0.765	0.706	0.706	0.647	0.706	0.706	0.765	0.880

Note: *Total number of filled metadata fields

Understandability in metadata fields of limited text content

The experts' agreement is validated with Kappa analysis. Two of three raters are in complete agreement, so $\kappa = 1$. The understandability metric for fields of limited text content is always 1 (Table XII). In the majority of the learning objects, the quantity of filled metadata fields is only eight from a total of 17 evaluated metadata fields.

Results of metadata congruence

The congruence metadata contrast the metadata field with the actual content of the object. However, there are metadata fields that cannot be compared considering only the content of a learning object; for example, author, identifier into catalogue or creation date. Therefore, only 45 are selected for the congruence evaluation.

Table XIII shows the κ coefficient for three experts. On average, the coefficient is 0.607; therefore, the agreement level is "moderate agreement".

The congruence metric varies between 0.474 and 0.971, and the average is 0.745 (Table XIV). In the majority of the learning objects, the quantity of filled metadata fields is lower than 17, from a total of 45 evaluated metadata fields.

Table X. Kappa with quadratic weighting coefficient for raters of the understandability evaluation in fields of free text content

Raters	Observed kappa	SE	0.95 confidence interval Lower limit	Upper limit
RATER 1 – RATER 2	0.718	0.047	0.626	0.810
RATER 1 – RATER 3	0.757	0.058	0.642	0.871
RATER 2 – RATER 3	0.802	*	*	*

Note: The designation* appearing in any of the cells means "this quantity cannot be calculated". This will typically occur only when data entries include a substantial proportion of zeros

Table XI. Results of understandability metric for fields of free text content

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Evaluated metadata fields*	5	4	5	5	5	5	5	10
Understandability metric in metadata fields of free text content**	3.4	3.333	2.6	4	3.333	4.8	3.8	4.733

Notes: *This amount varies owing to the total number of non-empty metadata field of each evaluated LO; ** These values vary between 1 and 5

Table XII. Results of understandability metric for fields of limited text content

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Total number of evaluated metadata fields*	8	8	8	7	7	7	8	13
Understandability metric for fields of limited text content**	1	1	1	1	1	1	1	1

Notes: *This amount varies due to the total number of non-empty metadata field of each evaluated LO; ** These values vary between 0 and 1

Results of metadata pedagogical coherence

The pedagogical coherence among educational-related fields must be assessed by experts, in terms of pedagogical aspects. Table XV shows the κ coefficient of the three experts. On average, the coefficient is 0.819; therefore, the agreement level is "almost perfect agreement".

The pedagogical coherence metric varies between 0.563 and 1, and the average is 0.728 (Table XVI).

Results summary

After obtaining the results of the learning objects for each of the metrics, it is possible to calculate the overall indicator of compliance (Table XVII and Figure 6).

As expected, the best results for each of the metrics are obtained for the LO8; that is, the control object. This object did not have the maximum value for each metric, owing to, in some cases, the repository having erroneously labelled empty fields.

Raters	Observed Kappa	Standard error	0.95 confidence interval	
			Lower limit	Upper limit
RATER 1 – RATER 2	0.655	0.067	0.523	0.787
RATER 1 – RATER 3	0.553	0.076	0.404	0.702
RATER 2 – RATER 3	0.613	0.074	0.469	0.757

Table XIII. Kappa with quadratic weighting coefficient for raters for the congruence evaluation in metadata fields

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Evaluated metadata fields*	17	13	15	10	10	10	15	32
Congruence metric**	0.895	0.833	0.789	0.579	0.474	0.579	0.842	0.971

Notes: *This amount varies due to the total number of non-empty metadata field of each evaluated LO; ** These values vary between 0 and 1

Table XIV. Results of the congruence metric for metadata fields

Raters	Observed Kappa	Standard error	0.95 confidence interval	
			Lower limit	Upper limit
RATER 1 – RATER 2	0.728	0.444	0	1
RATER 1 – RATER 3	1	0	1	1
RATER 2 – RATER 3	0.728	0.444	0	1

Table XV. Kappa with quadratic weighting coefficient for raters for the pedagogical coherence evaluation in the metadata fields

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Pedagogical coherence metric**	0.563	0.688	0.688	0.688	0.75	0.75	0.688	1

Note: ** These values vary between 0 and 1

Table XVI. Results of the pedagogical coherence for the metadata fields

Experiment 2: a practical application to the indicator of metadata compliance in the learning objects retrieval

With the intention of demonstrating the utility of the compliance indicator, an experiment was designed for analysing the relationship between this indicator and the chances of retrieval of a learning object in a repository. Because the compliance indicator is evaluated in the metadata, and not in the content, we expect that when a user searches learning objects in a repository through a query based on metadata, it should retrieve the well-labelled object in the better positions of the ranking.

To identify the metadata fields to be used for exact search, we reviewed fields used in six repositories that implement this type of search. The list of selected fields is shown in Table XVIII. The learning objects were labelled using the LOM-ES profile.

This experiment was performed in the AGORA repository (Menéndez *et al.*, 2010) where their leaning objects are labelled with the LOM-ES profile. This repository implements the exact searching mechanism. To determine the test queries, an expert was asked, who after reviewing a learning object (excluding metadata), defined the metadata values that it could retrieve. For example, the expert, after reviewing the LO1 titled "IF, use of operators" (Figure 7), defined the following query:

(Title = "structure decision" OR Description = "assessment conditions" OR (Keyword = "if" OR Keyword = "decision" OR Keyword = "programming")) AND (InteractivityLevel = "medium" OR InteractivityLevel = "high") AND (Difficulty = "medium" OR Difficulty = "easy").

Given the constraints of the repository for managing disjunctions in the query, when a field can be retrieved with more than one field value, combinations were created for each query. One expert defined all the queries required in the experiment. The repository sorts

Table XVII.
Results

Metrics	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8	pi	$\bar{x}$
mPedagogicalCoherence	0.563	0.688	0.688	0.688	0.75	0.75	0.688	1	0.2	0.727
mCorrectness	0.765	0.706	0.706	0.647	0.706	0.706	0.765	0.88	0.05	0.735
mCompleteness	0.318	0.318	0.318	0.318	0.318	0.318	0.318	0.591	0.15	0.352
mStandardization	0.143	0	0.2	0.333	0.143	0.143	0.143	0.6	0.2	0.213
mUnderstandability	0.7	0.687	0.55	0.813	0.687	0.963	0.775	0.95	0.2	0.766
mCongruence	0.895	0.833	0.789	0.579	0.474	0.579	0.842	0.971	0.2	0.745
mCompliance	0.546	0.525	0.528	0.563	0.494	0.57	0.576	0.837		0.58

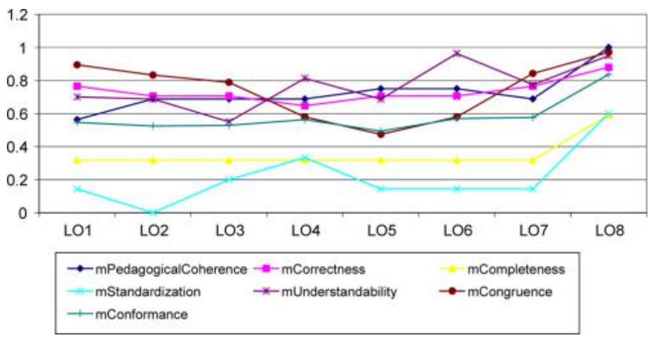

Figure 6.
Results summary for each metric

Table XVIII. Fields for an exact search in a repository

N°	Metadata field	N°	Metadata field
1.2	Title	5.2	LearningResourceType
1.3	Language	5.3	InteractivityLevel
1.4	Description	5.5	IntendedEndUserRole
1.5	Keyword	5.6	Context
1.6	Coverage	5.8	Difficulty
1.8	AggregationLevel	5.7	TypicalAgeRange
2.3.2	Entity	6.1	Cost
2.3.3	Date	6.2	CopyrightAndOtherRestrictions
4.1	Format	9.1	Purpose
4.3	Location	9.2.1	Source
4.4.1.1	Type	9.2.2.1	ID
4.4.1.2	Name	9.2.2.2	Entry
5.1	InteractivityType	9.3	Description

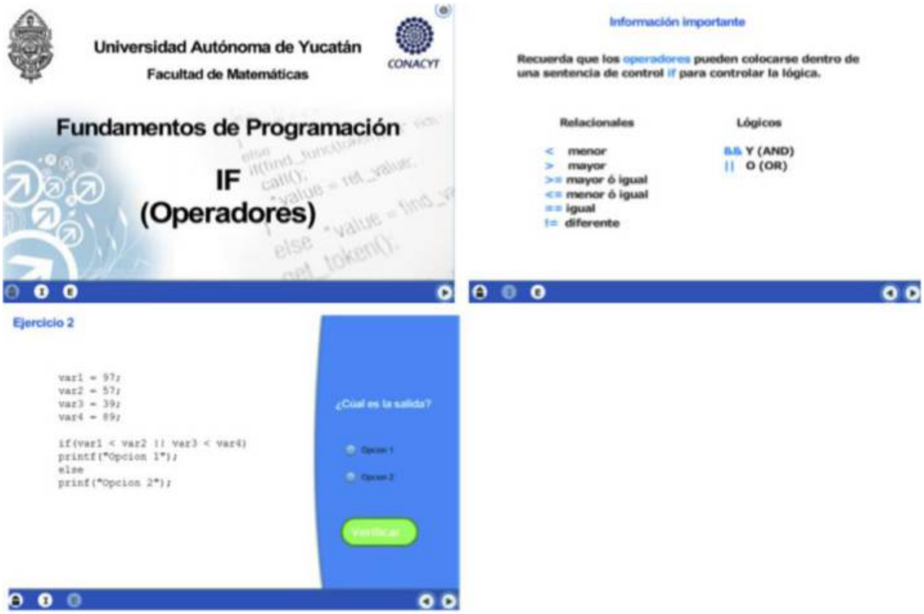

Figure 7. Snapshot of LO1, titled "IF, use of operators"

the results based on a similarity measure of the learning object content in the repository and the values of the fields used in the query.

The position indicator for each learning object is the best ranking position reached by the learning object in the executed queries. Table XIX presents the results of the exact search in the repository. Table XX shows the position for each learning object and its compliance indicator.

Using Pearson correlation analysis, it was possible to determine the level of relationship between two variables in the analysis. In this experiment, the following were calculated:

(1) The correlation factor between the compliance indicator and the indicator ranking position.
(2) The correlation factor between each metric and the indicator ranking position.

The index obtained for the first correlation (a) was rxy = −0.49 (Table XXI). This correlation is considered weak. This value indicates a negative correlation between the compliance indicator and the ranking position, which means that the higher level of compliance implies a best ranking position in which the learning object is retrieved.

The results of the second analysis (b) are presented in Table XXI. The highest correlation coefficient (rxy = −0.72) was obtained between the ranking position and the metric of congruence, indicating a strong negative correlation. The lowest correlation coefficient (rxy = −0.06) was obtained between the ranking position and the standardization metric, indicating a very weak negative correlation.

Discussion

RQ1 validates the proposed indicator over a set of learning objects labelled with the LOM-ES profile. It was found that for the control object, which had a high level of quality in its metadata, the best values for each metric were obtained.

In *RQ2*, the initial premise was that there is a relationship between the quality aspects of metadata and the search ranking. This premise is supported by the analysis explained in the previous section. According to the obtained results in the correlation analysis, the largest correlation (rxy = −0.72) occurs between the congruence metric and the ranking. That is, when the metadata is consistent with what a person observes in a learning object, this is retrieved in a better position ranking. The control object had the highest congruence metric = 0.971 (Table XVI) and it was retrieved in a better position in the ranking (Position = 11 in Table XXI).

In this way, it can be said that "there is a relationship between the level of learning object quality and its chance to be retrieved". The lower correlation coefficients obtained between

Table XIX. Ranking positions of each LO for an exact search in the AGORA repository

Learning object name	Learning object ID	Ranking positions in query combinations 1	2	3	4	5	6	7	8	9	10	11	12	Min
LO1	331	88	37	140	83	100	49	153	98	83	36	135	81	37
LO2	196	52	78	29	43	62	93	48	60	52	78	27	41	29
LO3	119	65	121	98	172	73	133	107	193	61	115	93	161	65
LO4	67	245	227	140	124	272	257	169	142	229	212	136	120	124
LO5	84	152	126	210	182	172	138	229	207	138	120	193	172	126
LO6	66	62	217	20	88	81	241	47	105	63	202	19	85	20
LO7	332	45	80	86	130	60	82	98	144	83	114	134	169	45
LO8	584	11	11	17	17	11	11	17	17	20	20	36	36	11

Table XX. Results of the congruence metric for the metadata fields

Criteria	LO1	LO2	LO3	LO4	LO5	LO6	LO7	LO8
Compliance indicator	0.546	0.525	0.528	0.563	0.494	0.57	0.576	0.837
Position indicator	36	27	61	120	120	19	45	11

mPedagogicalCoherence	mCorrectness	mCompleteness	mStandardization	mUnderstandability	mCongruence	mCompliance
−0.25	−0.63	−0.41	−0.06	−0.36	−0.72	−0.49

Table XXI.
Results of the pearson coefficient

mStandardization (rxy = −0.06) and mPedagogicalCoherence (rxy = −0.25), and the ranking can be explained because:

- Metadata fields involved in calculating these metrics are not the same fields used to search for metadata in the repository.
- The algorithms and criteria used to generate the ranking results are established by each repository and these could be coincidence or not with the quality aspects represented by the indicators. For example, in the MERLOT repository, the ranking calculating considers the relevance and evaluation. In this case, there should be a greater correlation between the metric of consistency and pedagogical coherence.

Conclusions and future work

This paper presents a refinement of the previously published model for assessing the quality of a learning object based on the ISO 9126 standard. This version improves and defines new metrics for evaluating metadata included in the functionality characteristic. To demonstrate its applicability, this indicator was used to assess the quality of eight learning objects from a repository.

The use of metadata quality indicators in the context of learning object retrieval in a repository was presented and discussed. The experiment showed that there is a relationship between the level of quality of learning object and its ranking in the search results.

One of the future directions that emerge from this research relates to the refinement compliance indicator composed of standardization, completeness, correctness, understandability, congruence and pedagogical coherence. In addition, the relationship or the dependency between the individual metrics should be analysed. A third direction relates to the integration and consolidation of other proposals that evaluate other aspects of the quality of a learning object, in the framework proposed in this paper.

Finally, any proposal related to quality evaluation, recommendation and labelling, among others, should be formally evaluated. In this regard, it is necessary to have a standard data set of learning objects to compare the results of different proposals.

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