Quality Models and Quality Attributes for Open Educational Resources: a Systematic Mapping

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***Abstract*—This research full paper presents a systematic mapping on quality attributes and quality models for Open Educational Resources (OER). The OER movement is part of a greater trend towards openness in education. They are represented by teaching materials that are available at no cost to the community to retain, reuse, review, remix, and redistribute. Given the wide availability of OER, how can one guarantee its quality? Motivated by this issue, some initiatives have proposed quality attributes or quality models to design, evaluate, and improve the quality of OER. However, to the best of our knowledge, a complete and detailed overview of how quality is being treated for OER is lacking. Besides, the literature lacks consensus on which quality attributes and quality models are the most relevant and which ones could be more suitable for OER. Also, there is an absence of a comprehensive analysis of the approaches used to establish quality attributes for OER. For this purpose, we carried out a systematic mapping addressing the following research questions: i) what are the quality models or quality attributes proposed for OER?; ii) how have these quality models or quality attributes been established for OER?; iii) how have quality models or quality attributes for OER been evaluated?. We identified quality models for different OER contexts, such as OCW and MOOC, in addition to quality attributes that are important for OER openness characteristics (i.e., retain, reuse, remix, revise, and redistribute). In order to contribute to the community, we presented discussions and highlighted some points and directions for future research.**

***Index Terms*—quality of open educational resources, quality attributes for open educational resources, quality models for open educational resources**

I. Introduction

Advances in computing technologies provide subsidies so that many educational programs can offer an online learning environment to enhance student learning [1]. In the face of so many advances, Open Educational Resources (OER) emerged as part of a greater tendency towards openness in higher education [2]. The OER term was introduced by UNESCO [3] and corresponds to educational materials to support teaching, learning, and research that are available free of charge. According to Wiley [4], the 'open' in OER comprises the 5R activities: retain, that represents the possibility of a student to have the control of a resource copy; revise, that refers to the possibility of modifying the retained resource copy; remix, that represents the possibility of merging the resource with another one; reuse, that allows the student to reuse the resource copy in another environment; redistribute, that allows the student to share the resource copy with the public.

The openness in higher education also enabled open initiatives such as OpenCourseWare (OCW) and Massive Open Online Courses (MOOC). OCW was an initiative of the MIT (Massachusetts Institute of Technology) to make MIT undergraduate and graduate course materials available on the web openly and free of charge to any user anywhere in the world [5]. In the meanwhile, MOOC are courses offered online and at a distance, which are open to any student who wishes to enroll and are free of charge [6].

Given the wide availability of OER for the community to retain, reuse, revise, remix, and redistribute, how can we know about the quality of these resources? Ensuring the quality of OER must be considered a fundamental concern for the community. Especially because OER could be designed and made available by anyone, not just educators, which can lead us to question the quality of the OER available in the repositories [7]. To shed some light on this problem, some initiatives have proposed quality attributes or quality models to design, evaluate, and improve the quality of OER [8]–[10]. However, to the best of our knowledge, a complete and detailed panorama of how quality is being handled for OER is missing. Besides, the literature lacks a consensus on studies on what are the most relevant quality attributes and quality models that could be more suitable for OER. Still, there is an absence of a comprehensive analysis on the approaches used to establish quality attributes for OER.

Thus, the main contribution of this study is to provide a broad and detailed overview of the main quality attributes and quality models for OER. For this purpose, we conducted a systematic mapping to identify and analyze the main approaches used to define and evaluate quality attributes and quality models for OER. The rest of this paper is structured in the following. Section II presents the theoretical background on quality attributes and quality models, as well as related works. Section III provides the protocol of our research. Section IV reports the results of our mapping, as well as discussions concerning it. Section V presents the threats to the validity of the study. Finally, Section VI presents our final considerations.

II. Theoretical Background

In this section, we address the background on the theme of this systematic mapping. In particular, we present definitions for quality attributes and quality models. In addition, we highlight some related works.

A. Quality attributes and quality models

The term quality model can be interpreted differently depending on the different points of view in the context in which it is used. Looking at the OER definition, we can see that they can be represented by different formats (i.e., videos, courses, software), which makes it difficult to define a quality model that comprises all its formats. To the best of our knowledge, we have not identified a generic definition of a quality model for the context of OER. In the literature, we observed that the term quality model was established in different ways to meet specific aspects of OER, such as quality models for OCW or MOOC, for example. In the study by Peláez et al. (2011) [11], a quality model was proposed for the OCW context with the objective of guaranteeing the quality in the production of educational materials on OCW sites. In this case, the quality model comprises eight different areas, such as technology and interoperability requirements, accessibility, presentation to the user, among others. The quality model by Vladoiu and Constantinescu (2013) [9] aims to assess the quality of OER, which also includes OCW. In this case, the quality model is composed of 70 quality criteria distributed in four categories, such as content quality, instructional design, among others.

Based on this understanding, we observe that the quality models are used both for the OER project and for its evaluation. Given that many OER are being made available in software format, we believe it is important to use the ISO standard as a reference for a quality model of a software product. Based on ISO/IEC 25010 [12], we define that a quality model is a reference resource for the design of OER, which determines which quality attributes are considered when evaluating its properties. Thus, it is possible to verify the degree to which a particular OER meets the stated and implicit needs of its stakeholders, such as usability, accessibility, reusability, among others. In a nutshell, quality models present quality attributes, which refer to quality characteristics and subcharacteristics that specify the degree to which the quality attributes will affect the quality of the OER.

B. Related works

Concerning related works, we have not identified any systematic mapping or systematic literature reviews on quality models or quality attributes for OER. However, we found the study by Ossiannilsson et al. (2015) [13], which provides an overview of quality models in the context of online and open education. In this study, the authors address the main challenges of the topic, the complexity of dealing with quality in online learning, and the new needs, such as quality in MOOC and OER. According to Ossiannilsson et al. (2015) [13], improving the quality of students' experiences is extremely important and warns against the implementation of quality models that restrict innovation and change.

Furthermore, we identified a literature review by Clements, Pawlowski, and Manouselis (2015) [14] that investigates quality approaches for learning object repositories (LOR). In the study by Clements, Pawlowski, and Manouselis (2015) [14], the LOR quality literature is analyzed in open and technology-enhanced learning domains. Besides, the authors summarized the main approaches, instruments, and quality metrics and, based on this information, developed a framework of quality approaches that LOR developers can take into account when designing new repositories, as well as improving the quality of the existing ones.

III. Systematic mapping process

To conduct this systematic mapping, we used the guidelines proposed by Petersen et al. (2008) [15] and Kitchenham and Charters [16]. In this section, we present the planning of systematic mapping planning and its execution in detail.

A. Planning systematic mapping

For the planning phase, we defined the research objectives, the research questions, the search strategy, the inclusion and exclusion criteria, the procedures for selecting primary studies, and the extraction form and the synthesis of the collected data.

1) Objective and research questions: To guide the planning of our systematic mapping and define its objective, we used the Goal/Question/Metric (GQM) systematic approach by Basili et al. [17]. In this perspective, our study aimed to **analyze** *primary literature studies* **for the purpose of** *characterizing them*, **with respect to** *the existing quality models and quality attributes for OER*, **from the point of view of** *the researchers*, **in the context of** *scientific publications databases*. Given the research objective, we formulated our research questions based on the research objective, they are shown in Table I.

TABLE I
RESEARCH QUESTIONS AND METRICS

Research questions		Metrics
RQ_1	What are the quality models and quality attributes proposed for OER?	(1) the quality models and quality attributes found in the literature for OER; (2) the number of occurrences of each quality model and quality attribute found.
RQ_2	How have these quality models and quality attributes been established for OER?	(1) the approach used to establish quality models and quality attributes (e.g., ISO); (2) the number of occurrences of each approach.
RQ_3	How have quality models and quality attributes for OER been evaluated?	(1) the approach used for evaluation (e.g., without evaluation, case study, experiment); (2) the number of occurrences of each approach; (3) the level of evidence for each study.

2) Search strategy: In our search strategy, we tried to use the terms that encompass most of the relevant primary studies in the area. Thus, in an iterative process, we conducted preliminary research to identify existing systematic reviews and verify the volume of studies resulting from the use of various combinations of terms related to the topic. Among the synonyms, we determined the keyword "open" as a representation of open access to resources, the keyword

"educational resource" that characterizes educational resources in general, and the keyword "quality" to refer to quality models and quality attributes. Our search string is presented in the following:

```
((("open" OR "free") AND ("OER" OR
"educational resource" OR "learning
object" OR "educational module" OR
"learning material" OR "learning
content" OR "courseware" OR "OERs" OR
"educational resources" OR "learning
objects" OR "educational modules" OR
"learning materials" OR "coursewares"))
AND ("quality")).
```

The search string was adapted to meet the following databases: ACM Digital Library, Elsevier (Science Direct), Engineering Village, IEEE Xplore, Scopus, and Web of Science. These adaptations of the search string can be accessed in the laboratory package[1].

3) Selection criteria: To select the primary studies that would be part of our systematic mapping, we used selection criteria to evaluate each study obtained through the search databases that we have selected. In this way, we could identify and include relevant studies that could answer the research questions of our systematic mapping, and exclude non-relevant studies. The inclusion criteria (IC) and the exclusion criteria (EC) that we defined can be viewed in the sequence:

- IC_1: The primary study addresses a quality model for OER.
- IC_2: The primary study addresses one or more quality attributes for OER.
- EC_1: The returned study refers to a technical report, a simple/expanded abstract, a presentation, a proceedings of a conference/workshop, a working in progress, a short paper, a secondary study/tertiary study.
- EC_2: The primary study is written in a language other than English.
- EC_3: The full text of the primary study is unavailable.
- EC_4: The primary study is out of the scope of systematic mapping (i.e., it does not address a quality model or quality attributes for OER).
- EC_5: There is a more updated version of the primary study with related authors.

4) Procedure for selecting studies: The selection of primary studies was carried out in three main activities, they are: automatic search, first selection, and second selection.

- **Automatic searches**: the automatic search was performed using the search string in the databases we selected. The studies identified in the results of this activity were organized on the Parsifal[2] platform. Parsifal facilitated the identification of duplicate studies, which were registered and removed from the set of studies. This initial set of studies can be verified in our laboratory package, including duplicates. We emphasize that the selection criteria (inclusion and exclusion) were not applied in this activity, as well as the year of publication filter.
- **First selection of primary studies**: for the first selection of primary studies, we applied the inclusion and exclusion criteria on the titles, abstracts, and keywords of the studies in the initial set recorded in the automatic search activity. Studies that met at least one of the inclusion criteria were passed on to the second study selection activity. Studies that did not have enough information in their titles, abstracts, and keywords to be included or excluded, also passed on to the second selection activity. This measure was adopted to avoid the loss of relevant studies.
- **Second selection of primary studies**: the second primary study selection activity comprises reading the studies in full using the inclusion and exclusion criteria to select the final set of primary studies. We emphasize that the studies were read and analyzed by at least two reviewers to ensure greater reliability on the final set of studies and so that no relevant studies were disregarded.

5) Data extraction process: Intending to answer the research questions of our study, we prepared a data extraction form[3] containing the necessary features to answer each of the research questions. Based on the extracted data, we were able to draw conclusions and synthesize the data through qualitative analysis.

B. Conducting the systematic mapping

Our systematic mapping was carried out during the winter of 2021 (from January to March). During its conduction, the primary studies were identified, selected, and evaluated using the selection criteria. We extracted and synthesized the data for each primary study selected in the final set, following our protocol. Fig. 1 shows the results for each of the activities described in Section III-A4.

The results of the automatic search for the five databases we established are 2.897 studies. However, 1.123 of those studies are duplicated. Thus, 1.774 studies were included in the first selection of primary studies. After applying the selection criteria in the first selection of primary studies, we obtained a result of 57 studies. The use of a more generic search string may have resulted in a very large number of studies in our initial set.

We read in full all of the 57 studies, and only 4 of them presented a quality model or quality attributes for OER. Given this small number of primary studies, we used the backward and forward snowballing[4] technique to find missing relevant studies. Using the snowballing technique resulted in

[1]The laboratory package can be accessed through the following link: <https://doi.org/10.5281/zenodo.4978152>.

[2]Parsifal is a platform that supports researchers in planning, conducting, and reporting systematic literature reviews and systematic mappings. More information available at: <https://parsif.al>.

[3]The data extraction form can be accessed at: <https://bit.ly/3wbLGrV>.

[4]Snowballing refers to the use of a study's reference list (backward snowballing) or the list of studies that cited that study (forward snowballing) to identify additional relevant studies [18].

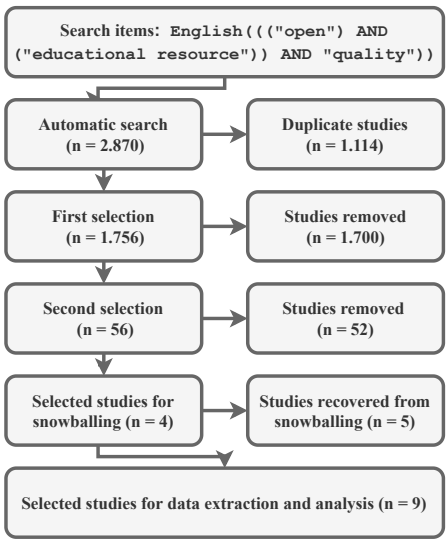

Fig. 1. Results of the selection process of primary studies

the inclusion of 5 primary studies, adding up to 9 studies in our final set. The final set of primary studies is presented in Table II.

IV. Results and Discussions

We dedicated this section to report the results of our systematic mapping. The following subsections are intended to answer the research questions.

A. What are the quality models and quality attributes proposed for OER?

The first research question investigates what are the quality models or quality attributes proposed for OER. To answer this question, we organized the quality models identified in Table II and added a brief description of their main objective in the field "quality models/quality attributes description". We can observe that the quality models were developed with different objectives for certain contexts. For example, the quality model by Vladoiu and Constantinescu (2013) [9] is intended for the evaluation of OER and OCW. In the meanwhile, the quality model by Stracke et al. (2018) [19] presents quality attributes to design MOOC.

The main quality attributes that make up these quality models are present in two Tables. In Table III, we present the main quality attributes that focus on the educational context of OER (i.e., they are more generic to the context of OER). The quality attributes were classified in Table III according to their absolute frequency, which should be greater than 2. The other quality attributes can be accessed in an organized table with all the quality attributes identified in the mapping (see table).

In the sequence, we present a brief description of the quality attributes according to the authors' point of view.

- **Navigability**: the navigability characteristic reflects the easy navigation through the options provided by the OER [8], the consistency of navigation through the user interface [9], and the possibility for the user to exit at any time [10], safely in case the user chooses the wrong functionality [20]. Besides, navigability refers to the clarity and transparency of the sequences of existing topics, concepts, and links so that students can understand the interrelationship among the topics [23]. Also, it refers to the availability of dynamic and intuitive navigation mechanisms to pursue desired contents [11]. Using content recommendation mechanisms based on the previous student navigation (a.k.a., user model) might improve navigability [21].
- **Accuracy of content**: the accuracy of learning material is fundamental to the content quality [8] and can reflect on how knowledge is conceptualized within the domain [20]. The accuracy of content can refer to the presentation of a legible text, with consistent and precise spelling and grammar [9], [11]. Besides, it refers to correctness, accuracy, and having the right level of detail and balanced ideas [23].
- **Learning goal alignment**: the characteristic refers to the alignment of the learning objectives and outcomes of the OER [9], [21], as well as its activities, with special attention to the specificity and perception of the student [S9], the assessments, and characteristics of the student [8]. In addition, the objectives must be clear, measurable [11], and explicit for students and teachers [20].
- **Content quality**: the characteristic is addressed with different meanings among the studies. In [9], we observed several quality attributes that refer to content quality, such as uniformity and adequacy of language, terminology, and notations so that students have multiple learning experiences. For [11], the content must be designed to meet the user's capabilities, such as learning model, color, motor skills, attention, and characteristics that comprise an intuitive design. In [8], content quality refers to the clarity of the content, so that it is impartial and accurate. The OER should contain information for the intended level of the students, using appropriate vocabulary and concepts [21]. Also, it must be meaningful, enriching, and compatible with the organizational strategies [23].
- **Appropriate support**: appropriate support can be related to the use of learning theories [9], [11], providing supporting materials for users [11], technological support for the user [9], [19], help functionalities that identify problems and solutions for the user [10], management support, infrastructure support, and support for learning activities [23]. Besides, OER must include broad information related to prerequisites [21].
- **Presentation design**: the OER presentation design must be adequate [9]. The organization and presentation of the content must be carried out thinking about the user's capabilities, with characteristics that define an intuitive design [11]. Presentation design is also related to content presentation formats to accommodate students with disabilities [10], [23], in addition to visual and auditory information design for enhanced learning and

TABLE II
FINAL SET OF PRIMARY STUDIES

ID	Primary study title	Primary study reference	SC	Quality models/quality attributes description
S1	Towards assessment of open educational resources and open courseware based on a socioconstructivist quality model	Vladoiu and Constantinescu (2013) [9]	IC_1	The socio-constructivist quality model (QORE) was developed to assess the quality of OER and OCW.
S2	Quality model proposal for educational material production in OCW sites	Peláez et al. (2011) [11]	IC_1	The quality model was designed to guarantee the quality of OCW contents.
S3	Methodology for Evaluating Quality and Reusability of Learning Objects	Kurilovas, Bireniene, and Serikoviene (2011) [10]	IC_1	The quality model was developed to assess the quality of learning objects with special attention to reusability.
S4	Fostering quality in MOOCs: a european approach	Stracke et al. (2018) [19]	IC_1	The Quality Reference Framework (QRF) provides quality criteria and a checklist for designing MOOC.
S5	A framework for evaluating the quality of multimedia learning resources	Leacock and Nesbit (2007) [8]	IC_1	Learning Object Review Instrument (LORI) was designed to support evaluation of multimedia learning objects.
S6	Evaluating learning objects for schools	Haughey and Muirhead (2005) [20]	IC_1	The Learning Object Evaluation Instrument (LOEI) was developed to examine school level learning objects.
S7	A framework for quality of learning resources	van Assche and Vuorikari (2006) [21]	IC_1	The framework for the quality of web-based learning resources provides quality characteristics for different processes that involve OER (e.g., its creation, evaluation, etc.)
S8	Ascertaining the relevance of open educational resources by integrating various quality indicators	Rodríguez et al. (2011) [22]	IC_2	The study presents quality attributes for OER that can be calculated automatically, ensuring the evaluation of all OER in a repository. Among them are reusability and content quality.
S9	Developing a conceptual framework for evaluation of e-content of virtual courses: e-learning center of an Iranian University case study	Akhavan and Arefi (2014) [23]	IC_1	The framework provides criteria for the evaluation of the quality and effectiveness of learning objects and e-content of virtual courses.

The acronym "ID" corresponds to the identification of the primary study. The acronym "SC" refers to the selection criteria (see Section III-A3).

TABLE III
MAIN EDUCATIONAL QUALITY ATTRIBUTES

Educational Quality Characteristics	Primary Studies								
	S1	S2	S3	S4	S5	S6	S7	S8	S9
Navigability	✓	✓	✓		✓	✓	✓		✓
Accuracy of content	✓	✓			✓	✓	✓		✓
Learning goal alignment	✓	✓			✓	✓	✓		✓
Content quality	✓	✓			✓		✓	✓	✓
Appropriate support	✓	✓	✓	✓			✓		✓
Presentation design	✓	✓	✓		✓				✓
Cultural aspects	✓		✓			✓	✓		✓
Interactivity	✓		✓		✓				✓
Feedback	✓	✓			✓	✓			
Standards compliance		✓	✓		✓				✓
Appropriate license	✓	✓	✓						
Understandability	✓		✓						
Motivation					✓		✓		
Appropriate assessments	✓				✓				
Instructional strategies	✓								✓
Metadata accuracy			✓				✓		
Decontextualisation			✓						✓

efficient mental processing [8].

- **Cultural aspects**: the OER must be appropriate for community and cultural affiliations, including language, dialect, reading, writing, and must be free from racial or gender stereotypes [20]. Besides, the OER must be sensitive, culturally diverse [9], [10], [21], free of prejudice [9], and be created at an international level (multilingual, multicultural) for good communication with the student [23].
- **Interactivity**: the characteristic refers to the student's interaction with the content and with other students, as well as technological interactivity, and interactive elements [8]–[10], [23].
- **Feedback**: according to [8], feedback is a limited form of adaptation in which the OER presents information concerning a localized action by the student. Students learn more effectively if they receive frequent, meaningful, and quick feedback [9]. In the quality model by [11], for example, it is mentioned about implementing feedback mechanisms for OCW.
- **Standards compliance**: the use of standards is important to enabling service interoperability and content exchange (e.g., SCORM[5]), in addition to accessibility standards (e.g., W3C[6]) [10], [11], [23]. Adhering to international standards and specifications is also necessary [8].
- **Appropriate license**: the appropriate use of licenses is important to make the OER available for the community, ensuring copyright and security for the various users [9]–[11].
- **Understandability**: the OER must be easy to understand, with clear, consistent, and accurate writing [9]. Also, it is important to have a shared understanding of the concepts to be used in an analysis [10].
- **Motivation**: the characteristic concers the ability to motivate and interest the apprentice [8]. Information should involve the student with satisfaction [21].
- **Appropriate assessments**: the assessments must measure students' knowledge according to the established learning objectives [8]. Appropriate assessments and self-assessments are highly desirable when intending to master the educational content [9].
- **Instructional strategies**: instructional strategies can

[5]SCORM refers to a set of technical standards for e-learning products. More information available at: <https://scorm.com/>.

[6]The World Wide Web Consortium (W3C) develops international web standards, such as HTML, CSS and others. More information available at: <https://www.w3.org/WAI/standards-guidelines/>.

impact the efficiency of instruction (e.g., interactive instruction, independent study, experiential learning) [9]. Instructional strategies may conform to the organization's strategies (e.g., copyright policy and management support for different content creation policies) [23].

- **Metadata accuracy**: this characteristic is related to the use of metadata standards when making OER available in a repository [10], [21].
- **Decontextualisation**: this characteristic concerns the usual context of the OER, as its level of aggregation (granularity), indivisibility, and modularity [10]. Decontextualisation is important so that the OER and its subparts can be reused [23].

We can see that the navigability quality attribute obtained the highest frequency in Table III, followed by the accuracy of content, the learning goal alignment, and the content quality. The popularity of a quality attribute (i.e., its frequency) may or may not be related to its importance in a quality model. We believe that, depending on the objective and context of an OER, the set and hierarchy of quality attributes may alternate. For example, the quality model by Stracke et al. (2018) [19] was developed with the MOOC project in mind. In the meanwhile, the quality model by Haughey and Muirhead (2005) [20] is intended to assess the OER at the school level.

Following this understanding, we organized Table IV with the quality attributes aimed at the software product. We feel this need because, in an increasingly technological world, the OER are being produced, too, in software format (e.g., a web-based OER designed for teaching and learning to program [24]). Besides, the quality attributes shown in Table III may not be sufficient to design open educational software.

To identify the quality attributes of Table IV, we used ISO/IEC 25010 as a reference, which is a widely adopted standard to assess the quality of the software product. The quality model of the software product defined in ISO/IEC 25010 comprises eight quality characteristics, which are composed of sub-characteristics [12]. To organize Table Y, we used only the characteristics and sub-characteristics that we identified in the primary studies. To facilitate the understanding of the quality attributes of Table IV, we added a brief description for each quality characteristic and subcharacteristic. The description was prepared based on the definitions present in the ISO/IEC 25010 [12].

We can see that reusability and accessibility are the most frequent quality attributes, followed by operability, user interface aesthetics, and appropriateness recognizability. Also, quality attributes such as portability, learnability, security, and modularity were mentioned by only one study. We believe that these four quality attributes are important for OER because they affect the openness characteristic, reuse, and adaptation. To reuse an OER, for example, modularity is an essential characteristic. When analyzing the quality attributes, we can see that some of them are related to the 5Rs of OER (i.e., the openness characteristics such as retain, reuse, review, remix, and redistribute) [Wiley]. For example, concerning the characteristics of remix, reuse, and revise, the quality attributes of modularity, reusability, modificability, portability, adaptability, replaceability, and decontextualisation are the most related since many of them refer to the maintainability and portability of the OER and/or its parts and are important for the community to be able to reuse OER.

B. How have these quality models and quality attributes been established for OER?

The second research question aims to understand how the quality models and quality attributes were identified, established, and defined. To answer this question, we investigated which sources of information are most used to identify quality attributes and summarized these sources in Table IV-B. This table shows four types of sources: i) standards; ii) expert opinion; iii) secundary studies; iv) related works; and v) own authorship.

Next, we present a brief description of the reference sources used by the authors.

- **Standards**: the use of standards as a reference source was used in four studies. Two studies [9], [19] used the ISO standards to define quality attributes, such as ISO/IEC 25000 SQuaRE, ISO/IEC 40180, and ISO/IEC 19796-1. The study by Peláez et al. (2011) [11] used other standards to define their quality attributes, such as the Online Course Evaluation Project Standards (OCEP) and the National Standards of Quality for Online Courses (NACOL). In this category, there were also sources such as the CLOE draft guidelines, the Learning Federation Soundness Specification [20], and the Quality Matters Rubric, 20081 [11].
- **Expert opinion**: two studies used expert opinions, such as educational experience [9], semi-structured interviews, and the feedback from the MOOQ Workshops at international conferences [19].
- **Secondary studies**: the study by Stracke et al. (2018) [19] also used a literature review as a reference source to define quality attributes.
- **Related works**: four studies used related works as a reference source [10], [20], [22], [23]. Among the related works are the study by Sanz et al. (2009) [25], Vargo et al. (2003) [26], Paulsson and Naeve (2006) [27], Buzzetto and Pinhey (2006) [28], Belfer et al. (2002) [29], Krauss and Ally (2005) [30], Kurilovas and Dagiene (2009) [31], Nash (2005) [32], Kubilinskiene and Kurilovas (2008) [33].
- **Own authorship**: in this category we classify primary studies that do not cite reference sources that were used to define quality models or quality attributes [8], [21].

The use of standards and related work to define quality models and quality attributes. Notice that some studies used more than one type of reference source to define quality models or quality attributes, which increases the study's credibility [9], [19], [20]. In the meanwhile, some studies did not mention reference sources [8], [21]. Though, the quality model by Leacock and Nesbit (2007) [8] has been widely

TABLE IV
QUALITY ATTRIBUTES - ISO/IEC 25010

Software Product Quality		Primary Studies									
Characteristics	Subcharacteristics	S1	S2	S3	S4	S5	S6	S7	S8	S9	Description
Functional Suitability	Functional Completeness	✓						✓			The degree to which the OER feature set covers all specified user tasks and objectives.
	Functional Appropriateness	✓		✓			✓	✓			The degree to which OER features facilitate the achievement of specified tasks and objectives.
Performance Efficiency	Capacity	✓									The degree to which the OER ceilings meet the requirements.
Compatibility	Interoperability	✓	✓	✓				✓			The degree to which two or more OER can exchange and use exchanged information.
Usability	Usability			✓		✓	✓			✓	The degree to which the OER can be used by specific users to achieve specific objectives with effectiveness, efficiency, and satisfaction in a specified context of use.
	Appropriateness Recognizability	✓		✓		✓	✓	✓			The degree to which users are able to recognize whether an OER is appropriate for their needs.
	Learnability	✓									The degree to which an OER can be used by specific users to achieve specific goals of learning how to use the OER effectively, efficiently, and satisfying in a specified context of use.
	Operability	✓		✓		✓	✓	✓			The degree to which an OER has attributes that make it easy to operate and control.
	User Interface Aesthetics	✓	✓	✓		✓	✓				The degree to which a user interface allows pleasant and satisfying interaction for the user.
	Accessibility	✓	✓	✓		✓	✓	✓		✓	The degree to which an OER can be used by people with the widest range of characteristics and capabilities to achieve a specific objective in a specific use context.
Reliability	Reliability	✓						✓			Degree to which an OER performs specified functions under specified conditions for a specified period of time.
	Avaiability	✓						✓			The degree to which an OER is accessible and operational when needed for use.
	Recoverability			✓							Degree to which an OER can recover from an interruption or failure and restore its desired state.
Security	Security	✓									The degree to which an OER protects information and data so that people or other OERs have the appropriate degree of access to data for their types and levels of authorization.
	Integrity						✓	✓			The degree to which an OER prevents unauthorized access or modification of data.
Maintainability	Modularity			✓							The degree to which an OER is made up of discrete components, so that a change in one component has minimal impact on other components.
	Reusability	✓	✓	✓		✓		✓	✓	✓	The degree to which an OER can be used in more than one system or in the construction of other OER.
	Analysability				✓						The degree of effectiveness and efficiency with which it is possible to assess the impact on an OER of an intended change in one or more of its parts, or to diagnose an OER for deficiencies or causes of failures, or to identify parts to be modified.
	Modificability	✓	✓	✓							The degree to which an OER can be modified effectively and efficiently without introducing defects or degrading the quality of the existing resource.
	Testability				✓						The degree of effectiveness and efficiency in establishing test criteria for an OER and tests can be carried out to determine whether those criteria have been met.
Portability	Portability	✓									The degree of effectiveness and efficiency with which an OER can be transferred to another operating or use environment.
	Adaptability	✓	✓	✓		✓		✓			The degree to which an OER can be adapted effectively and efficiently to another operating environment or for a different or evolving use.
	Replaceability	✓						✓			The degree to which an OER can replace another OER specified for the same purpose in the same environment.

accepted and cited by the community in the area [10], [20], [22], [23].

C. How have quality models and quality attributes for OER been evaluated?

The third research question explores how primary studies have evaluated the quality models and quality attributes that have been proposed for OER. The following evaluation approaches were identified: i) empirical study, ii) evaluation with specialists, iii) practical use, iv) committees, and v) no evidence. This information is relevant for the community to be aware of the best evaluated approaches.

Next, we describe the means of evaluation that were used by the authors.

- **Empirical study**: two studies carried out an empirical evaluation to validate the quality model [8], [10].
- **Specialists**: four studies carried out the evaluation of the quality model with specialists in the field [9], [11], [22], [23].

TABLE V
SOURCES FOR ESTABLISHING QUALITY ATTRIBUTES

Sources	Primary studies								
	S1	S2	S3	S4	S5	S6	S7	S8	S9
Standards	✓	✓		✓		✓			
Expert opinion	✓			✓					
Secondary studies				✓					
Related works			✓			✓		✓	✓
Own authorship					✓		✓		

TABLE VI
APPROACHES TO EVALUATE QUALITY MODELS

Evaluation approach	Primary studies								
	S1	S2	S3	S4	S5	S6	S7	S8	S9
Empirical study			✓		✓				
Specialists	✓	✓						✓	✓
Practical use	✓	✓			✓	✓			✓
Committee				✓					
No evidence							✓		

- **Practical use**: this category is for studies that applied the quality model in a real context to evaluate it. For example, the study by Vladoiu and Constantinescu (2013) [9] applied their quality model to assess OER and OCW. In [11], the quality model was used to evaluate OCW products from UTPL (Universidad Técnica Particular de Loja). The quality model by Leacock and Nesbit (2007) [8] is well consolidated in the literature and has already been applied at Athabasca University and Simon Fraser University in Canada, among others. In [20], the quality model was used to evaluate learning objects from the Le@rning Federation repository. In the study by Akhavan and Arefi (2014) [23], the quality model was applied to evaluate e-content from two MBA programs.
- **Committee**: Stracke et al. (2018) [19] submitted their QRF to the European and international standardization committees as New Work Item (NWI) for discussion and approval.
- **No evidence**: this category comprises studies that did not present evidence in their works that the quality model was evaluated [19], [21].

Regarding the evaluations, the category of practical use was the most used by the authors, followed by the evaluation with specialists. Some studies used more than one way to evaluate their studies [8], [9], [11], [23], while others did not mention evidence of evaluation of their models or defined quality attributes [21].

V. THREATS TO VALIDITY

Next, we describe the main threats to validity identified in the systematic mapping performed:

- *Absence of relevant primary studies*: to mitigate this threat, we defined a protocol before carrying out the mapping. In this way, we defined the research questions, the search string, the selection criteria, and the databases. To define the search string, and the databases, we used secondary studies in the area. Therefore, we believe that we covered a significant number of studies for selection.
- *Selection confidence*: to mitigate this threat, we defined a set of inclusion and exclusion criteria in the protocol, which were defined by the three researchers involved in the study.
- *Data extraction*: the way we extracted data from primary studies is also a threat to the validity of our study since not all information was clear to answer the research questions and some data had to be interpreted. To mitigate this threat, we defined a data extraction form based on a set of preliminary studies and discussed it when some information was not clear.

VI. CONCLUSIONS

In this paper, we presented a systematic mapping on quality models and quality attributes for OER. Among our research questions, we investigated what are the sources of information that the authors of the field are using to define quality models and quality attributes for OER, and how these authors are evaluating their approaches.

Following our protocol, we were able to identify quality models and quality attributes for different OER formats, such as OCW and MOOC. In addition, we identified quality attributes that have been widely used in the proposed quality models, such as reusability, accessibility, and decontextualisation, which is an important characteristic to consider when reusing OER. Besides, we organized the quality attributes for OER in software format, as they are important in the face of an increasingly digital world. Considering the reference sources for the establishment of quality models and quality attributes, most studies have used standards, followed by related works. For their evaluation, most of the studies used practical application and evaluation with experts in the field.

Although there are several works on the subject, we believe that some issues can be improved. To begin with, quality models and quality attributes must be better validated. Some studies did not present evidence of evaluation. Also, studies should highlight quality attributes that meet the main characteristics of OER, such as retain, reuse, remix, review, and redistribute [4] (i.e., what quality attributes meet these characteristics?). When analyzing our results, we highlighted some quality attributes that may meet these characteristics, such as modularity, reusability, modificability, portability, adaptability, replaceability, and decontextualisation. The highlighted points need to be further investigated.

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