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Towards a Semantic Definition of a Framework to Implement Accessible e-Learning Projects

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Abstract: The growth of education faces a constant evolution, and the adoption of new technologies for education is reflected in the inclusion of virtual courses in the educational process. However, accessibility in cloud-based applications, virtual platforms and online courses has not been widely taken into account in the educational process. In this sense, the inclusion of accessibility features for online applications and digital content represents a very important benefit for everyone, but in the context of e-learning, it is imperative for students with disabilities. The lack of interest and awareness in online accessibility for education is especially evident in developing countries that do not have legislation that encourages stakeholders to bear in mind accessibility features for web-based applications and contents.

This paper proposes a methodological framework to take into account accessibility in the different processes of the life cycle of a virtual educational project. In this work, a semantic definition based on a conceptual model of the identified components for this methodology is presented. The proposed methodology has been prepared under an iterative design process, based on an international standard and complemented with online resources for dissemination.

In order to validate and improve the methodological framework, seven accessible virtual training courses were prepared following the phases and components defined in the methodology. The seven courses were promoted in an open call for participation launched in Latin America with the support of a cooperation initiative between European and Latin American universities called ESVI-AL. At the end of the experience, a total of 748 teachers and 937 students from 150 different educational institutions were enrolled. The participants in the experience provided comments and suggestions for further improvement. The proposed work is intended to be used as a reference for educational institutions to identify the necessary changes needed to incorporate accessibility into their own production processes for virtual courses.

Keywords: Accessibility, Instructional Design, Educational Technology, Ontologies
Categories: K.3.1 K.4.2 K.4.3 K.5.0 L.2.2 L.3.0 L.3.5 L.1.3 L.1.4

1 Introduction

There is a wide range of diversity of people and abilities; this is why web and software developers should be aware of how people with disabilities interact with computers. In this regard, there are many reasons why people may be experiencing accessibility barriers. The diversity of disabilities can be summarized in six groups: auditory, cognitive, neurological, physical, speech and visual disabilities [Abou-Zahra, 12]. Nevertheless, accessibility is a benefit for all people, including people with age-related impairments, temporary disabilities or technological limitations.

The Web Accessibility Initiative (WAI) was created with the mission to encourage developers to understand the principles of accessibility and design systems and solutions for everyone. The aim is to promote the use the Web as an instrument for all people, regardless of their hardware, software, language, location, culture or physical or mental ability. [W3C, 12a]. On this matter, accessibility in web systems has a great impact to all levels in the information society, particularly in virtual education or e-learning. In developed countries such as United States, United Kingdom, Spain or Canada, there is legislation on accessibility at all levels, especially for web-based systems. These laws promote the development of accessible systems. However, in developing countries, there is a big difference in terms of legislation on accessibility, technological limitations and access to assistive technologies for people with disabilities [Kelly et al., 10].

E-learning accessibility is a complex endeavor that involves a multidisciplinary effort mainly for a technological, didactic and administrative perspectives. In this respect, an e-learning platform should be accessible, but the most important part is the e-learning content in order to have an effective solution. The technical staff in an educational institution should be aware of the different accessibility standards and assistive technologies. However, teachers, tutors and instructional designers should be encouraged to understand the needs of a diverse population of students in order to create accessible content [Fichten et al., 09a] [Fichten et al., 09b], improve alternative teaching methods and evaluate different strategies for assessment. Therefore, there is a need to have a holistic approach for the implementation of accessible virtual educational projects in different contexts.

This work aims to provide a holistic approach towards the implementation of accessible virtual educational projects. The proposed solution takes into account the different accessibility aspects involved in the processes for the creation of accessible virtual courses. This work presents a methodological framework based on the international standard ISO/IEC 19796. The proposed framework details the adaptations to incorporate accessibility in the different production processes for online courses. It is a seven-part process model within the life cycle of virtual learning environments. As an accessibility framework based on an international standard, it may be used by any educational institution to describe, compare and adapt their own processes towards an accessible virtual education.

The proposed framework is a result of a cooperation initiative between higher education institutions in Europe and Latin America. The initiative was called ESVI-

AL and was partially funded by the European Union. The cooperation initiative allowed to validate the proposal in ten higher education institutions with different contexts. These universities are from seven Latin American countries (Colombia, Ecuador, El Salvador, Guatemala, Paraguay, Peru and Uruguay) and from three countries in Europe (Finland, Portugal and Spain). Moreover, the proposal was disseminated in a massive online training course for teachers and students from more than 150 educational institutions.

This paper is organized as follows: [Section 2] presents an overview of the state of the art related to accessibility in virtual education. Then [Section 3] presents the proposed methodological framework processes and components. Later on, [Section 4] presents a semantic definition of the framework towards accessible e-learning projects and describes the dissemination resources prepared using the semantic definition are described. [Section 5] then presents the results of the validation process used for the proposed methodology. Finally, conclusions and future work are presented in [Section 6].

2 Overview of the State of the Art

Two types of literature are relevant for this work and will be reviewed briefly: the literature on the evaluation of technical aspects and learning technologies related to accessibility for e-learning platforms, and the literature on didactic methods and proposed models for a holistic e-learning project.

2.1 Technical aspects related to accessibility in e-learning

The Web Accessibility Initiative (WAI) brings together a multidisciplinary group of people with expertise in different sectors from academy, industry, disability government and the most important group, final users with disabilities leaded by disability organizations [W3C, 12a]. This group develops standards, guidelines, resources and techniques for making accessible websites, authoring tools, web applications and digital content. A summary of the main standards and guidelines useful for technical staff in educational institutions is presented in [Tab. 1].

Besides the standards and guidelines published by the WAI [W3C, 12a], the International Organization for Standardization (ISO) and other entities, as an example, the European Committee for Standardization (CEN), American National Standards Institute (ANSI) and the IMS Consortium, provide standards and specifications to manage accessibility in different aspects related to education. In this sense, Santos et al. [Santos et al., 11] compiled several standards with a special emphasis on addressing accessibility for an educational context. The standards are classified by scope and interaction aspects as the following: content, hardware, software, adaptation and user interfaces. Hilera et al. [Hilera et al., 13] presented a study related to web content in educational institutions; the authors complied a group of standards related to web content when dealing with educational settings. A summary of the most relevant standards for this work is presented in [Tab. 2].

People with disabilities use assistive technologies to surpass the different barriers they may experience when interacting with computers to accomplish a personal independence. The term assistive technology is used to refer to equipment, devices,

applications and systems intended to help people with disabilities for everyday activities. In this sense, Burstahler et al. [Burgstaher et al., 11] present a compilation of the most used assistive technology based on the type of disability and Seale [Seale, 07] describes how students with disabilities use assistive technology to achieve learning outcomes. Complementarily, Hersh [Hersh, 14] proposes an evaluation framework to classify assistive technologies based on different aspects: accessibility and usability, compatibility, learning outcomes, end-user factors and technology-related factors among others.

Id	Title	Scope
WCAG	Web Content Accessibility Guidelines 2.0	Accessible websites. Provides principles, guidelines, techniques and success criteria to create perceivable, operable, understandable and robust web content.
WAI-ARIA	Accessible Rich Internet Applications 1.0	Interaction. Provides semantic information for widgets, structures and behaviors.
UAAG	User Agent Accessibility Guidelines 1.0	Browsers, media players and assistive technologies. Defines how user agents should support keyword navigation and respond to roles and properties.
ATAG	Authoring Tool Accessibility Guidelines 1.0	Tools to produce accessible web content. Related to applications intended to create reusable educational resources.
EARL	Evaluation and Report Language 1.0	Evaluation tools. Provides a standardized vocabulary to express accessibility test results.
IndieUI	Independent User Interface	Definition of user preferences. Abstraction between device-specific user interaction events.
Mobile A11Y	Mobile Accessibility Working Draft	Informative guidance to interpreting and applying WCAG guidelines to web and non-web mobile content and applications.

Table 1: Summary of standards and guidelines WAI [W3C, 12a]

2.2 Didactic methods and proposed models for an accessible e-learning

The life cycle of an e-learning project is divided in different processes, concepts, products and stakeholders involved in the educational activities. The processes that make up the life cycle of a virtual educational project are usually based on empirical experiences for the education institutions. Processes are defined with the support of successful experiences of implementation of e-learning projects and there is no generic or common formula to follow. Because of this diversity of implementation models, the International Organization for Standardization proposed the standard ISO/IEC 19796 [ISO, 05]. The standard is a basic framework for quality development in organizations within the field of learning, education, and training. It was defined as a framework to describe, compare and analyze quality management and quality assurance approaches for e-learning projects. The aim of this standard is to identify

the components of a seven-part process model within the life cycle of a virtual education initiative. This standard may be used for educational institutions to describe the different components and processes for their own formative projects. The model produced by the institutions may be later compared with other proposals looking for a harmonization between them. The experiences of institutions implementing the standard ISO/IEC 19796 [ISO, 05] have provided valuable knowledge to improve to a new standard titled ISO/IEC 36000 [ISO, 15]. Unfortunately these standards do not address accessibility as suggested in [ISO, 14], but can be used as a reference framework to model the processes and components involved in an e-learning project with accessibility features.

Examples of formal models that can be used as a reference to be compared with the aforementioned standard ISO/IEC 19796 are: German model with a focus on e-learning DIN PAS 1032-1 [DIN, 04]; French model AFNOR Z 76-001 [AFNOR, 04]; Chinese model CELTSC [Yi et al., 04] and the Spanish model [AENOR, 10].

Title	**Reference**
EN 301-549 Accessibility requirements suitable for public procurement of ICT products and services in Europe.	[ETSI, 15]
ISO/IEC Guide 71 -- Guide for addressing accessibility in standards	[ISO, 14]
ISO/IEC 40500 Information technology -- W3C Web Content Accessibility Guidelines (WCAG) 2.0	[ISO, 12]
ISO/IEC TR 29138: Information technology – Accessibility considerations for people with disabilities	[ISO, 09b]
ISO/IEC 24751-1, Individualized adaptability and accessibility in e-learning, education and training.	[ISO, 08a]
ISO/IEC 24751-2, Part 2: "Access for all" personal needs and preferences for digital delivery.	[ISO, 08b]
ISO/IEC 24751-3, Part 3: "Access for all" digital resource description.	[ISO, 08c]
ISO 9241-151 Ergonomics of human-system interaction – Part 151: Guidance on World Wide Web user interfaces	[ISO, 08d]
ISO 9241-171 Ergonomics of human-system interaction – Part 171: Guidance on software accessibility	[ISO, 08e]
ISO 9241-210 Ergonomics of human-system interaction – Part 210: Human-centered design for interactive systems	[ISO, 10]
IMS Global Access for All (AfA)	[IMS, 12]
IMS Guidelines for Developing Accessible Learning Applications (IMS DALA).	[IMS, 04]
IMS Learner Information Package Accessibility for LIP (IMS ACCLIP).	[IMS, 03]
CWA 15554: Specification for a Web Accessibility Conformity Assessment Scheme and a Web Accessibility Quality Mark.	[CEN, 06]
BS 8878: Web accessibility. Code of practice.	[BS, 10]
ANSI/HFES 200, Human Factors Engineering of Software User Interfaces. Part 2: accessibility	[HFES,08]

Table 2: Summary of standards and guidelines related to accessibility

Seale [Seale, 07] defines three categories to identify approaches to developing accessible learning practices. The categories are adapted to this study as follows:

1. Training for stakeholders and approaches to develop accessible environments, content, multimedia and learning objects.
2. Holistic approaches to develop accessible e-learning experiences
3. Institutional approaches to address accessibility based on the local context.

In order to identify the most relevant proposals to include accessibility in e-learning, the three categories were used to classify the different studies in [Tab. 3].

Category	Description of the proposal	Reference
1	Competencies that a teacher should have to design accessible online courses	[Smith et al., 10]
1	A curriculum in universal design competencies proposed for training to e-learning stakeholders	[CEN, 11]
1	Minimal knowledge required for teachers with students with disabilities	[Cooper, 07]
1	Adaptation of online learning resources with a proposal of a professional training in accessibility for teachers	[McAndrew et al., 12]
1	Universal Learning Design guidelines and principles towards an inclusive education	[CAST, 11]
2	A contextualized model of accessible e-learning practice in higher education based on: legislation, universal guidelines and universal standards.	[Seale, 06]
2	A holistic approach to e-learning accessibility with a framework based on: awareness, investigation, understanding, implementation and evaluation.	[Phipps and Kelly, 06]
2	A holistic approach based on a stakeholder model of accessibility.	[Kelly et al., 07]
2	An exploration of the potential role of generic pedagogical tools for an accessible e-learning initiative.	[Seale and Cooper, 10]
3	An institutional case study of the experience of providing accessible online learning for students with disabilities.	[Cooper, 07]
3	Didactic guidelines to design inclusive e-learning activities	[Guglielman, 13]
3	Development of accessibility indicators for distance learning programs	[Burgstahler, 06]
3	Guidelines for designing and evaluating recommendations in accessible personal learning environments.	[Santos and Boticario, 15]
3	Institutional change for improving accessibility at The Open University	[Slater et al., 15]

Table 3: Classification of relevant proposals to include accessibility in e-learning

3 Methodological framework for an accessible e-learning

The overview of literature in [Section 2] allowed to identify the initial actions to propose a methodological framework for a holistic approach towards an accessible e-learning project. First, the international standard ISO/IEC 19796 [ISO, 05] was selected as a reference framework to describe the processes and components of the life cycle for an e-learning project, then the accessibility features were added to the components following best practices and the guidelines presented in [ISO, 14]. Second, the components of the methodological framework and their relations were represented with an RDF vocabulary for a semantic definition. Finally, the three categories to identify approaches to developing accessible learning practices [see Section 2.2] were expressed as actions to be included in the activities in the methodology and the validation of the proposal. The identified actions are:

1. Propose a holistic approach to develop accessible e-learning experiences.
2. Validate the proposal in different contexts with a special focus on raising awareness of the importance to address accessibility in e-learning.
3. Organize a massive training for stakeholders in Latin America to disseminate and validate the methodological framework.

The proposed methodological framework is based on the standard ISO/IEC 19796 [ISO, 05]. This is a common and generic framework used to describe, specify, understand and compare the components of the life cycle of an e-learning project. This framework harmonizes existing and future approaches, components, terms, and definitions related to projects for learning, education and training [ISO, 15]. The proposed methodological framework was constructed with seven components categories: processes, activities, tasks, products, methods, metrics and participants. The description of each of the categories is presented in the following sub-sections.

3.1 Process

The methodological framework is divided into seven processes within the whole lifecycle of an accessible e-leaning project. The processes are the following:

- Needs Analysis: The purpose of this process is the identification and description of demands, needs, requirements, constraints and stakeholders of an accessible virtual education project.
- Framework Analysis: The objective of this process is to identify the framework and context related to the initiative. This process involves a complete analysis of staff resources, target groups, and time and budget planning. In this phase it is important to take into account legislation and the local, political and cultural factors related to accessibility in the institution.
- Conception and Design: The aim of this phase is to define and design the different components of an educational process. Activities involve the inclusion of accessibility within the definition of learning objectives, didactical methods, organizational concepts, educational resources, interaction design and evaluation rubrics.
- Development and Production: The aim of this process is to produce the educational resources with accessibility features. This process involves the

participation of the technical staff with good knowledge of the different standards and guidelines related to accessibility [see Section 2.1].

- Implementation: The purpose of this phase is to implement appropriate technological components to be used in the educational process based on an accessible technical infrastructure. This process involves the testing, adaptation and activation of learning resources.
- Learning Process: This is the main iterative process in the methodological framework. The aim of the process is to perform the accessible learning activities designed and implemented in previous phases. This phase involves the active participation of teachers and tutors.
- Evaluation and Optimization: This is considered a transversal process. The objective of the process is to describe the evaluation methods, principles and procedures for quality and accessibility assurance in the educational project. This phase involves the optimization and improvement in the different processes for the accessible e-learning project.

3.2 Activity

The seven processes in the proposed methodological framework have been divided into sub-processes or activities. Each of the processes was divided into three to six activities for a total of 29 activities including accessibility features. The partition into activities enables a correct involvement from stakeholders with different experience and competencies. These activities can be planned and applied according to the specific needs and the given situation of the education organization. The activities can be organized as linear sequences, individually adapted sequences, feedback loops or parallel implementation towards an accessible e-learning project.

3.3 Task

The activities defined for each process have been broken down into tasks. A total of 79 tasks with a focus on accessibility have been proposed for the activities in the methodological framework to create accessible online courses. The tasks are mainly described by the products or results obtained. Additionally, the profiles and required competencies for the stakeholders involved in the tasks have been identified.

3.4 Product

Broadly speaking, products or results represent the main output of the action to perform a process. In the context of accessible online courses, products represent the different components of the educational process. In the case of the proposed methodological framework, products are the main output of tasks, considered as sub-processes. Therefore, in the case of the main processes, the products to be obtained are the sum of the results obtained in each of the activities and tasks in which each process is decomposed.

A total of 98 products are defined for the proposed methodology. Examples of these products are: a paragraph within a template (a learning objective), a descriptive document (a corporate accessibility policy or a catalog of educational activities), or a

learning resource (content package of an accessible training unit or an accessible video).

3.5 Method

The methodological framework is complemented with a formalized description of methods that can be easily implemented and adapted to achieve products, taking into account accessibility aspects. A total of 101 methods have been selected and defined with the format depicted in the reference model in [ISO, 09a]. The aim of the selected methods is to support stakeholders to implement concrete guidelines to achieve accessible products to be used in the educational process. Further, a set of digital templates were prepared as a reference for the users of the methodological framework towards an accessible e-learning project. The proposed templates are intended to provide a guideline to achieve a course planning, teaching guide, didactic unit, accessible document or inclusive learning activity among others.

3.6 Metric

A group of 102 metrics are proposed to validate the products that comprise the proposed methodology. In general, a metric is a measurement method and values or scales defined with the aim to validate, through the provision of objective evidence, that the accessibility requirements for specific expected results have been fulfilled. The metrics have been defined using the reference model proposed in [ISO, 09a]. The metrics have been selected with the following minimum characteristics: definition of the product under evaluation, an attribute or characteristic that is measured on the product, and clearly defined rules and scores to evaluate that the product complies or not with the required quality. The importance of an accurate definition of metrics for the different products involved in an accessible e-learning project resides in the fact that products and the implemented courses can be evaluated, compared, audited and optimized.

3.7 Participant

The main stakeholders in an accessible online educational project can be categorized into at least eight categories: academic authority, program director, teacher, instructional designer, tutor, technical staff, quality auditor and student. However, for the proposed methodology, at least 51 competency profiles have been identified for the participants involved in the different processes. In practice, a participant may perform more than one of the identified profiles. The identified skills and competency profiles can be considered in the training plan for the personnel involved in the educational project.

4 Implementation of the methodological framework

4.1 Semantic definition of the framework to accessible e-learning projects

The semantic web movement aims to promote a web of data; a space where information is complemented with its meaning in order that it can be processed and

reused by machines. The semantic web technologies enable developers to provide semantic definition to a particular domain, create data banks, build vocabularies and define instructions to handle data. In this sense, [Al-Yahya et al., 15] presented a literature review related to ontologies in e-learning and it is possible to identify that there is a lack of studies related to accessibility and e-learning. People with disabilities can benefit with semantic web because data stored with its own meaning will be flexible and may be adapted to all means of access, especially with the use of assistive technologies. Additionally, machines will have more information about the data in a processable and interoperable format; in this way, machines will be able to find alternative resources, find access to support services, find recommendations and adapt the content to a different structure or presentation layout based on users' preferences and needs.

In this work, a semantic definition of the methodological framework was prepared to allow data interchange and interoperability among heterogeneous information systems and final users. In order to structure the semantic definition, a comprehensive ontology engineering process was followed [Uschold and Gruninger, 96]. The process to define the ontology had the following phases: (1) specification of the ontology goal and scope; (2) domain description; (3) identification of classes, relations and attributes; (4) development of a domain conceptual model; (5) and finally, generation of RDF resources.

The first and second phases to define the ontology are related to the specification of the goal and domain description. The goal of the semantic definition of the methodological framework is to have a formal ontology to develop a SPARQL [W3C, 13] endpoint with the aim of using it as a foundation for the implementation of the following applications: an interactive web application to disseminate the framework, a faceted semantic search engine, an accreditation assistant application and a recommender system for stakeholders using the methodology. The domain of the ontology is the methodological framework that implements accessible e-learning projects presented in [Section 3].

The third phase, related to the identification of classes, relations and attributes, was based on the components of the proposed methodological framework [see Section 3]. The seven main components were identified as the classes for the proposed ontology. A total of 467 components in seven categories are distributed as follows: processes (7), activities (29), tasks (79), products (98), methods (101), metrics (102) and participants (51). For the process of defining the ontology, the RDF Schema [Brickley and Guha, 14] and OWL [W3C, 12b] definitions were used to describe a vocabulary with the components in [Section 3]. Additionally, SKOS [Miles and Bechhofer, 09] was selected to establish an organization model of knowledge for educational institutions. A group of vocabularies presented in [Table 4] were selected to be used as a foundation for the components of the methodological framework.

The fourth phase developed a domain conceptual model for the ontology. Two RDF vocabularies have been created. One of the vocabularies named "iso19796" is related to the standard ISO/IEC 19796, including the classes: Process, Method and Metric, because the concepts in the methodology are similar to the identified standard. The RDF vocabulary named "esvial" includes the classes related to the following components: Activity, Task, Product and Participant as a mean to complement the ontology with classes and properties not found in other vocabularies. The seven

classes and their relations are depicted in [Figure 1] as a conceptual map of the proposed methodological framework.

Class	Vocabulary	URI
Process	iso19796	http://esvial.org/data/iso19796#Process
Method	iso19796	http://esvial.org/data/iso19796#Method
Metric	iso19796	http://esvial.org/data/iso19796#Metric
Activity	esvial	http://esvial.org/data/esvial#Activity
Task	esvial	http://esvial.org/data/esvial#Task
Product	esvial	http://esvial.org/data/esvial#Product
Participant	esvial	http://esvial.org/data/esvial#Participant

Table 4: Vocabularies selected to identify the components of the proposed methodological framework

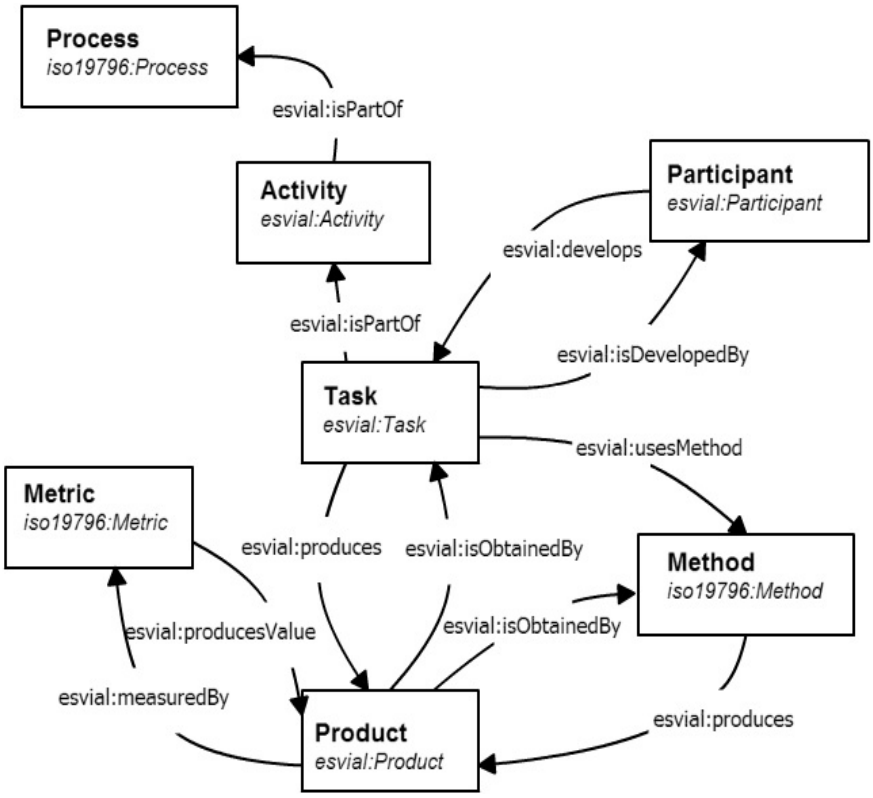

Figure 1: Conceptual map of the proposed methodological framework expressing the relation among components.

As properties for RDF classes: Process, Method and Metric, the "iso19796" vocabulary defines metadata to represent the information field established by

ISO/IEC 19796 standard. For example, "Process" class have the 13 properties, derived from the Part 1 of the Standard [ISO, 05].

It is important to mention that the ISO/IEC 19796-3 standard [ISO, 15] includes sub-properties to complement the information for each entity, as an example, [Listing 1] presents an extract of the definition of property "metricType", in this sense, this property is complemented with four sub-properties: Metric category, Calculation, Scale type and Criterion. The "esvial" vocabulary includes the classes "Activity" and "Task", as subclasses of "Process"; and new the classes "Product" and "Participant".

```
<?xml version="1.0" encoding="utf-8"?>
<rdf:RDF>
    <owl:Ontology rdf:about="http://esvial.org/data/esvial" dc:title=" \
    Accessibility (ESVIAL) vocabulary" dc:description="Accessibility \
    framework RDF vocabulary."></owl:Ontology>
...
    <owl:ObjectProperty rdf:ID="metricType">
        <rdfs:domain rdf:resource="#Metric" />
  ...
    </owl:ObjectProperty>
...

    <owl:ObjectProperty rdf:ID="metricCategory">
        <rdfs:subPropertyOf rdf:resource="#metricType" />
        <rdfs:range rdf:resource="xsd:string" />
  ...
    </owl:ObjectProperty>
...

```

Listing 1: Representation of sub-categories in the proposed Accessibility vocabulary, extract to identify the definition of sub-properties for the metricType property.

4.2 Dissemination resources for the proposed methodological framework

For dissemination purposes, the methodology was edited as a digital book [see Figure 2]. An interactive website was prepared as a reference with the 467 components and guideline templates of the proposed framework. The interactive website can be used as a knowledge source to perform accurate searches when a stakeholder asks for information related to components involved in the processes to produce an accessible e-learning project. Complementarily, a web interface with a search engine and an interactive graph based on the proposed ontology was prepared [see Figure 3].

5 Validation of the proposed methodological framework

The validation process for the methodological framework presented in this work was planned in two phases: The first phase was designed as a validation with teachers of the components involved in an accessible e-learning project [see Section 3]. The second phase consisted in a validation, with students with disabilities, of real e-learning courses implemented using the proposed methodology.

This experience was planned within the context of the ESVI-AL initiative (www.esvial.org). The ESVI-AL initiative was a three-year cooperation action between higher-education institutions in Europe and Latin America. ESVI-AL was designed with the aim of promoting the inclusion of accessibility in all phases of the life cycle of an e-learning project and raising awareness, among stakeholders of the barriers that a student with disability may experience when dealing with e-learning platforms and learning resources with accessibility issues.

Figure 2: Front cover of the digital book edited to disseminate the methodology: "Methodological guide for the creation of virtual accessible curriculum developments".

5.1 Results for the first validation phase with teachers

The first phase was designed as a validation, with teachers, of the components involved in an accessible e-learning project [see Section 3]. The first phase was designed with the aim of implementing an accessible e-learning course following the proposed steps in the seven processes of the methodology. The course was titled: "Instructional design for the creation of accessible virtual courses". The course was designed with a duration of six weeks, with a special dedication to the processes with a strong involvement of teachers: (1) Conception and Design; (2) Learning Process; (3) Evaluation and Optimization [see Section 3.1].

For the first validation phase, four editions of the online training course were planned. An open call for participation was promoted among educational institutions in Latin America. A total of 748 teachers from 150 different educational institutions were registered in the four editions of the online training course to promote the methodological framework. The summary of participation in the four editions is

presented in [Table 5]. At the end of the experience, a total of 336 teachers (45% of the registered participants) finished and approved the online training.

In the learning activities designed for the course, the teachers were invited to use and comment on the resources created as supporting material to implement the methodological framework [see Section 4.2].

Figure 3: Screenshot of the interactive website prepared as a reference to implement the proposed methodological framework. The screenshot presents a search engine and an interactive graph based on the proposed ontology.

In this validation phase, the learning activities invited teachers to identify an online course developed at their institution or to propose course contents that they wanted to adapt to an accessible e-learning course. The identified course was then analyzed and adapted to include accessibility features following the methodological framework. The experience has allowed to have more than 300 proposals of different courses in various topics in which participating teachers have explored and implemented the proposed processes supported by templates and guidelines. The experience has ensured valuable feedback to improve the definitions of the various components of the methodology. The experience also provided the opportunity to validate the proposed methods and to identify new techniques to help stakeholders obtain better products [see Section 3.5].

Edition	Registered participants	Approved participants	Approval rate
1	231	122	53%
2	225	103	46%
3	131	54	41%
4	161	57	34%

Table 5: Results of participation in the four online editions for the accessible course

5.2 Results for the second validation phase with students with disabilities

The ESVI-AL initiative had the objective of using the methodological framework to create accessible virtual educational programs oriented to the improvement of employability of the population with disability. With this purpose in mind, an analysis of the educational needs for the population with disabilities in Latin America was prepared. For this work, the ESVI-AL initiative had the cooperation of two valuable associates: The Latin American Union of the Blind (www.ulacdigital.org) and the Latin American section of the Disabled People's International Organization (www.dpi.org).

The analysis identified limitations related to digital literacy. In this sense, accessible virtual educational programs prepared by educational institutions provide an alternative for people with physical disabilities. For this reason, the coordinators of the ESVI-AL initiative selected six themes to implement accessible e-learning courses following the proposed steps in the methodological framework. The selected topics for the courses intended to improve the employability of people with disabilities are:

- Office suites fundamentals based on the international computer driving license (ICDL) (www.ecdl.org). The course has a focus on the basic modules for digital literacy: computer essentials, online essentials, word processing and spreadsheets with a special emphasis on the creation of accessible documents.
- Online community management and social media skills. The course is based on the fact that people with disabilities may work in these activities with telecommuting.
- Customer service fundamentals with a focus on call center agents. The contact center and business process outsourcing (BPO) industry represents a growing employment sector in Latin America, and the fundamentals for customer services were identified as building blocks for people with disabilities starting businesses from home.
- Entrepreneurship: starting a business from home. Entrepreneurship is considered a key competence for lifelong learning [EC, 06]; it is considered a foundation for acquiring skills and knowledge needed by people with disabilities establishing a commercial activity from home.
- Pre-employment hiring preparation course. The course provides the participants with advices on how to write a personal resume, highlighting relevant information and how to prepare for an oral interview process.

- Communication and writing skills for business. The aim of the course is to provide participants with the basic skills to communicate a message with clarity with a focus on the target audience.

The partner universities that are part of the ESVI-AL initiative prepared the six accessible e-learning courses following the processes in the methodological framework proposed in this work [see Section 3]. The development teams followed each of the processes using the guidelines and templates supporting the methodology. The courses were prepared as full-online courses, with six learning units and a duration of eight weeks. This experience provided a valuable feedback to improve the components defined in the methodology, paying special attention to the definition of products [see Section 3.4], the different methods proposed to obtain the products [see Section 3.5], and the metrics as a quality criteria for the aforementioned products [see Section 3.6].

Following the implementation of the six accessible e-learning courses in a virtual learning environment adapted with accessibility features, the second validation phase was focused on the tasks involved in the "Learning Process" [see Section 3.1].

With the purpose of validating the courses with students with disabilities, a massive call for participation was launched in Latin America with the cooperation of the partner institutions and associate organizations. In this experience, the ESVI-AL initiative has given a special focus on two type of disabilities: physical and sensory. In this context, the term sensory disability is used to refer to vision and hearing impairment. However, the call for participation was planned as an inclusive experience, so the participation was open to everyone, including students without disabilities, in order to have an enriched feedback with multiple points of view.

As a result of the open call for participation, a total of 937 students took part in the six accessible e-learning courses. The participants were 485 (52%) men and 452 (48%) women. The students were from 18 different countries in Latin America; the five countries with more representatives were: Peru (20%), Ecuador (17%), Paraguay (16%), Colombia (15%) and Argentina (5%). The rest of the countries had a participation of 27% of the total of students registered to the courses. A summary of the registered participants for each of the courses, grouped by type of disability, is presented in [Table 6].

It is important to mention that a total of 421 students (53% women and 47% men) finished and approved at least one of the courses, representing an acceptable rate of 45 percent of the registered participants. The total of students that finished each of the six accessible e-learning courses is presented in [Table 6]. Moreover, an encouraging fact is that a total of 357 students that approved the courses reported to have a disability. From the total of students with a disability that finished the courses, representing the 85% of the approved participants, 232 of them reported a sensory disability and 125 reported a physical disability. The outstanding participation of students with disabilities in the e-learning courses allowed to validate the level of accessibility that can be reached by following the proposed methodological framework.

Course	Participants with physical disability	Participants with sensory disability	Participants without disability	Approved participants
Office suites fundamentals	35	159	5	125
Customer service fundamentals	64	77	47	95
Online community management skills	35	89	36	65
Employment preparation course	31	53	7	58
Entrepreneurship: starting a business	67	66	21	45
Communication and writing skills	18	23	104	33
Total	250	467	220	421

Table 6: Results of participation of students in the six accessible e-learning courses

6 Conclusions and Future Work

The continuous advances in technology are changing the concept of E-Learning [García-Peñalvo and Pardo, 15], and fortunately the assistive technologies are helping students with disabilities to have a complete learning experience. In this sense, it is important to mention that to provide a successful E-learning accessibility experience is a complex endeavor that involves a multidisciplinary effort mainly for a technological, didactic and administrative perspectives. In this respect, a clear example is the following scenario: A business faculty in an educational institution identifies an increasing demand in formation related to entrepreneurship and decides to implement a lifelong learning course as an accessible e-learning approach. The technical staff in the educational institution, aware of the different accessibility standards and assistive technologies, prepares the course within an e-learning platform with accessibility features. Later, teachers will publish the e-learning content in the prepared environment.

It is important to mention that a relevant part of this scenario is the e-learning content prepared for the teachers, but e-learning content must be accessible, too, in order to have an effective solution. In this scenario, at least three different stakeholders take part in the accessible educational process. Besides this, teachers, tutors and instructional designers should be encouraged to understand the needs of a diverse population of students in order to create accessible content, improve alternative teaching methods and evaluate different strategies for evaluation. Therefore, there is a need to have a holistic approach to the implementation of accessible virtual educational projects in all the phases of the life cycle of the production of a course, taking into account different contexts.

In terms of accessibility, it has been identified that there is a lack of interest in and awareness of online accessibility for education in developing countries, particularly in the context of this work in Latin America. In Latin America, the

biggest part of the countries do not have legislation that encourages stakeholders to bear in mind accessibility features for web-based applications and contents.

In this work, three actions were implemented towards an accessible e-learning:

- A holistic approach to the development of accessible e-learning experiences was proposed. This work presented a methodological framework, a seven-part process model integrated by 467 components within the life cycle of a virtual e-learning project. As an accessibility framework based on an international standard, it is intended to be used as a reference by any educational institution to describe, compare and adapt their own processes towards an accessible virtual education experience.
- This work prepared a semantic definition of the methodological framework with the aim of having a formal conception and setting the foundations to develop a SPARQL [W3C, 13] endpoint with the aim of being used as a starting point for the implementation of the following applications: interactive web application to disseminate the framework, faceted semantic search engine, and a recommender system for stakeholders using the methodology.
- The methodological framework was intended to be validated in different contexts, with a special focus on raising awareness among stakeholders of the importance to address accessibility in e-learning. For this, a massive training for stakeholders in Latin America was organized to disseminate and validate the methodological framework; an experience that provided positive results. In this experience, seven accessible e-learning courses, prepared by following the methodology, were promoted in an open call for participation launched in Latin America with the support of a cooperation initiative between European and Latin American universities called ESVI-AL. At the end of the experience, a total of 748 teachers and 937 students from 150 different educational institutions were enrolled. The experience provided valuable feedback from participants and was used to improve the different components and resources in the methodology.

For dissemination purposes, the methodology was edited as a digital book. Additionally, an interactive website was prepared as a reference with information records for the 467 components that give shape to the methodology. Furthermore, guidelines and online templates of the proposed framework were prepared as supporting resources. The idea behind the interactive website that was developed was to provide an interface that can be used as knowledge sources to perform accurate searches when a stakeholder, following the methodology, asks for information related to components involved in the processes to produce an accessible e-learning project. Complementarily, a web interface with a search engine and an interactive graph based on the proposed ontology was prepared.

Future work will mainly cover the development of a quality management and quality assurance approach based on a weighing scale for the metrics defined in the methodological framework proposed in this work [see Section 3.6]. The idea behind this quality approach is based on the fact that the proposed methodology is based on the international standard ISO/IEC 19796 [ISO, 05], that provides a reference framework for the description of quality approaches. Based on this, proposals of any educational institution, which are based on the standard ISO/IEC 19796, can be compared, combined and complemented with the proposed methodology towards a

harmonization to evaluate quality and accessibility for e-learning projects. With this quality approach, e-learning projects could be certified based on the quality and accessibility level reached by its implementation. Furthermore, the SPARQL endpoint defined in this work could be used to develop an accreditation assistant based on recommendations.

Finally, a potential field of action is to raise awareness on accessibility on cloud based applications for education and massive online open courses (MOOC) [Sanchez-Gordon and Lujan-Mora, 16]; both fields with a scarce presence of studies related to accessibility in literature.

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