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New Perspectives in Instructional Design using Semantic Web Technologies: A Systematic Literature Review

Nuevas perspectivas en diseño instruccional usando tecnologías de la web semántica: Una revisión sistemática de literatura

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Abstract

Systems development based on the application of semantic web technologies is gradually growing, especially in the field of e-learning. A key aspect in the field of e-learning is instructional design, which facilitates the creation of online courses. Several studies have been conducted on the use of ontologies and semantic web technologies in open e-learning platforms, which have obtained several benefits in terms of better learning and better orchestration of instructional practices. Nevertheless, there are notably few reports related to instructional design using semantic web technologies. Thus, the primary objective of this paper is to present a systematic literature review of primary research proposals that involve the field of instructional design combined with the use of semantic web technologies. From a total of 5035 initially gathered papers, 21 of them were related to instructional design and were deeply analyzed. Our results indicate a lack of interest in including certain aspects, such as pedagogical approach, standards, and compatibility with virtual learning environments. It is suggested that the systems should incorporate characteristics of semantic web technologies in virtual learning environments.

Keywords: e-learning, instructional design, ontologies, semantic web technologies, systematic literature review.

Resumen

El desarrollo de sistemas basados en la aplicación de las tecnologías de la web semántica está creciendo gradualmente, especialmente en el campo del elearning. Un aspecto clave en el campo del elearning es el diseño instruccional, el cual permite la creación de cursos en línea. Varios estudios se han realizado sobre el uso de ontologías y otras tecnologías de la web semántica en plataformas de elearning abiertas, las cuales indican varias ventajas en términos de un mejor aprendizaje y una mejor organización de las prácticas de enseñanza. Sin embargo, hay pocos estudios relacionados con el diseño instruccional utilizando tecnologías de web semántica. Por lo tanto, el objetivo principal de este trabajo es presentar una revisión sistemática de literatura de los aportes de investigación primaria que implican el campo del diseño instruccional combinado con el uso de las tecnologías de la web semántica. De un total de 5035 documentos recopilados, solo 21 de ellos fueron analizados detenidamente. Los resultados sugieren una falta de interés en incluir ciertos aspectos como; el enfoque pedagógico, los estándares, y la compatibilidad con los entornos virtuales de aprendizaje. Se espera en un futuro que ciertos entornos de aprendizaje incorporen ciertas características de la web semántica.

Palabras claves: diseño instruccional, elearning, ontologías, revisión sistemática de literatura, tecnologías de la web semántica.

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I. INTRODUCTION

Semantic Web Technologies (SWTs) are generating expectations in the fields of knowledge processing and representation. Undoubtedly, SWTs have been steadily increasing in relevance in certain areas such as research and business [1]. One of the areas of advancement that has seen a strong impact is education, especially higher education. The integration of elearning and semantic web has already produced several important results [2]. One of the most interesting results is the opportunity to combine SWTs with educational theories, teaching practices and learning practices to enable the development of educational technologies that understand and use theories of learning/instruction to support better education [3].

One way to increase the use of the e-learning environment is to make it more pedagogically attractive. According to [4], it has been established that the e-learning environment is a teaching and learning environment that uses electronic media as a tool to improve communication and interaction with students. Focusing on the context of elearning, Instructional Design (ID) is used to refer to the systematic application of principles and theories that guide the design of learning resources [5]. We believe that the ID process involves the whole design process, including the generation of a course, teaching unit, or system that details which educational resources are available within a learning environment.

Several studies have been conducted on ontologies and the semantic web for elearning [6]–[9]; these stand out as pioneers in proposing some of the foundations for a new generation of systems learning based on the semantic web. Initial approaches, such as frameworks, services, and systems management focused on the ontologies to represent knowledge in different contexts of teaching and learning. These works highlight the management of ontologies, which are widely employed for their ability to be shared and reused and are necessary to facilitate semantic interoperability [10]. Although semantic webbased elearning is at an early stage, it has already spread extensively, perhaps because of the many technologies involved in it and because of its adoption in pedagogical sciences [9].

Other studies have addressed issues related to interoperability, annotation, reusability, and intelligent/adaptive systems, such as [11], which allows the integration of different systems and learning through SWT. Others works

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present systems and adaptive learning based on SWTs [12], [13]. There are also studies that propose innovative approaches for recommendation of e-learning content through SWTs [14], [15]. However, there are very few reports related to instructional design using SWTs in the field of e-learning. Although these proposals fulfill the specific purposes for which they were developed, they do not incorporate characteristics or aspects considered by other approaches to be essential to SWTs, but rather, present innovative functionalities.

Several studies have conducted literature reviews that focus on specific topics of e-learning based on the use of the semantic web. Among them, we mention the work in [16], which focuses on the implementation of a framework for the classification of ontologies and SWT for aspects of the content of educational technology. The work in [17] produces a compendium in the field of education and the semantic web, but focuses on aspects such as knowledge, representation, architectures, technologies, and applications. In [18], different types of educational ontologies were reviewed, along with tools and applications involved in these ontologies. In another study, the current and potential applications of SWT in several areas of e-learning were analyzed [19]. However, no literature reviews have been found that are specifically related to instructional design using SWTs.

Given the above considerations, a research study that considers characteristics and ID guidelines in combination with the SWTs is required. The aim of this paper is to present a Systematic Literature Review (SLR) of primary research proposals involving both the field of ID and the use of SWTs. In addition, aspects of standardization and intelligent systems have been considered. The remainder of this paper is organized as follows: the second section describes background material and main concepts of Instructional design for elearning; the third section presents the methodology that was used for our systematic literature review; the fourth section reports the results of the investigation based on four research questions; and the last section presents the study's conclusions and suggestions for further research.

II. LITERATURE REVIEW

The semantic web enables the incorporation of semantic information into web contents to create an environment in which software agents will be able to perform sophisticated tasks for their users [20]. Considering the

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semantic web as a set of technologies, tools and standards that are part of a system helps the web to give meaning to its contents [21]. Semantic web technologies significantly improve the performance of knowledge management [22] by contributing to the creation and use of metadata. In the following passages, we present an overview of the semantic web in the scope of educational and instructional design.

An ontology is the main component of the semantic web since it allows the semantic representation of web resources. Ontologies provide a way to formalize specific domains of human knowledge to allow inter-operability between computers [23]. To properly represent an ontology, a formal language must be used to describe the structured information. Several ontology languages have been developed in recent years. Resource Description Framework (RDF) is a generalpurpose language for representing Web resources [24]. RDF uses XML to exchange descriptions of Web resources. XML is a meta-language that is used for describing and representing structured documents on the web using markup [23]-[25]. There is an ontology language specifically designed for use on the Web, which is called DAML+OIL for historical reasons [26]. W3C has a syntax that is based on RDF Schema. We also highlight Web Ontology Language (OWL), which is the W3C recommendation for publishing and sharing ontologies on the Web [27].

To extend the set of OWL axioms, it is necessary to establish some definitions. To accomplish this, Semantic Web Rule Language (SWRL) is used. SWRL was built to be the rule language of the semantic web [28]. SWRL allows users to express Horn-like rules in terms of OWL concepts. To complete our set of tools, we describe SPARQL, which is a query language that is designed to express queries across diverse data sources, whether the data are stored natively as RDF format or viewed in RDF format via middleware. SPARQL is considered a W3C recommendation [29]. One typical characteristic is that it allows for the handling of complex structure queries for data stored in RDF repositories.

ID is the application of teaching and learning theories for the creation of educational resources and online educational experiences [30], [31]. This process is performed by applying a set of methods that help the designer plan the learning activities. There is a very similar design approach called Learning Design, which is the application of an educational model for a specific learning objective and specific context or knowledge domain [32]. Some authors

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assert that Learning Design is used more generally [30]; therefore, we will use ID to refer to the systematic process based pedagogically on the theories of teaching and learning that allow for the development of educational materials and analysis of their application in virtual learning environments.

Instructional design encompasses the building of learning environments. According to [33], a Virtual Learning Environment (VLE) is defined as "*a software system that combines a number of different tools that are used to systematically deliver content online and facilitate the learning experience around that content*". A VLE may also be known as a learning management system (LMS) or a course management system (CMS), or be part of a broader integration of web services and information systems in what is usually known as a managed learning environment [34]. One common example of an LMS is Blackboard [35], which is a proprietary system, but there are others, such as Moodle [36], that are opensource systems. In the present study, based on the presented literature, a VLE can be considered as either a CMS or an LMS.

III. METHODOLOGY

This research was conducted following the methodology of systematic literature review that was described in [37]. The steps for conducting SLR include the following: (1) Identification of the need for a review, (2) development of a review protocol, (3) identification of research, (4) selection of primary studies, (5) data extraction (6) data synthesis, (7) interpretation of the results, and finally, (8) drafting the report. The main objective of this study is to review and analyze the primary research work concerning instructional design systems that use SWT. This study focuses on both the existing models of ID and the tools used to support the construction of virtual courses, if these are based on SWTs. This analysis aims to answer the following research questions:

- RQ1: What characteristics influence instructional design studies based on semantic web technologies?
- RQ2: What are the main issues related to semantic web and instructional design in the field of education?
- RQ3: What types of contributions involving instructional design based on semantic web technologies are identified most frequently?

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- RQ4: What semantic web technologies based on authoring tools are available?

Resources and search strategy

The search for information that resulted in the discovery of the answers to the posed questions was performed using the following databases: ACM Digital Library, IEEE Explore, ScienceDirect, and Springer. These databases were chosen because they are the most important ones in the field of Computer Science/Semantic Web. Additionally, specific chapters of books relating to the proposed study were considered. The inquiry covers the period from 2000 to 2015. The year 2000 was established as the base year because the concept of the semantic web began to emerge in that year [38]. The search string that was defined for this SLR meets the following criteria:

> *((“Semantic Web Technologies” OR “Semantic Web” OR Ontolog* OR “Semantic Web Rule Language” OR RDF) AND (“Instructional Design” OR “Learning Design” OR “e-learning” OR “Online Course” OR “Courseware” OR “Virtual Learning Environment” OR “Learning Management System” OR “Intelligent Tutoring System” OR “Authoring Tool”))*

This search string mentioned was adapted to meet the requirements of each of the databases. Additionally, certain terms were adapted to satisfy the research questions.

Document selection

To select the appropriate research papers, we consider the following inclusion and exclusion criteria.

Inclusion criteria:

- Studies focused on instructional design proposals, such as models, frameworks, architectures, and approaches based on SWTs;
- Studies focused on authoring tools or virtual learning environments based on SWTs;
- Papers focused on aspects related to building online courses supported by SWTs.

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Exclusion criteria:

- Educational systems or applications developed by applying SWTs, except approaches that involve instructional design processes to build online courses;
- Studies focused on instructional design proposals such as models, frameworks, architectures and approaches that are not based on semantic web technologies;
- Published papers based on conferences. This with the aim of only selecting the primary studies.

The initial results of the search contained 5035 documents. Of these, 4589 documents were discarded from the first analysis because the titles indicated no relation to the process of ID or creating online courses. From this initial search, only 446 documents remained. In a similar way, we discarded all the documents that were published based on conferences or congresses. In other words, to be considered in this study, the documents must have been published in scientific journals. Due to this criterion, an additional 376 documents were withdrawn. Subsequently, a check was performed to identify items that were repeated in different databases. 10 repeated documents were found and discarded.

Finally, a thorough review of the papers was conducted. A total of 21 documents met the criteria for analysis in this study. Figure 1 shows the detail of the selection process.

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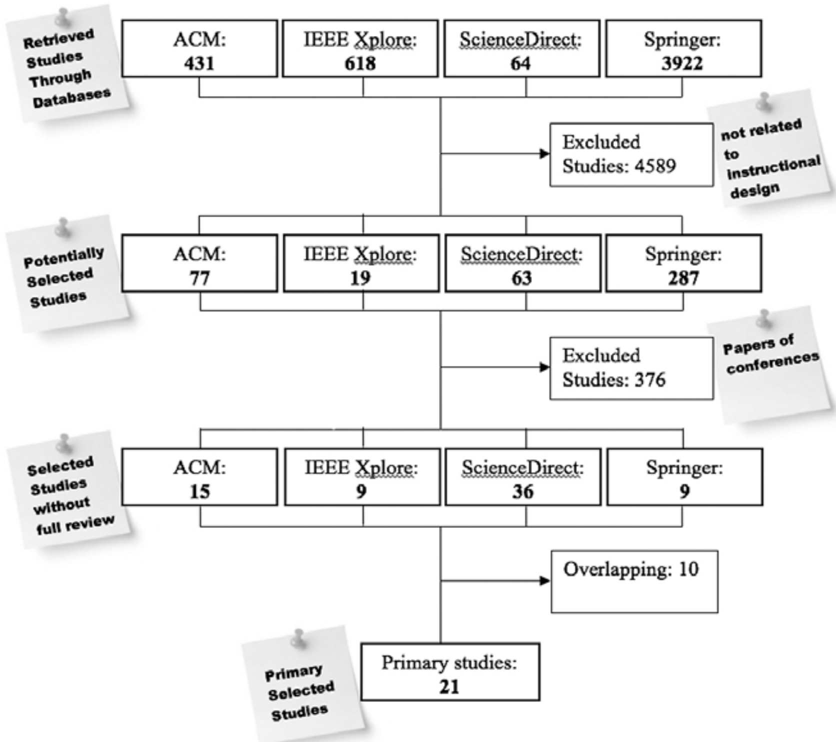

Figure 1. Flow diagram showing the details of the selection process

Data extraction and synthesis

The data extraction process was conducted using Zotero version 4.0 [39] and a Microsoft Excel spreadsheet. This allowed the bibliographic information and specific details of the research papers to be registered to include the following: title, author, publisher, abstract, extraction date, research aim, relevant contribution of the study, and specific personal comments. To generate the analysis of the data, a categorization scheme was proposed which is described in the next section. Using the SLR approach [37], specific relevant papers were identified.

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Proposed categorization scheme

To describe the categorization scheme, some information was extracted and adapted from [40], according to the type of contribution. To begin with, we must specify the types of contributions, which have been adapted to the scope of our study:

a. Tool: Research articles that introduce specific tools based on SWT in the field of instructional design;
b. Method: Research articles that suggest new methods in the field of instructional design based on semantic web technologies;
c. Model: Research articles that propose new models of instructional design and learning, and models for the creation of online courses, based on semantic web technologies;
d. Framework: Research articles that recommend new frameworks or instructional design architectures and Learning Design Systems for the creation of online courses based on semantic web technologies.

In addition to centering our study on instructional design approaches based on semantic web technologies, reference works [8], [9], [17] were analyzed. These works summarize key research themes related to the convergence of the semantic web and e-learning. From that analysis, we identified and selected the key issues in each work that we believe play a significant role in SWTs and determined how they relate to investigations of instructional design. The following categories were identified:

a. Ontologies Building: Research works that propose building ontologies in the context of instructional design;
b. Semantic Content Retrieval: Research papers that suggest the use of ontologies and SWTs to interpret, organize, share, retrieve, and exchange educational resources;
c. Architectures: Research works that identify frameworks or models that represent educational systems based on SWTs;

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d. Metadata and Annotation: Research papers that propose the use of standards related to the semantic web and the annotation of learning resources using metadata;

e. Intelligent e-learning Systems: Research works that propose intelligent e-learning applications, tools, or systems including methods that suggest the adaptation and customization of e-learning applications.

IV. RESULTS

RQ1: What characteristics influence instructional design studies based on semantic web technologies?

Twenty-one research papers were identified as relating to research question 1 (RQ1). From the original twenty-one papers, ten characteristics of instructional design models that use SWTs were identified. Reliable characterization schemes were used and adapted to support the above selection. We based our schemes on work [41], which proposes a reference model for developing semanticwebbased educational systems. Additionally, work [16] was used, which presents a classification system of different forms of ontology applications and SWTs for learning technology systems.

Table 1 details the ten characteristics that are most frequently found in the reviewed literature. The first, "*Role of involved individual*" refers to individuals who are typically involved in any process of teaching, learning, collaboration, or authorship. Then we have "*Architecture of ontologies included*", which describes the representation of ontologies in the various layers that make up the framework system. The third, "*Pedagogical approach employed*" is aimed at systems that are used to demonstrate a knowledge of pedagogies (e.g., learning theories). Next, we have "*Semantic web technologies involved*", which includes each of the technologies or languages that the system uses in its modeling. Additionally, we have the "*Standards or specifications of e-learning*", which describes the type of standardized outline or specification in the field of elearning. "*Type of interface with users*" describes the interface that is utilized to interact with users according to their unique roles. The following characteristic, "*Management of educational resources*", classifies learning objects and open educational resources.

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Table 1. Characteristics of instructional design models based on semantic web technologies

#	Characteristics	Possible Options
1	Role of involved individual	Instructor (Teacher), Learner, Author, Developer.
2	Architecture of ontologies included	Domain, Student (Learner), Pedagogical, Interface
3	Pedagogical approach employed	Learning Styles, instructional design theories
4	Semantic web technologies involved	OWL, RDF, RDFS, XML, SWRL, SPARQL, SWS.
5	Standards or specifications of elearning	IMSLD, SCORM, IMSQTI, IEEE LOM.
6	Type of interface with users	LMS, Intelligent Tutoring System, Webbased systems, Adaptive Educational Hypermedia Systems
7	Management of educational resources	Learning Objects, LORs,
8	Type of compatibility with VLEs	SOA, Web services, SCORM
9	Type of knowledge in e-learning	Content, Instruction, User, System, Metadata, etc.
10	Method of application of ontology	Development, Building, Adaptability, sequence, Interoperability, Organization, Metadata & Annotation

The characteristic "*Type of compatibility with VLEs*" specifies a mechanism of integration, compatibility, and interoperability with traditional LMSs. "*Type of knowledge in e-learning*" refers to the aspect of knowledge of ID systems. Lastly, "*Method of application of ontology*" aims to describe a characteristic pattern of how the system utilizes the involved ontology.

A complete analysis was performed and all data were tabulated from each of the proposed aspects and organized, as shown in Table 2. It is clear that there are characteristics that are not considered in most of the analyzed studies.

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Table 2. Analysis of characteristics of instructional design models based on semantic web technologies

Paper reference	Role of involved individual	Architecture of ontologies included	Pedagogical approach employed	Semantic Web Technologies involved	Standards or specifications of e-learning used	Type of interface with users	Management of educational resources	Type of compatibility with VLEs	Type of knowledge in e-learning	Method of application of ontology
[42]	Learner, Instructor	Domain, Student, Task, Teaching strategy, Interface	Learning Styles	OWL, SWRL	SCORM	ITS	LO	Not specified	User, Instruction	Adaptively, Presentation
[43]	Learner, Instructor	Domain, Student	Not specified	OWL	IEEE LOM, IMS-LIP	ITS	LO	Not specified	User, Instruction	Adaptively, Presentation
[2]	Learner, Instructor, Author	Student, Pedagogical, Interface	Learning Theories	OWL, RDF, SPARQL	IMS-LD	LMS, ITS	LO	Not specified	Instruction	Organization, Sequencing
[44]	Developer	Domain	Not specified	OWL	Not specified	Wizard	Database	Through Ontology	Metadata	Interoperability
[45]	Learner, Instructor	Domain, Pedagogical, Student	Pedagogical strategies	Not specified	SCORM SN,	ITS	LO, LOR	Through SCORM	Metadata	Metadata Annotation
[46]	Instructor, Developer	Domain, Interface	Teaching template	XML, RDF	SCORM	Web based	LO, LOR	Not specified	Instruction	Organization, Sequencing
[13]	Learner, Instructor	Domain, Student, Pedagogical, Interface	Learning Styles	OWL,	SCORM	LMS	LO, LMS resources	Through SOA	User	Adaptively, Presentation
[47]	Learner, Developer	Domain, Student	Not specified	XML, RDF, RDFS	IEEE LOM, IMS LIP	Web based	LO	Not specified	Instruction	Organization, Sequencing
[48]	Learner, Instructor	Domain, Student	Not specified	XML, OWL, SWRL, RDQL	Not specified	Web based	LMS resources	Not specified	Content, Instruction, User	Creation Generation
[5]	Author, Instructor	Domain, Pedagogical	ID Theories	XML, OWL, SWRL	IMS-LD	Not specified	LO, LOR	Not specified	Content	Creation Generation
[49]	Author	Pedagogical	ID Theories	OWL, SWRL	IMS-LD	Not specified	LO	Not specified	Content	Creation Generation
[11]	Developer	Domain	Not specified	RDF	Not specified	Wizard	Database	Through Ontology	Metadata	Interoperability
[50]	Learner, Instructor	Domain	Not specified	XML, OWL	SCORM, IEEE LOM	Web based	LO, LOR	Through SCORM	Metadata	Metadata Annotation
[51]	Learner, Instructor, Author	Domain, Student, Pedagogical	Not specified	OWL	Not specified	Web based	LO	Not specified	Content, Instruction, User	Ontology development
[52]	Author	Domain, Student	Not specified	OWL, RDF, RDFS	Not specified	Not specified	Not specified	Not specified	Content, User	Ontology development
[53]	Author, Provider	Domain, Peda-gogical	Not specified	OWL, SWRL	Not specified	Web Based	LO, LOR	Not specified	Instruction	Organization, Sequencing
[41]	Learner, Developer, Author, Instructor	Domain, Student, Pedagogical, Interface	Pedagogical strategies	OWL, RDF, SWS	IEEE LOM, IMS-QTI	LMS, Web based	LO	Web services	Content, Instruction, User, System	Adaptively Presentation
[54]	Leaner, Instructor	Domain, Student, Pedagogical	Learning theories	Not specified	Not specified	Not specified	Not specified	Not specified	Content Instruction	Ontology development
[55]	Author, Developer	Domain, Pedagogical, Student	Pedagogical strategies	OWL, SWRL	SCORM, IMS-LD	ITS	Learning Knowledge Object	Through SCORM, IMS-LD	Content, Instruction, User	Ontology development
[56]	Author, Instructor	Pedagogical, Student	Not specified	OWL, RDF, SPARQL	SCORM	Web based	LO, LOR	Not specified	Metadata	Metadata Annotation
[57]	Author, Instructor	Domain, Pedagogical, Student	Designed by Instructor	XML, RDF	SCORM, IMS-LD	Desktop	LO, LOR	Through SCORM, IMS-LD	Content, Instruction, User	Ontology development

* Not specified: denotes that it was not applicable, not available, or was not specified

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The "*Pedagogical approach employed*", "*Standards or specifications of e-learning*" and "*Type of compatibility with VLEs*" characteristics have the most "*Not specified*" data. The reason could be that there are still very few ways to model learning theories and instructional designs and standards (i.e., IMS LD) by utilizing formal languages (e.g., ontology), in addition to the complexity of representing pedagogical approaches (e.g., IDT) in a manner that can be processed by computers. The lack of compatibility with VLEs confirms that many systems do not include this characteristic, undoubtedly because of the design principle that states that there should be no dependence on a VLE. However, some initiatives are beginning to emerge that support the creation of VLE-integrated frameworks or promote the idea of intelligent LMS.

Moreover, in some domains and learner ontologies, other characteristics prevail when analyzing the models of ontologies. Few studies reference Pedagogical, Interface, and Task Ontology models. Nevertheless, this interpretation may be somewhat incorrect because some studies consider pedagogical ontologies such as domain ontologies as knowledgespecific areas, i.e. learning processes, learners, and learning styles, among others. Regarding "*Semantic Web Technologies involved*", a strong tendency to use OWL and RDF is discerned. There were only a few studies that used SPARQL, which is not unusual because of the current preference to create and generate content using ontologies.

Regarding the "*Method of application of Ontologies*", a uniform development process in the different forms of application was found. However, some advancement was noted in ontology development, organization and sequencing, adaptability, and presentation. Less improvement was seen in metadata and annotation, packing, and interoperability.

RQ2: What are the main issues related to semantic web and instructional design researched in the education field?

The five aspects mentioned above, namely "*Building Ontologies*", "*Semantic content retrieval*", "*Architectures*", "*Metadata and Annotation*", and "*Intelligent e-learning systems*", were used to systematically review the identified research papers to determine the main issues related to the semantic web and instructional design. The results are shown in Figure 2. The highest frequency of issues was found under the topic of "*Building Ontologies*" (43%), followed by "*Semantic content retrieval*" (31%) and "*Architectures*" (24%). The

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areas with the lowest incidences of issues were "*Annotation Metadata*" (8%) and "*e-learning intelligent systems*" (14%). The high incidence of issues in *Building Ontologies* is likely because ID environments are currently using an established knowledge base to develop their teaching and learning methods.

The works were analyzed using a schema of ontologies to effectuate a process of extraction, analysis, and interpretation of the formalized information. This process is commonly used for "*Semantic content retrieval*". It is not unusual to use ontologies to represent, organize, integrate, share, and exchange elearning contents in VLEs.

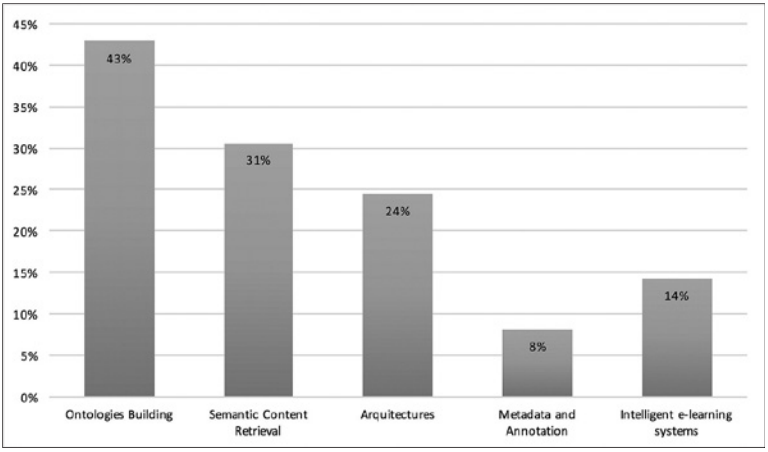

Figure 2. Main issues related to semantic web and instructional design in the education field.

Architectures have a moderate presence, especially in intelligent and adaptive elearning systems, VLEs, LMS, etc. The lower incidence of issues in "*Metadata and Annotation*" reflects the effort to standardize the sharing and re-use of educational resources. With regards to intelligent elearning systems, a gradual improvement can be noted.

RQ3: What types of contributions involving instructional design based on semantic web technologies are identified most frequently?

After examining the selected works, the types of contributions could be clearly discerned based on the analysis of semantic web technologies, how

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often SWTs were referenced, and which types referenced them most often, as shown in Table 3. It is wort mentioning that one type of contribution may correspond to more than one of the four categories that were defined previously: Tool, Method, Model, and Framework.

Contribution Type	Paper References	Frequency (# Papers)	Percentage
Tool	[42], [43], [2], [11], [45], [46], [13], [47], [48]	9	25%
Method	[44], [5], [2], [46], [49], [11]	6	17%
Model	[46], [50], [51], [52], [53], [41], [11], [5], [49]	9	25%
Framework	[54], [55], [44], [56], [57], [41], [5], [42], [45], [47], [13], [49]	12	33%

Table 3. Observation frequencies of different types of contribution in the papers

It is easy to observe that there is a higher incidence of research works that reference the creation of ID frameworks based on SWTs, compared to the other three categories. For example, works [13], [44], and [48] propose the establishment of LMS architectures that use either SWTs to either interpret or to integrate parts of the learning management platforms. Some studies discuss frameworks for formalizing learning objects using ontologies and SWTs [55]–[57]. Also evident was the use of frameworks to represent learning theories and ID methods using SWTs [5], [49], [54]. Tools and Methods utilize SWTs with the same frequency. A good example is [2], which proposes a tool for creating intelligent collaborative scenarios using SWTs.

There are also studies that suggest the development of Intelligent Tutoring Systems for the customization or recommendation of content for a course or curriculum using SWTs and ontologies [42], [43], [47]. Although works that develop methods for the integration of different e-learning systems [11], and the checking, creation and provision of educational designs [5], [49] are less common, they are of no lesser importance.

A bubble chart that assists in the visualization of the results has been created to show the frequency of references among the categories of the semantic web and instructional design, with the contribution rates described below, as shown in Figure 3. Most of the studies belong to the category of "*Building Ontologies*", and many of them are new frameworks, which indicates a strong inclination to develop models and frameworks using ontologies.

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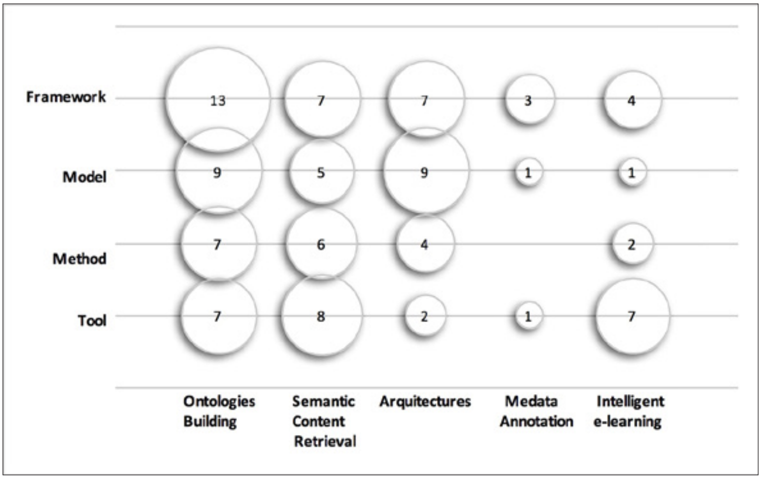

Figure 3. Number of papers by type of contribution and semantic web using instructional design.

In contrast, the category of "*Metadata and Annotation*" has very little impact on the different types of contributions. We can perceive a clear lack of maturity in instructional design methodologies; there is a need for further research and investigation in this area.

RQ4: What semantic web technologies based on authoring tools are available?

Five research papers were identified as providing responses to Research Question 4 (RQ4). Four elements of comparison were used to maintain a link with question RQ3. Four characteristics are proposed, which are derived from those discussed in the previous question. These characteristics are used to analyze the authoring tools that use SWTs, as shown in Table 4.

Table 4. Comparison of the authoring tools based on semantic web technologies

Authoring Tool	Usage of SWT	Aware of ID Theory	Standards LD or LO incorporated	Supports LMS
PROTUS [42]	Yes	No	No	No
INES [43]	Yes	No	Yes	No
CHOCOLATO [2]	Yes	Yes	No	No
TMDC [46]	Yes	No	Yes	No
PASER [47]	Yes	No	Yes	No

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The first element, "*Usage of SWT*", refers to authoring tools that include the use of an SWT such as OWL, RDF, SWRL, or SPARQL. The next element is "*Aware of ID theory*", which is comprised of the management of learning/instructional theories and has an ontologybased architecture. The element, "*Standards LO or LD incorporated*" indicates that some form of standardized outline or specification in the field of Learning Design and Learning Objectives was used. Finally, "*Supports LMS*" indicates that the system includes some mechanism of integration, compatibility, or interoperability with LMS.

One can observe in the analysis that there are very few tools to help users perform intelligent design based on an ontological structure. All such cited tools use either one or more semantic technologies. The use of OWL and RDF are examples of common denominators. Also evident is the inadequate support for pedagogy, i.e., systems are developed without the pedagogical knowledge that is commonly used in instructional design theories.

The authors may feel justified because they are considering a distinctive pedagogical approach that is independent of the design. However, due to the lack of pedagogical support, it is crucial that those designing learning systems prioritize it more highly when authoring tools that support teachers. With respect to the third component, it can be stated that three of the five tools considered the standards IEEE LOM, and SCORM, which are employed for describing learning resources. However, they do not incorporate other standards, such as IMS-LD, or specifications, such as LAMS LD, which are utilized for the same purpose. Finally, it is noteworthy that no tool uses LMS as a support mechanism, which results in a lack of compatibility with VLEs.

V. CONCLUSIONS

Semantic web technologies have had a positive impact in several areas of knowledge management. One of the most noticeable influences has been in the educational field. Many sub-areas have been identified, such as adaptive learning, learning objects, collaborative learning, instructional design, and authoring tools. In this research, we have tried to analyze the studies that have combined the use of ID with SWTs. The review followed a systematic process, which allowed for a more openminded analysis from an integrated perspective.

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According to the results of the SLR, there is more growth in the number of research works related to the construction and use of ontologies and semantic technologies within the context of instructional design, compared to research works related to models, frameworks, tools, and standards in the context of ID. Thus, it can be confirmed that the trends are similar on a global scale to the trends in educational systems related to using semantic web technologies. Most of the analyzed studies showed little interest in representing certain aspects of instructional design using semantic web technologies. We are referring specifically to those works that did not consider the pedagogical approach, the standards or specifications of instructional design, and compatibility with virtual learning environments. We believe this could be due to the complexity of representing these aspects through ontologies and semantic web technologies. It is suggested that the systems should incorporate characteristics of semantic web technologies in virtual learning environments.

Another aspect to consider is the strong tendency to use OWL as a key technology for instructional design systems. This tendency is implied by constant levels of ontological deployment and development, especially in the domain models. The lack of representation in educational models, however, remains. Other technologies such as SPARQL and SWRL are applied to a lesser extent, which corroborates that the generation, integration, sequencing and annotation of semantic instructional design studies are still maturing.

In relation to the use of authoring tools for instructional design based on semantic web technologies, we can confirm that there are very few intelligent educational/tutoring systems to support the instructional design process. Additionally, it was observed that there are no widely disseminated systems that are compatible with VLEs. Therefore, there is a clear need for approaches that consider the use of VLEs when applying semantic web technologies. This could provide a great assistance in supporting instructional design and content management. With all this in mind, we must consider the usefulness of incorporating characteristics of SWTs within a traditional LMS, either intrinsically or extrinsically, to create intelligent educational systems within a framework that includes LMS.

There are other benefits that are not directly perceived, but that contribute to the teaching and learning process. For example, all the pedagogical approaches, standards, and specifications which we suggest should be integrated

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into the semantic web technologies, could be developed in unique intelligent settings so that students would acquire a more intelligent user experience. This would allow them to cope with virtual learning environments more quickly, practically and intuitively.

Based on this research, many opportunities arise. For example, the combination of ID with SWTs could be applied to more specific aspects of educational design. Models, frameworks, systems and VLEs could be proposed to integrate more of the suggested approaches and certain characteristics such as standards or LD specifications, educational guidelines, authoring tools, and semantic web environments. This could result in improvements in education systems.

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