Smart Learning Environments

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Accessibility within open educational resources and practices for disabled learners: a systematic literature review

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Abstract

The number of disabled students is rapidly increasing worldwide, but many schools and universities have failed to keep up with their learning needs. Consequently, large numbers of disabled students are dropping out of school or university. Open Educational Resources (OER) and Open Educational Practices (OEP) contain several relevant features, including the possibility of reusing and remixing, which have led researchers to consider using OER and OEP to facilitate meeting the needs of disabled and functional-diverse students in order to increase their accessibility and e-inclusion capabilities in educational settings. The very limited research to date, however, has provided a limited holistic understanding of accessibility within OER and OEP in order to aid researchers in pursuing future directions in this field. Therefore, this paper systematically reviewed 31 papers to provide insights about functional diversity within OER and OEP. The results obtained highlighted that accessibility is still in its infancy within OER and that researchers should focus more on considering the four accessibility principles — perceivable, operable, understandable and robust — when providing OER. Additionally, while several researchers have focused on several issues related to accessibility within OER, limited focus has been given to assistive technologies using OER. Finally, this paper provides several recommendations to increase accessibility within OER and help design more accessible OER for students with functional diversity.

Keywords: Open educational resources, Open educational practices, Accessibility, Inclusion, Disability

Education is a key issue of the 2030 Agenda for Sustainable Development, being both directly connected to the 17 goals of the agenda and at the core of Sustainable Development Goal 4 (SDG4), which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (United Nations, 2015). One target of SDG4 is equity, which is defined by its goal to, 'by 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations' (United Nations, 2015, p. 17).

Open Educational Resources (OER), defined as 'teaching, learning and research materials in any medium that may be composed of copyrightable materials released under an open license, materials not protected by copyright, materials for which copyright protection has expired, or a combination of the foregoing' (UNESCO, forthcoming), have the potential to contribute to reaching this objective by increasing access to learning as well as improving the quality of the learning experience (Ehlers, 2011). The OER movement is based on the idea that educational resources (e.g., content or course designs) should be released under licenses that allow anyone to freely access, retain (e.g., download, duplicate, store), reuse, revise (e.g., translate, adapt, modify), combine and-or re-share them (Tlili, Huang, Chang, Nascimbeni & Burgos, 2019). The use of OER for teaching in an innovative and collaborative environment is referred to as Open Educational Practices (OEP). Ehlers (2011), p. 4 defined OEP as 'practices which support the (re)use and production of Open Educational Resources through institutional policies, promote innovative pedagogical models, and respect and empower learners as co-producers on their lifelong learning paths'. Research is coalescing around the fact that these practices can help enhance learning quality, access and effectiveness in universities (Weller, 2014).

Despite the growing number of OER (Hoosen & Butcher, 2019) and the policy attention devoted to OER accessibility, as demonstrated by the presence of guidelines to increase the accessibility of OER within the Ljubljana OER Action Plan (UNESCO, 2017), the extent to which OER are actually accessible is currently being questioned. Accessibility refers to the use of a product, service, framework or resource in an efficient, effective and satisfying way by people with different abilities (ISO 9241-171, 2008). Functional diversity is a key issue in the development of any online resource, including OER, since it is potentially focused on almost every single user. The approach has moved from handicapped users (essentially, those with motor, cognitive or sensorial impairments) through accessibility (improving specific issues to facilitate a better user experience) to functional diversity and e-inclusion (of any feature of any user who requires additional support, like the ones associated with elderly or those on sick leave) (Iniesto, Covadonga, & Moreira Teixeira, 2014; Sanchez-Gordon & Luján-Mora, 2013; Tekleab, Karaca, Quigley, & Tsang, 2016).

The present paper aims to provide a holistic and systematic review of the literature in the field of the accessibility and functional diversity of OER and OEP, as a valuable guide for better designing open educational ecosystems that support inclusive learning, improving the potential effect of OER on twenty-first century teaching and learning for learners with different needs. This is particularly urgent since recent data estimates that 15% of world population — more than a billion people — live with some form of disability (World Health Organization and World Bank, 2011). The structure of the paper is as follows. Section 2 presents the background of the research, section 3 details the research method, section 4 presents and discusses the obtained results, and section 5 concludes the paper with a summary of the findings, limitations and potential future directions.

Background

According to the World Health Organization, disability cover[s] impairments, activity limitations, and participation restrictions. An impairment is a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in

executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. (World Health Organization, 2015).

The Office for Civil Rights (OCR) of the U.S. Department of Education defines 'accessible' as meaning that a person with a disability is afforded the opportunity to acquire the same information, engage in the same interactions, and enjoy the same services as a person without a disability in an equally effective and equally integrated manner, with substantially equivalent ease of use.

In educational contexts, accessibility for disabled students means that, in order for all to have equitable learning experiences, the learning experience, including its learning content and teaching process, should be adjusted according to students' needs, including their disabilities. While people with disabilities have the same educational needs as others, they are less likely to attend schools and graduate, and consequently may face difficulties in finding jobs in future (Ingram, 1971; Iwarsson & Ståhl, 2003; World Health Organization and World Bank, 2011). Various international policies, including the United Nations 2030 Agenda for Sustainable Development (United Nations, 2015) and the UNESCO Education for All initiative (UNESCO, 1990), have highlighted the importance of providing fair learning experiences for all students regardless of their differences. Still, a great proportion of schools and universities fail to properly address equitable access, especially with regard to disabled students (Catlin & Blamires, 2019), partly due to the lack of effective teaching methods and content targeted to these student categories (Virnes, 2008).

In the area of web accessibility, several standards released by the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3) can be applied to OER. Among these standards, WCAG 2.0 has been widely accepted and adopted (W3C., 2012) and is based on four attributes that lay the necessary foundations for anyone to access and use websites, as shown in Table 1. Based on these four attributes, 12 guidelines and 61 success criteria are provided, categorised into three levels of conformance: AAA (highest), AA or A (lowest) (Crespo, Espada, & Burgos, 2016; W3, 2008).

Table 1 shows that OER can increase the accessibility of web-based education in many ways. This potential is mainly connected to the inner OER features of re-using, remixing and redistributing learning content that can help adapt existing materials to disabled students without having to develop resources from scratch. OER can serve the needs of those with diverse abilities for a number of complementary reasons:

- Permissions granted by an open license remove legal barriers to adapting and customising OER, making it possible to create learning environments that are more flexible and robust for all students.
- OER offer the opportunity for instructors to curate materials authored by a diverse set of individuals, including those who identify as disabled, normalising and reducing stigma while sharing viewpoints that have historically been marginalised.
- Unlike commercially published materials, OER that are adapted to meet accessibility requirements can be retained and freely shared with communities, reducing duplicative work at and across institutions.
- OER adoption can reduce costs, which benefits all students but can be especially beneficial for students with disabilities who may face additional financial pressures.

Table 1 Description of the WCAG 2.0 Attribute and Guidelines applied to OER

Attribute	Attribute Description	Guidelines	Guidelines Description
Perceivable	The content and interfaces of OER can be perceived by users.	Text Alternatives	Provide a variety of forms that people need for non-textual content, such as large print, Braille, and so on.
		Time-based Media	Provide access to time-based media.
		Adaptable	Ensure that all OER are available in some way to all users.
		Distinguishable	Make the default presentation easy to perceive by people with disabilities.
Operable	OER, including the content and interface, must be operable for users.	Keyboard Accessible	Make all functionalities achievable by using the keyboard.
		Enough Time	Provide enough time for users to use OER.
		Seizures	Do not design OER in a way that might trigger seizures.
		Navigable	Support navigation and retrieval functions.
Understandable	OER, including the content and interface, must be understandable by users.	Readable	Make OER text readable and understandable.
		Predictable	Make OER contents display and operate predictably.
		Input Assistance	Provide more assistance to avoid and correct mistakes.
Robust	OER must be robust enough that it can be accessed by a variety of types of user agents, including assistive technologies.	Compatible	Increase compatibility with the current and future user agents, especially assistive technologies: i.e., screen reader or Braille display devices.

- It is more common for OER to be shared in formats that can be adapted for accessibility, unlike proprietary publisher content, from whom editable files are notably difficult to obtain (Thomas, 2018).

Hejer, Khribi, and Jemni (2017) mentioned that despite the fact that the OER paradigm can facilitate inclusive learning by reusing the open resources in a way which caters to the needs of disabled students, limited work has been done to achieve this purpose. Similarly, Iniesto, McAndrew, Minocha, and Coughlan (2017) stated that few Massive Open Online Courses (MOOCs) are fully accessible for disabled students. Undeniably, not enough research is being conducted to support inclusive and equitable learning using OER (Navarrete, Peñafiel, Tenemaza, & Luján-Mora, 2019). Specifically, to our knowledge, only one conference paper has conducted a systematic literature review to investigate the actual accessibility of OER for disabled learners (Moreno, Caro, & Cabedo, 2018), providing only information about the trends of OER and accessibility without summarising and discussing findings related to accessible learning within OER and OEP. In addition, while several literature reviews have been conducted to better understand the use of OER for the general student population, no literature review has focused on investigating the work done on the accessibility of OER and OEP. To fill this gap, this paper presents a systematic literature review to understand how the application of OER and OEP can increase learning accessibility.

Methodology

A rigorous literature review is an important step that builds the foundation for knowledge accumulation, which in turn facilitates the expansions and improvements of theories, closes existing gaps in research and uncovers areas previous research has missed (Marangunić & Granić, 2015). This study presents a systematic review based on published papers related to OER and OEP for learning accessibility, with particular reference to disabled students. It follows the steps reported by Okoli and Schabram (2010) as described in the next subsequent sections.

Investigated research questions

To gain insight into the use of OER and OEP for accessible learning, a systematic review is needed. Specifically, this study attempts to answer the following research questions:

RQ1. What are the trends in publications on learning accessibility using OER and OEP in terms of time series, country and keyword distribution?
RQ2. What kinds of disabilities and issues were investigated in the identified papers?
RQ3. Which assessment methodologies were used in the identified papers?

Search strategy and inclusion/exclusion criteria

To answer the above research questions, several keywords were adopted as follows: accessib* AND Open AND Educational Resource*, accessib* AND OER, accessib* AND Open Educational Resource, accessib* AND OEP, accessib* AND Open Pedagogy, accessib* AND Open teaching, accessib* AND Open assessment, accessib* AND Open educational Practices, Inclusive learning AND Open educational resource, Inclusive learning AND OER. The search was conducted in several databases, including ScienceDirect, Wiley Online Library, IEEE Xplore Digital Library, Core Collections of Web of Science and Taylor & Francis Online. ResearchGate, a network for researchers to share, discover and discuss research, was also used to retrieve the related papers. The obtained papers were then filtered based on specific inclusion/exclusion criteria. Specifically, we excluded papers that: (1) were not in English; (2) did not discuss openness using OER and OEP for learning accessibility; (3) did not focus on disabled students; or (4) did not have available full-text online. A total of thirty-one papers were finally included during the review process. Figure 1 presents the selection procedure of papers during this review process.

Data extraction and analysis

Each study was then reviewed and examined based on seven items, as presented in Table 2. These items provide information to answer the above research questions and conduct the synthesis. Finally, a qualitative synthesis was conducted to answer the research questions.

Results and discussion

Trends in publications on learning accessibility using OER and OEP

Distribution by year

As shown in Fig. 2, Caruso and Ferlino (2009) published the first paper on OER and inclusive learning in 2009, which reported that, for disabled people, the number of available open software programmes was less than the number of non-open software

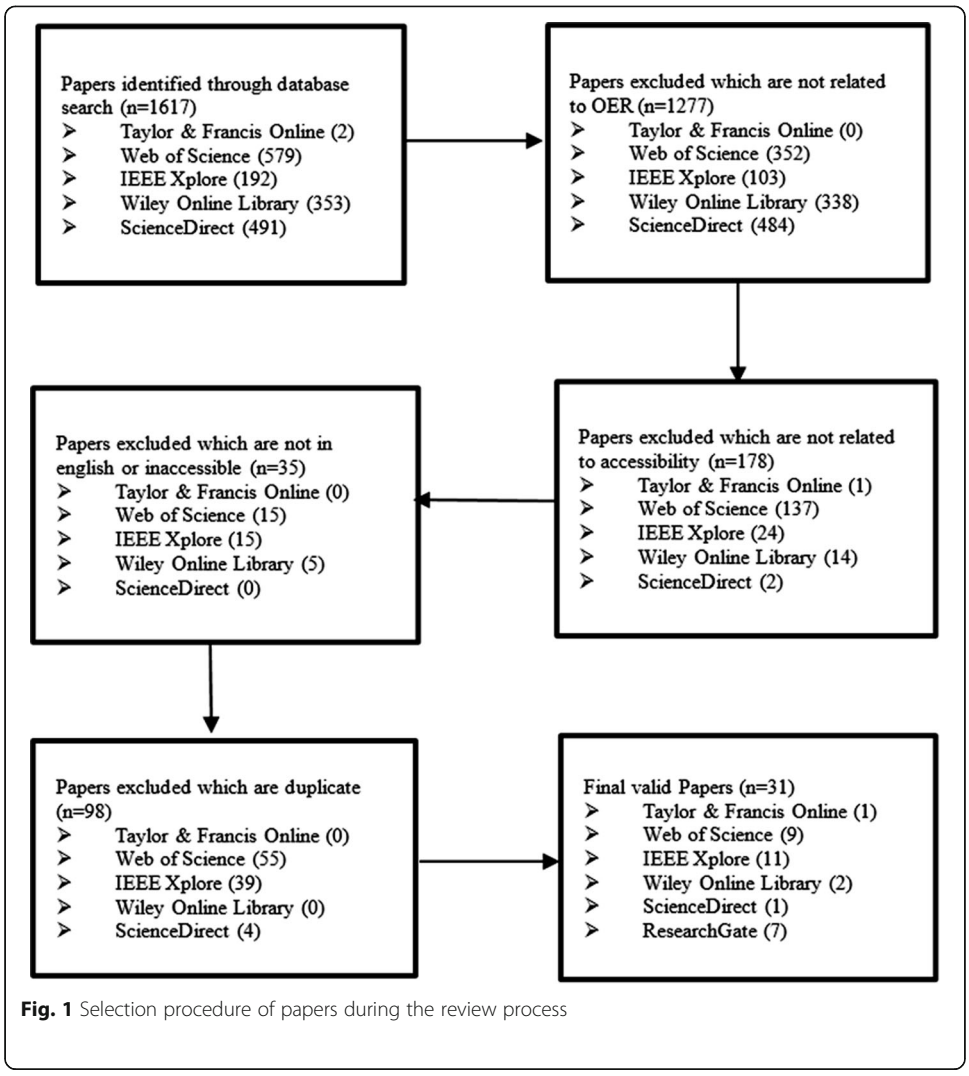

Fig. 1 Selection procedure of papers during the review process

programmes. In particular, the authors focused on open software because by nature it can be modified and adapted to different needs, fulfilling more accessibility requirements than proprietary software (Klironomos, Antona, Basdekis, & Stephanidis, 2006). Since then, experts have realised the importance and necessity of research on the topic of accessibility and open education, intended here as education based on OER and OEP. Specifically, as shown in Fig. 2, the interest in open education for disabled students has increased since 2014; the number of related papers published in 2014, 2015 and 2016

Table 2 Coding scheme during the literature review process

Item	Description
Authors	Author(s) information, including affiliation and country
Year	Publication year
Disability type	Type(s) of disability discussed in each paper
Issues	Issue(s) discussed in each paper: e.g., metadata or system design
Evaluation Methods	Methods applied to evaluate the accessibility of OER and OEP
Evaluation results	Evaluation results obtained while using OER and OEP
Challenges	Challenges that might impede the accessibility of OER and OEP

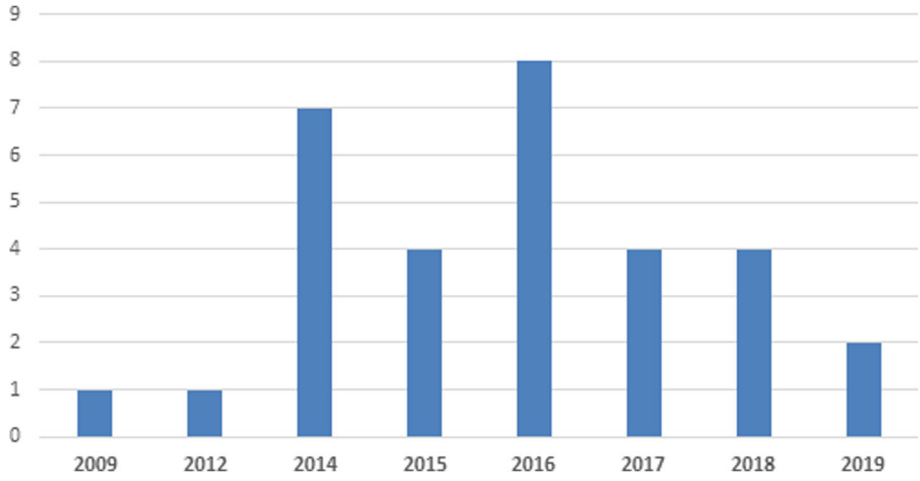

Fig. 2 Distribution of papers by year of publication

accounted for more than 60% of all the production of the last decade. Additionally, the year 2016 saw a peak in interest in this area, probably connected with the fact that the UN 2030 Agenda for Sustainable Development was launched in 2015, providing an impetus for research in the areas of accessibility and inclusion.

Distribution by country

The distribution of the first author's countries is presented in Fig. 3, showing that authors from only nine countries have led research about OER and OEP for accessible learning. This shows that the use of OER and OEP for inclusive learning is still in its infancy and that more awareness should be raised to encourage further investigation in this field. In particular, authors from Ecuador had 11 papers related to this topic,

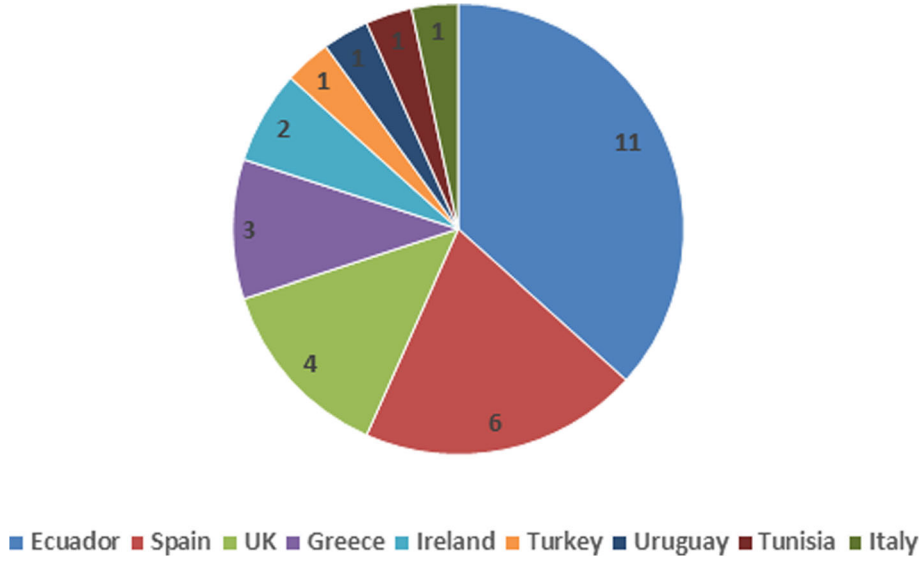

Fig. 3 Distribution of papers by country

accounting for more than one third of all papers, followed by Spain, with six papers. Ecuador is indeed considered as a leading country in the field of disability support, since the government proposed in 2007 several policies to address the needs, including educational needs, of disabled persons. Spain has long attached great importance to inclusive education; as early as 1982, Spain passed legislation to integrate disabled youth in schools. In 1985 the decree on special education moved many disabled children from special schools to mainstream schools. In 1994, the United Nations World Conference on Special Needs Education was held in Spain, where the fundamental principle of inclusion at school was declared and widely endorsed. Interestingly, four out of the nine countries present at that conference (Ireland, Italy, Spain and the UK) have adopted the Web Content Accessibility Guidelines 2.0 (WCAG 2.0) noted earlier (W3, 2017).

Distribution by keyword

Finally, the keyword distribution of the 31 research papers in the systematic review was analysed in order to understand the use of OER and OEP for accessible learning more deeply. Keywords with similar meanings, such as 'OER' and 'Open Educational Resources' or 'Learning object' and 'LO', were normalised. The final distribution of the keywords is presented in Fig. 4. It can be seen that accessibility, OER and disability are the most commonly used keywords in the 31 papers reviewed. In particular, disability and accessibility focus on the category of students on which these research papers focus, while OER focus on the category of education that can contribute to improving the accessibility of earning opportunities. Importantly, we discovered that the term Open Educational Practices (OEP), as well as sub-terms, such as open pedagogy, open teaching and open assessment, have not yet been discussed in the literature when it comes to accessible learning. Therefore, in the subsequent analysis we will focus only on accessibility and OER.

Disabilities and issues investigated

As shown in Table 3, when investigating the use of OER, researchers focused on several disabilities, including visual disabilities, hearing disabilities, motor disabilities, speech disabilities, cognitive disabilities and aging-connected disabilities. Researchers paid almost

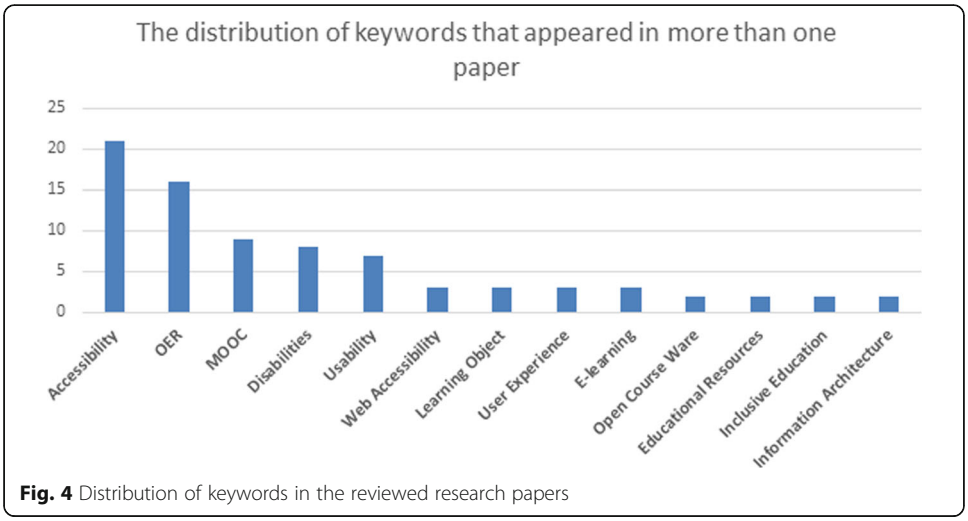

Fig. 4 Distribution of keywords in the reviewed research papers

Table 3 Distribution of papers according to disability type

Disability type	Number of papers	Authors
Visual disabilities	7	Caruso & Ferlino, 2009; Iniesto et al., 2014; Iniesto & Rodrigo, 2014; Navarrete & Luján-Mora, 2018; Sanchez-Gordon & Luján-Mora, 2016; Navarrete, Luján-Mora, & Peñafiel, 2016; Navarrete et al., 2019
Hearing disabilities	7	Caruso & Ferlino, 2009; Kourbetis & Boukouras, 2014; Kourbetis, Boukouras, & Gelastopoulou, 2016; Navarrete et al., 2016; Navarrete & Luján-Mora, 2015a; Navarrete et al., 2019; Sanchez-Gordon & Luján-Mora, 2016;
Motor disabilities	6	Caruso & Ferlino, 2009; Iniesto & Rodrigo, 2014; Navarrete & Luján-Mora, 2018; Sanchez-Gordon & Luján-Mora, 2016; Navarrete et al., 2016; Navarrete et al., 2019
Speech disabilities	1	Iniesto et al., 2014; Iniesto & Rodrigo, 2014; Navarrete & Luján-Mora, 2018
Cognitive disabilities	6	Navarrete & Luján-Mora, 2018; Navarrete et al., 2016; Navarrete et al., 2019; Sanchez-Gordon & Luján-Mora, 2016
Age-related disabilities	2	Iniesto et al., 2014; Iniesto & Rodrigo, 2014
Unspecified disabilities	21	Avila Garzon, 2018; Avila Garzon, Baldiris, Fabregat, & Graf, 2016; Coughlan, Rodríguez-Ascaso, Iniesto, & Jelfs, 2016; Hejer et al., 2017; Iniesto & Covadonga, 2018; Iniesto et al., 2017; Iniesto, McAndrew, Minocha, & Coughlan, 2019; Iglesias, Moreno, & Martínez, 2014; Iniesto & Rodrigo, 2016; Morales and Benedi, 2017; Moreno et al., 2018; Mulwa, Fitzpatrick, Trapp, & Moebs, 2016; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2015c; Navarrete & Luján-Mora, 2014; Politis et al., 2014; Rodriguez, Pérez, & Rommel Torres Tandazo, 2017; Rosa & Motz, 2016; Sanchez-Gordon & Luján-Mora, 2015; Yalcinalp & Emiroglu, 2012; Zervas, Kardaras, & Sampson, 2014

equal attention to different types of disability, including seven studies on visual disabilities and hearing disabilities, respectively, and six papers on motor disabilities and cognitive disabilities. It is obvious that aging also imposes certain limitations on the ability of humans, so researchers have also considered it. It should be noted that some papers discussed more than one disability. For instance, Zervas et al. (2014) developed an online teaching and learning portal for students with visual and/or hearing disabilities.

The use of OER to address the above disabilities was discussed from five different angles: system design, personalisation, metadata, authoring tools and OER accessibility framework/architecture. As shown in Table 4, most authors focused on system design to increase accessibility and usability for students with disabilities. For instance, Ngubane-Mokiwa (2016) conducted a literature review and identified several guidelines to facilitate MOOC access for visually impaired students. These guidelines are from three different perspectives: (1) multiple means of representation, which focuses on the strategies to make MOOCs accessible; (2) multiple means of action and expression, which focuses on the strategies that facilitates user actions on MOOCs; and, (3) multiple means of engagement, which focuses on strategies to provide accessible interaction within MOOCs.

Several researchers also analysed personalised learning experiences based on the 'type of disability' or 'user profile' as a personalisation parameter. For instance, Zervas et al. (2014) designed an OER-based educational portal to facilitate learning and teaching for students with different disabilities, including those with visually impairments. Similarly, Navarrete and Luján-Mora (2018) developed an OER website that takes into consideration the disability of students, including visual and hearing disabilities, as a personalisation parameter. This 'disability-personalisation' path is extremely relevant, as recognised by the National Academy of Engineering, which mentioned that personalised learning is one of the fourteen most important challenges of the twenty-first xentury (Tlili, et al., 2019).

Table 4 Issues investigated during the use of open educational resources and practices for accessible learning

Issue	Number of papers	Authors
Personalisation	6	Hejer et al., 2017; Navarrete & Luján-Mora, 2018; Navarrete et al., 2016; Navarrete & Luján-Mora, 2015a; Iniesto & Rodrigo, 2016; Navarrete et al., 2019
Metadata	5	Iniesto & Rodrigo, 2016; Navarrete & Luján-Mora, 2018; Navarrete & Luján-Mora, 2014; Navarrete et al., 2019; Zervas et al., 2014
System design	12	Avila Garzon et al., 2016; Hejer et al., 2017; Iglesias et al., 2014; Iniesto & Rodrigo, 2016; Iniesto and Rodrigo, 2018; Kourbetis & Boukouras, 2014; Mulwa et al., 2016; Navarrete & Luján-Mora, 2018; Navarrete et al., 2016; Navarrete & Luján-Mora, 2015a; Navarrete et al., 2019; Zervas et al., 2014
Authoring tools	2	Mulwa et al., 2016; Zervas et al., 2014
Framework/ Architecture	12	Avila Garzon et al., 2016; Avila Garzon, 2018; Iniesto and Rodrigo, 2018; Morales and Benedi, 2017; Navarrete & Luján-Mora, 2018; Navarrete et al., 2016; Navarrete & Luján-Mora, 2014; Navarrete et al., 2019; Rodriguez et al., 2017; Sanchez-Gordon & Luján-Mora, 2015; Sanchez-Gordon & Luján-Mora, 2016; Zervas et al., 2014

Other researchers focused on discussing metadata, defined and machine-processable data that describe resources, either digital or nondigital (Haslhofer & Klas, 2010), in inclusive learning using OER and OEP. An accurate metadata set can enhance the retrieval of educational resources and provide a friendly navigation experience. For instance, in order to better describe and identify resources, Navarrete and Luján-Mora (2018) applied a subset of descriptors from the Learning Object Metadata (LOM) standards. Similarly, Navarrete and Luján-Mora (2014) applied other metadata standards, including DCMI (Dublin Core Metadata initiative) and AfA (Access for All). Some researchers have put forward innovative frameworks to improve the accessibility of OER. Rodriguez et al. (2017) argued that the development of a framework for improving web accessibility should be based on existing standards, such as WCAG 2.0, and proposed a framework for enhancing the accessibility and usability of open courseware sites. Innovative architectures are also presented by Sanchez-Gordon and Luján-Mora (2016) as ways to improve the accessibility of MOOCs and OER.

Finally, some researchers have focused on developing authoring tools for accessible OER. For instance, Mulwa et al. (2016) developed an OER authoring tool to facilitate the creation of OER for students with visual disabilities by selecting the navigation methods and text sizes. As shown in Table 4, only two papers focused on authoring tools to develop accessible OER. This might explain the limited number of fully accessible OER. Therefore, more focus should be put on developing tools that can help educators create and publish OER for disabled students. Additionally, no reviewed paper discussed the accessibility of OER from the assistive technology perspective. Given that different assistive technologies for disabled persons exist within different Operating Systems (OS), OER designers should try to make their resources compatible with as many assistive technologies and OS as possible in order to ensure high accessibility.

Assessment methodologies used

Based on the review of the 31 identified studies, 16 papers conducted assessments to evaluate the accessibility of OER, while the 15 remaining papers did not conduct any assessment. Specifically, to assess the accessibility of OER, three different methods were

used, as shown in Table 5: automatic tools, simulator tools and manual assessment. In particular, automatic tools were based on different software, such as AChecker (Avila Garzon, 2018; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2015c; Navarrete & Luján-Mora, 2018; Rodriguez et al., 2017) and eXaminator (Iniesto et al., 2014; Iniesto & Rodrigo, 2014; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2015c; Navarrete & Luján-Mora, 2018; Rosa & Motz, 2016). Disability simulators, on the other hand, are used to simulate the requirements of a disabled person (Iniesto et al., 2014; Iniesto & Rodrigo, 2014; Navarrete & Luján-Mora, 2015a), enabling the system to better understand the problems and requirements of people with impairments. For instance, the simulator named

Table 5 Accessibility evaluation methods

Accessibility Evaluation Methods	Specific Methods/Tools	Authors
Using automatic tools method	eXaminator	Iniesto & Rodrigo, 2014; Iniesto et al., 2014; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2018; Navarrete & Luján-Mora, 2015c; Rosa & Motz, 2016
	TAW	; IGLESIAS et al., 2014; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Rodriguez et al., 2017; Navarrete & Luján-Mora, 2018; Navarrete & Luján-Mora, 2015c; Rosa & Motz, 2016
	WAVE	Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2018; Navarrete & Luján-Mora, 2015c
	AChecker	Avila Garzon, 2018; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2018; Navarrete & Luján-Mora, 2015c; Rodriguez et al., 2017
	W3 Validation Service	Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2015b; Navarrete & Luján-Mora, 2014; Navarrete & Luján-Mora, 2015cRosa & Motz, 2016;
	Hera	Iglesias et al., 2014
	SortSite	Iniesto & Rodrigo, 2014
	Tanaguru	Rosa & Motz, 2016
Using simulator tools method	aDesigner	Iniesto & Rodrigo, 2014; Iniesto et al., 2014
	Spectrum	Navarrete & Luján-Mora, 2015a
	NoCoffee	Navarrete & Luján-Mora, 2015a
Using manual evaluation method	Questionnaires	Avila Garzon et al., 2016; Avila Garzon, 2018; Caruso & Ferlino, 2009; Mulwa et al., 2016; Navarrete & Luján-Mora, 2015a; Navarrete et al., 2019; Navarrete & Luján-Mora, 2018; Rodriguez et al., 2017; Sanchez-Gordon & Luján-Mora, 2016
No assessment	N/A	Coughlan et al., 2016; Hejer et al., 2017; Iniesto and Rodrigo, 2018; Iniesto & Rodrigo, 2016; Iniesto et al., 2017; Iniesto et al., 2019; Kourbetis & Boukouras, 2014; Kourbetis et al., 2016; Morales and Benedi, 2017; Moreno et al., 2018; Navarrete et al., 2016; Politis et al., 2014; Sanchez-Gordon & Luján-Mora, 2015; Yalcinalp & Emiroglu, 2012; Zervas et al., 2014

aDesigner, used by Iniesto and Rodrigo (2014) and Iniesto et al. (2014), aimed to simulate the use by people with visual disabilities in order to help the designer assess the extent to which a given content is accessible to users with that particular disability. Finally, manual assessment is mostly based on users' questionnaires (Avila Garzon, 2018; Avila Garzon et al., 2016; Caruso & Ferlino, 2009; Mulwa et al., 2016; Navarrete et al., 2019; Navarrete & Luján-Mora, 2015a; Navarrete & Luján-Mora, 2018; Rodriguez et al., 2017; Sanchez-Gordon & Luján-Mora, 2016). In these cases, the purpose of the questionnaire is to obtain a qualitative analysis to appreciate the users' experience of the process of using a given OER (Navarrete et al., 2019), based on questions like 'Is it easy to learn how to use the website?' or 'Can the user resolve the tasks on the website without unnecessary effort?' (Navarrete & Luján-Mora, 2018). Several researchers, however, claimed that using questionnaires may not be motivating for learners, since they are typically too long. Additionally, learners may not fully reveal their experiences and may try to respond optimistically when they feel that they are being assessed by others (Okada & Oltmanns, 2009). To counterbalance these attitudes, given the rapid growth of technology and the era of big data and learning analytics, researchers should focus more on using the data generated by learners to obtain insights about the accessibility of OER-based learning processes. If we consider that the accessibility of OER and OEP should aim at enabling all users, including disabled ones, having equitable learning opportunities, this focus on technical accessibility suggests that the research on OER and OEP for disabled learners is still in its infancy, since most researchers have focused on a rather superficial analysis that does not rely on rich datasets. Therefore, further research should be conducted to investigate how OER and OEP facilitate the deployment of accessible and inclusive learning from a more holistic perspective.

WCAG 2.0 provides guidelines on how to make web content more accessible to people with disabilities and four principles to lay the foundation of Web accessibility (W3, 2008). Table 6 presents the results of the review along with the four accessibility attributes presented in the Background section: perceivable, operable, understandable and robust. It appears that the majority of researchers discussed accessibility as one concept without considering specific accessibility attributes. Table 6 shows that the general OER accessibility level could be improved: among the 16 papers which reported accessibility assessment results, 15 generally agreed that there was much room for improvement in the accessibility of OER, especially for disabled users. For instance, the accessibility evaluation results by Iniesto and Rodrigo (2014) show a low degree of compliance of the analysed OER with the WCAG 2.0 accessibility guidelines. Navarrete et al. (2019) also conclude that neither the OER website interface nor the educational resources are fully accessible.

If we analyse the accessibility attributes individually, Rodriguez and Pérez (2017) stated that more errors are found under the attributes 'robust' and 'perceivable', which account for 50% and 31.81%, respectively, of the errors made when using the automatic tool TAW. On the other hand, for the attributes 'operable' and 'understandable', the percentage of errors is 20% and 17.64%, respectively. After accessibility evaluation with TAW of four OER platforms, including MERLOT, OCW UPM, OER COMMONS and OLI, similar results were reported in Navarrete and Luján-Mora (2015c), which showed that the greatest number of warnings are annotated under the attributes 'robust' and 'perceivable', while all of these warnings may be related to some issues that need to be

Table 6 Accessibility assessment results

Papers	Accessibility attributes			
	Perceivable	Operable	Understandable	Robust
Caruso & Ferlino, 2009	Open software programmes complied with most requirements related to perceivable, such as 'meaning of graphic symbols', 'presence of visual or textural equivalents with sound items' and 'accessibility of documents'.	'Flashinglight features' and 'recognition and operation within focus', which are related to 'operable', are complemented by open software.	Few open software programmes complied with 'reading of interface objects by the assistive technologies'.	About two-thirds of the open software was compatible with the operative system's accessibility features.
Iniesto & Rodrigo, 2014	None of the three MOOC platforms, including UNED COMA, COLMENIA and Miriada X, included alternative text for audio content, and none supported images with text alternatives.	UNED COMA and COLMENIA provided no navigation function .	Link errors, which are related to the 'understandable' attribute', exist on the three platforms, meaning that the same content on the three platforms leads to different pages.	Not mentioned.
Rodriguez et al., 2017	31.81% of errors were associated with the 'perceivable' attribute.	20% of errors were associated with the 'operable' attribute.	17.64% of errors were associated with the 'understandable' attribute.	50% of errors were associated with the 'robust' attribute.
Navarrete & Luján-Mora, 2015a	Images had alternative text.	Neither OER Commons and MERLOT offered retrieval function through their interface for disabled students.	Users employ 43% of the assistive technology for enlarging text size (setting button), 14% of screen readers and 7% of screen magnifiers.	Not mentioned.
Navarrete & Luján-Mora, 2015b	Based on the accessibility evaluation results obtained using TAW, eXamination, AChecker and Validator on three OER websites — namely MERLOT, OER COMMONS and OCW UPM — MERLOT achieved the highest score, followed by OER COMMONS. It was also found, however, that the MERLOT website had accessibility limitations on its home page for the person with blindness or limited mobility.			
Navarrete & Luján-Mora, 2014	OER Websites — including MERLOT II, ARIADNE, OLI Carnegie Mellon and TILE (The Inclusive Learning Exchange) — had some accessibility barriers which affected disabled persons' access to learning objects.			
Iniesto et al., 2014	After evaluation of accessibility while surfing and the textual alternative functions for images were supported by MERLOT, OER COMMONS and OCW UPM.	The lowest results on OER platforms, which affected the usage of OER, were related to navigation.	Some negative results were also reported, including the fact that font size cannot be changed and that 'title' elements are missing.	Not mentioned.
Navarrete & Luján-Mora,	Among seven OER websites (OER Commons, MERLOT, MIT OCW, OLI, AIRADNE, OpenStax, OERfAll), only one (OERfAll) provided adaptive	Among seven OER websites, only one (OERfAll) provided accessibility options for the search function.	Disability profile and more semantic functions need to be improved to better comply with the understandable attributes.	Not mentioned.

Table 6 Accessibility assessment results *(Continued)*

Papers	Accessibility attributes			
	Perceivable	Operable	Understandable	Robust
2018	interface functions.			
Avila Garzon, 2018	After accessibility evaluation, the OER was 80.8% accessible in the 'perceivable' attributes.	The evaluation result showed that OER was 85.1% accessible in the 'operable' attribute.	The result showed that OER was 61.5% accessible in the 'understandable' attribute.	Not mentioned.
Navarrete et al., 2019	Most of the OER supported text alternative and adaptive display transformability function.	The access mode was also variable depending on the different types of disability. However, full keyboard accessible is only provided for motor skills disability.	Descriptions were provided for all OER elements which is helpful for users to understand.	Not mentioned.
Mulwa et al., 2016	Adaption functions, such as text enlargement, are provided.	In searching, finding and navigation functions, users showed positive experiences after using the EAGLE (EnhAnced Government Learning) platform.	The combination of content components and design components for textual material were easy for users to understand.	Not mentioned.
Rosa & Motz, 2016	For the level A requirements related to the 'perceivable' attribute, of the eight investigated websites, seven comply with 'Use of Color' and 'Sensory Characteristics', six were satisfied with 'Meaningful Sequence'; two sites complied with 'Info and Relationships' and only one complied with 'Non-text Context'.	For the level A requirements related to the 'operable' attribute, of the eight investigated websites, seven comply with 'Focus Order', 'Page Titled', 'Three Flashes or Below Threshold' and 'No Keyboard Trap', six were satisfied with 'Keyboard'; three complied with 'Link Purpose' and only two complied with 'Bypass Blocks'.	For the level A requirements related to the 'understandable' attribute, among the eight sites, seven comply with 'Error Identification' and 'On Focus', six were satisfied with 'On Input', four complied with 'Labels or Instructions' nad three complied with 'Language of Page'.	Among the eight sites, only three had no errors for 'Parsing' guideline and only two had no errors for the 'Name, Role, Value' guideline, which is related to the 'Robust' principle.
Navarrete & Luján-Mora, 2015c	According to the accessibility evaluation results with TAW on four websites — = MERLOT, OCW UPM, OER COMMONS and OLI — 26 errors and 187 warnings related to the 'perceptible' attribute were detected. Specifically, ten errors on OLI, nine errors on OCW UPM and five errors on OER COMMONS were detected.	According to the accessibility evaluation results with TAW on four websites — MERLOT, OCW UPM, OER COMMONS and OLI—19 errors and 149 warnings related to the 'operable' attribute were detected. Specifically, 17 errors were detected on OER COMMONS and 1 error each on OCW UPM and OLI.	According to the accessibility evaluation results with TAW on four websites — MERLOT, OCW UPM, OER COMMONS and OLI — 5 errors and 48 warnings related to the 'understandable' attribute were detected. Specifically, two errors each on OER COMMONS and OLI and one error on OCW UPM were detected.	According to the accessibility evaluation results with TAW on four websites — MERLOT, OCW UPM, OER COMMONS and OLI — 19 errors and 1441 warnings related to the 'robust' attribute were detected. Specifically, 14 errors on MERLOT, 2 errors each on OLI and OCW UPM and 1 error on OER COMMONS were detected.
Iglesias et al., 2014	After accessibility evaluation, the OER was 80.8% accessible in the 'perceivable' attribute.	The evaluation result showed that 85.1% was accessible in the 'operable' attribute.	The result showed that 61.5% accessible in the understandable attribute.	Not mentioned.
Avila Garzon	Accessible images contained an alternative text, which is related to the 'perceivable'	The results showed that the criteria related to the 'understandable' and 'operable'	The results showed that criteria related to the understandable and operable attributes are	Not mentioned.

Table 6 Accessibility assessment results *(Continued)*

Papers	Accessibility attributes			
	Perceivable	Operable	Understandable	Robust
et al., 2016	attribute.	attributes are better complied with.	better complied with. Abbreviations, however, which are related to the 'understandable' attribute, need to be enhanced; more functions are required.	
Sanchez-Gordon & Luján-Mora, 2016	edX Studio cannot support authors adding fully accessible images or videos.	After accessibility evaluation, edX Studio did not comply with criteria related to the 'operable' attribute, such as keyboard navigation.	edX studio did not supply enough documentation for users to understand how to access and generate course content.	Not mentioned.

judged by experts. Meanwhile, the fewest errors were detected by TAW under the attribute 'understandable'.

Conclusion, recommendations and future directions

This study presented a systematic review of the use of OER and OEP to provide accessible learning. The final notes based on the results discussed above (in the three presented research questions) are as follows:

- A limited number of countries (nine) were involved in the investigation of the use of OER and OEP for accessible learning (research question 1). Therefore, researchers worldwide should be encouraged to get involved in this research field. This can be changed by raising awareness about the new opportunities that OER and OEP could provide to disabled students for effective accessible learning, or by launching new projects or policies (e.g., governmental or institutional) that encourage the use of OER and OEP for inclusive learning.
- Only two papers discussed the development of authoring tools with features to create accessible content, which might explain the reasons for having limited online OER and OEP for disabled students (research question 2). This should be changed by developing more inclusive authoring tools (that work with different functional diversities) that educators can use to create and publish open content.
- Most assessments conducted focused only on the accessibility of the provided OER (research question 3). Therefore, more research should also be conducted to investigate the effectiveness of OER and OEP in providing accessible learning experiences and enhancing disabled students' learning achievements.
- There is still much room for improvement in OER accessibility (research question 3). Therefore, researchers and practitioners should consider different accessibility guidelines (e.g., WCAG 2.0) while developing their OER platforms, tools and devices. This helps provide an effective approach to accessibility, functional diversity and e-inclusion in educational settings.
- Only three assessment methods are used: automatic tools, simulator tools and manual tools (research question 3). Therefore, in the era of big data, researchers and practitioners should also begin applying learning analytics for more accurate assessment of the accessible learning experience provided to disabled and functional-impaired students.
- Among the four accessibility attributes, 'robust' has the highest percentage of errors (research question 3). Therefore, OER developers should place more emphasis on OER's compatibility with most assistive devices, as well as operating systems (Windows, Mac OSX and Linux).

In addition, the authors consider direct support to educators a key issue, so that they learn the foundations of functional diversity, develop the skill set to operate learning resources under these terms and are fully aware of the significance of and need for specific actions around the topic. Indeed, providing specific competencies and training for educators are a challenge but nonetheless a required measure to improve the impact of functional diversity and accessibility on the educational system.

This study opens new research perspectives for researchers and practitioners on the use of open educational resources and practices for accessibility and functional diversity in educational contexts by uncovering gaps in this field that should be investigated. This study has several limitations, however, that should be acknowledged. For instance, the review results are limited to the search keywords used: thus, some studies may not be included. This study is also based on findings from the literature review and is not supported by any experimental setup. Despite these limitations, this study provides a solid ground from which to explore the use of open educational resources and practices in this context.

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