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Review Article

Bibliometric Analysis of Global Scientific Literature on the Accessibility of an Integrated E-Learning Model for Students with Disabilities

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ABSTRACT

The main objective of this study is to present a bibliometric analysis of research on e-learning accessibility at the global level. The bibliometric literature was comprised of 1,325 documents, after data pre-processing, published in Scopus database, covering the period from 1985 to 2021. First, a performance analysis was conducted to assess the publication performance of authors, institutions, countries, and other actors. Second, a science mapping analysis was performed to reveal the structure and dynamics of the e-learning accessibility field. As a result, the most productive, sources, authors, institutions, and countries were identified. Also, the collaboration patterns between particular actors were assessed. Furthermore, the e-learning accessibility research themes and their interrelationships were uncovered. This study contributes to the literature by providing useful information about the e-learning accessibility research status quo and, helps policymakers to achieve effective research planning. That is, it helps in objectively identifying strengths and gaps in e-learning accessibility research in terms of its growth, development, themes, impact, and coverage.

Keywords: bibliometric analysis, e-learning, accessibility, disability, educational technology

INTRODUCTION

Academic institutions have been rapidly turning to information and communications technology (ICT) to enhance the quality of their programs and to expand their horizons (Rodrigues et al., 2019). It is believed that the term e-learning was coined since ICT was incorporated into educational practices to promote learning (Moore, 2015). As a result of the ongoing advancement of ICT, many terminologies emerged throughout the evolution of e-learning. These terminologies map several theoretical approaches in the education discipline into ICT-based practices aiming at enhancing the learning processes (Aparicio et al., 2016; Tibaná-Herrera et al., 2018a). This suggests that there are different types, models, and frameworks of e-learning (Hung, 2012). As a result, many e-learning related concepts have been used interchangeably by scholars although they are not all the same but share some common characteristics (Moore et al., 2011; Wisher et al., 2015), which are using ICT tools to mediate learning activities. Consequently, the definition of e-learning has been a rather controversial issue (Sangrà et al., 2012). Thus, because there is no clear definition of what comprises e-learning, for this study, e-learning is defined as the use of any ICT tool, be it stand-alone, networked, or mobile, to mediate learning activities (Abbad et al., 2009; Kocur & Kosc, 2009; Seale, 2013).

The entire notion of non-traditional learning began with the idea of distance learning where learning materials, in physical format, used to be posted to students by mail, and students would correspond with their schools by mail as well (Kaplan & Haenlein, 2016). Once personal computers came to light, along with primitive internet applications, email, in particular, the delivery medium of learning materials was switched from physical to electronic which was either sent by email or stored on a compact disk-read only memory and

sent by mail (Al-Arimi, 2014). Meanwhile, ICT tools, in various forms, started to appear in classrooms and laboratories to support the learning processes (Livingstone, 2012). After that and with the ongoing and rapid advancement of ICT, a wider range of the Internet, computer, and mobile technologies started to emerge. This is when many academic institutions began to host some of the learning materials and activities on the web to complement their face-to-face learning activities and thus the term blended learning came into existence (Hofmann, 2018). Meanwhile, the concept of online learning or virtual learning started to emerge referring to using the web to deliver learning materials and activities, instruction, and assessment (Palvia et al., 2018). Such that many academic institutions began to utilize their websites whether it is password protected or not, or to adopt learning management systems, learning content management systems, virtual learning environments, and so on to deliver part of their programs or their entire programs (Kentnor, 2015). Then, along the continuum of technology development, mobile learning emerged (Lim & Churchill, 2016).

There has been an ongoing growth in the number of online learning programs within the world, and the number of students enrolled in those programs is growing rapidly (Allen & Seaman, 2017; Bates, 2018; Qayyum & Zawacki-Richter, 2019). In 2020, the exceptional circumstances, represented by the lock-down measures taken to prevent the diffusion of COVID-19, all over the world, sent many, if not all, academic institutions to either strengthen and capitalize on their ongoing digital transformation or start their journey toward it (Ali, 2020; Dhawan, 2020; Pace et al., 2020). Thus, 2020 marked a new era of education as whoever was reluctant to adopt e-learning, be it individuals or institutions, has experienced e-learning. Research suggests that e-learning will be an integral part of education within many institutions all over the world because of, relatively speaking, its successful experience during the COVID-19 pandemic (Cahapay, 2020; Korkmaz & Toraman, 2020; Zhu & Liu, 2020).

A user utilizes three subsystems when interacting with a computer:

1. a system that receives sensory input from the computer (e.g., vision or hearing),
2. a system that allows and controls users' inputs into the computer (e.g., the motor system), and
3. a cognitive system which connects and regulates the other two subsystems (Petrick, 2020).

Therefore, users with disabilities may have difficulties using mainstream ICT tools. As a result, users with disabilities rely on assistive technology to enable them to use ICT tools (Smith et al., 2018). Assistive technology is "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (The Individuals with Disabilities Education Act of 1997, 1997).

Worldwide, according to the World Health Organization (WHO), more than one billion individuals have some kind of disability, and the number is expected to rise in the future (WHO, 2020). Disability types include sensory, physical, mental, and intellectual impairments (WHO, 2011). Owing to the significant proportion of disabled people around the world, several legislations were passed, and many initiatives were established to ensure that students with disabilities are not prevented from accessing e-learning on the ground of their disabilities (Seale & Cooper, 2010). This resulted in the development of several accessibility standards and guidelines to help in the design of accessible e-learning tools (Seale, 2020). E-learning accessibility is the ability of the e-learning tools to accommodate the needs of all learners including those with disabilities (Seale, 2013).

There are legal, moral, and business arguments for making e-learning applications and content accessible (Gilbert, 2019). The moral argument is characterized by social inclusion and equity. That is disability is observed social rather than medical. Hence, people should not be designing environments in a way that creates barriers for people with disabilities (Bennett & Keyes, 2020). The legal argument is manifested in legislation passed by governments, around the world, to ensure that people with disabilities have the same rights and responsibilities as their able-bodied counter partners (Lazar, 2019). The business argument stems from the fact that making educational websites accessible means attracting more students due to the considerable proportion of people with disabilities around the world (Solovieva & Bock, 2014).

The standards regulating accessibility issues in e-learning can be classified into three categories, including learner-centered, learning resource-centered, and user interface-centered (Francisco Iniesto & Rodrigo, 2016). The learner-centered specifications are based on students' individual characteristics (students' needs). They describe students' accessibility preferences of learning materials and assessment. That is, they describe

accommodations needed by students with disabilities in terms of learning content and assessment type, presentation, and control mode (Brown & Mirri, 2013). Mainly, three standards provide specifications for students with disabilities' idiosyncratic needs including the IMS access for all personal needs and preferences, the IMS accessibility for learner information package, and ISO/IEC 24751-3 individualized adaptability and accessibility in e-learning, education and training.

The learning-resource-centered specifications are based on the description of learning content or objects. They provide a description in terms of metadata for resources available that can be used as alternatives to the primary ones to present the same content to students with disabilities, but via different media (Brown & Mirri, 2013). The most adopted standards that provide specifications for learning content or objects in e-learning environments include IMS access-for-all metadata, IMS access for all digital resource description, universal design for learning, and ISO/IEC 24751-2 individualized adaptability and accessibility in e-learning, education, and training.

The user-interface-centered specifications are based on e-learning applications, namely, elements of the learning management systems or course management systems. They describe how to make various e-learning applications accessible to students with disabilities (Brown & Mirri, 2013). Several standards provide guidelines for designing accessible e-learning applications including those that were specifically developed for e-learning, and others that were developed for guiding the design of web applications in general. E-learning is a subset of web-based applications. Hence, the design of accessible e-learning applications relies heavily on the technical specifications for designing accessible web (Lewis & Seeman, 2019).

The web is an integrated system. That is, it combines several elements including content, user agents, authoring tools, and evaluation tools (Anderson, 2016). Developers use authoring and evaluation tools to create web content. The users access and interact with the content via user agents (e.g., web browsers, media players, or assistive technology) (Takagi & Asakawa, 2017). The web's elements are interdependent; hence, they must all be accessible and work together for the web to be accessible (Henry, 2018). To coordinate the relationship among the web's different components and to address the accessibility issues for each one, the world wide web consortium (W3C) web accessibility initiative (WAI) has developed a set of accessibility guidelines for each component. The three essential sets of guidelines are the web content accessibility guidelines (WCAG), the authoring tool accessibility guidelines, and the user agent accessibility guidelines (Abou-Zahra & Brewer, 2019). Besides the W3C's WAI guidelines, there is another number of guidelines, for example, section 508 of the rehabilitation act in USA.

E-learning, if designed according to accessibility standards and guidelines, provides students with disabilities with alternative ways of accessing learning content and activities using assistive technologies (Amka & Dalle, 2022). Therefore, accessible e-learning increases access to education and supports inclusive and adaptable education for students with disabilities (Lee, 2017; Mike, 2015). That is besides bridging the geographical barrier when conducted entirely or partially online, accessible e-learning allows students with disabilities to have equal opportunities with their non-disabled counter partners in terms of participating in mainstream educational settings, whether inside the classroom or at a distance.

Considering the importance of e-learning and the impact that it has had on education, a great amount of research has been conducted to examine several aspects of e-learning in education. Surely, the accessibility of e-learning is one aspect of what has been examined. Meanwhile, several studies have conducted bibliometric analyses of global scientific literature on e-learning (Chiang et al., 2010; Fatima & Abu, 2019; Kapo et al., 2016; Tibaná-Herrera et al., 2018a, 2018b, 2018c). However, none of these studies have been specifically conducted to examine the state and trends of research on e-learning accessibility.

Therefore, this study, using a descriptive and relational bibliometric analysis approach, aims to show the development, conceptual structure, and thematic evolution of research on e-learning accessibility, since it was commenced. That is, it provides a description of publications in terms of volume, distribution, citations, sources, author keywords, indexed keywords, and languages. It also assesses the productivity of authors, institutions, and countries, and the collaboration patterns of countries in the field. Also, with the help of this approach, the trends, and themes of scientific research in e-learning accessibility and their interrelationships can be identified and summarized.

This study contributes to the literature by providing useful information about the developmental status of e-learning accessibility research comprehensively and systematically. That is, it helps in objectively identifying strengths and gaps in e-learning accessibility research in terms of its growth, development, themes, impact, and coverage. Furthermore, the findings of this study will help identify further research that is necessary to bring more valued knowledge into the field of e-learning accessibility. Also, the findings will provide a guide for determining research priorities in this field. In addition to that, the findings will help stakeholders in their decision-making processes related to e-learning accessibility.

Bibliometric analysis is a branch of library and information science, which was established in the late 1960s, that uses quantitative methods to measure, track, and analyze scholarly literature in a particular scientific field (Roemer & Borchardt, 2015). Typically, bibliometric is employed to provide different levels of analysis to assess the scientific production in a particular scientific discipline (Bellis, 2009). That is, they evaluate different actors including journals, institutions, countries or regions, and authors in terms of scientific literature productivity (Rousseau et al., 2018). The bibliometric analysis takes the form of descriptive and relational indicators. Descriptive indicators help to identify trends of scientific literature production, over periods of time, by augmenting the number of scientific publications for a particular scientific discipline for different actors. On the other hand, relational indicators help identify patterns of similarity and collaboration within the actors' research output at the national and international levels (Gauthier, 1998). With this perspective in mind, the goal of this study is to answer the following research questions:

1. What are the descriptive statistical characteristics of research on e-learning accessibility?
2. What is the annual trend of research on e-learning accessibility?
3. Which authors, institutions, countries, sources, and document types contributed more research on e-learning accessibility?
4. Which are the most cited documents of research on e-learning accessibility?
5. What are the major topics, themes, trends, and their inter-relationships of research on e-learning accessibility?
6. Which are the main documents that have influenced the intellectual structure of research on e-learning accessibility?
7. What is the pattern of collaboration among countries which contributed to research on e-learning accessibility?

METHODS

To obtain relevant studies to perform a bibliometric analysis on e-learning accessibility, a search query was developed and run. The search query was composed of four parts which were joined using the "AND" operator. The aim of the first part of the search query was to capture studies related to e-learning. Drawing on the perspective that an e-learning system is an integrated model (Aparicio et al., 2016; Dabbagh, 2005; Oliver & Herrington, 2003), several key terms pertaining to an integrated e-learning model were identified by consulting relevant literature (Aparicio et al., 2016; Tibaná-Herrera et al., 2018b). The second part of the search query aimed at narrowing down the results of the first part into studies conducted on e-learning accessibility. This was reflected by adding terms relevant to accessibility. The third part of the search query aimed at further narrowing down the results of the first and second parts into studies conducted on e-learning accessibility for individuals with disabilities. Finally, as e-learning has multiple stakeholders (Aparicio et al., 2016), this study is scoped only into e-learning use in the education discipline, and not in the workplace or other fields. Thus, the fourth part of the search query was added, and it included terms relevant to educational settings.

The data were collected through Scopus database. Scopus is the world's largest abstract and citation database of multidisciplinary scientific literature (Ballew, 2009; Bar-Ilan, 2008; Burnham, 2006). In addition to that, Scopus database is the most used bibliometric tool by practitioners (Gadd & Rowlands, 2018). The identified search terms were applied to document titles, document abstracts, author keywords, and indexed keywords because it is believed that this combination provides a detailed picture of the documents' subjects (Li et al., 2011; Müller et al., 2004; Terra et al., 2021; Xie et al., 2008), and, in turn, rigorously supports mapping

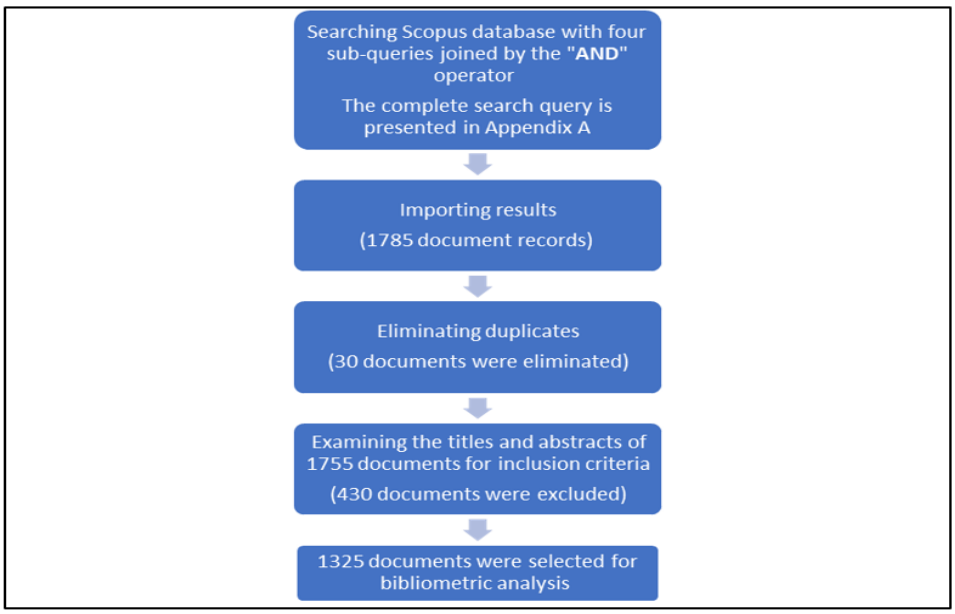

Figure 1. The search and selection process of documents on e-learning accessibility

the global research trends and emphasis on e-learning accessibility (Fu et al., 2010; Tan et al., 2014). The search was conducted on 15 August 2021. The search query is provided in **Appendix A**.

The initial search results from the Scopus database yielded 1,785 documents. The retrieved documents' years of publication, titles, abstracts, author keywords, index keywords, references, citation counts, digital object identifiers, author names, author affiliations, author identification numbers, source titles, source types, languages, and correspondence addresses were imported into a computer as BibTeX file. Then the imported file was converted into a Microsoft Excel file to examine the retrieved documents for duplicates. Thirty documents were identified as duplicates, and they were eliminated from the original BibTeX file. The duplicated documents resulted from documents published in two different sources. For example, a document may be presented in a conference as a conference paper, and the same paper was published as a full journal article or book chapter. In such a case, the document with the most recent date was considered. After that, all retrieved documents' titles and abstracts were examined to ensure that they fit the goal of the study, 430 documents were excluded. Consequently, 1,325 documents remained for the analysis. **Figure 1** depicts search and selection process of documents on e-learning accessibility. Mainly, the excluded documents pertain to

1. **physical accessibility:** accessibility of buildings and facilities in schools and other academic institutions;
2. **digital orientation:** providing accessible computerized orientation services for students with disabilities;
3. **disability simulation:** simulating how people with disabilities interact with ICT;
4. **disability screening:** diagnosing a learning disability;
5. **general web accessibility:** designing and examining the accessibility of web-based applications, other than e-learning applications, for people with disabilities;
6. **learning web accessibility:** studying how to design web-based applications, for disabled students, by web developers;
7. **health, rehabilitation, and disability resources on the Internet:** providing people with disabilities information, in accessible formats, to assist them in various aspects of their lives; and
8. **documents that do not focus on the technology side of the universal design for learning framework:** universal design for learning aims at designing, creating, and delivering inclusive learning and teaching practices and content that address the idiosyncratic needs of all students within educational settings, including those with learning disabilities, and others.

Table 1. Descriptive statistics of the dataset

Description	Results
Main information about documents	
Number of documents	1,325
Timespan	1,985:2021
Number of sources (journals, books, etc.)	652
Average years from publication	7.36
Average citations per documents	5.112
Average citations per year per documents	0.6576
Number of references	31,528
Document types	
Article	474
Book	7
Book chapter	65
Conference paper	670
Conference review	76
Data paper	1
Retracted	1
Review	31
Document contents	
Number of keywords plus	3,773
Number of author's keywords	2,343
Authors	
Number of authors	2,839
Author appearances	3,896
Authors of single-authored documents	176
Authors of multi-authored documents	2,663
Authors collaboration	
Single-authored documents	271
Documents per author	0.467
Authors per document	2.14
Co-authors per documents	2.94
Collaboration index	2.53

The data analysis was done using the BiblioShiny App, which is an application of the Bibliometrix package version 3.1. This package is written in R programming language. Bibliometrix is a powerful and integrated package for conducting a bibliometric analysis (Aria & Cuccurullo, 2017).

RESULTS AND DISCUSSION

Descriptive Statistics of the Documents

A total of 1,325 documents were analyzed. The timespan of the documents was from 1985 to 2021. The documents originated from 652 sources. These documents included 474 (35.77%) journal articles, seven books (0.52%), 65 (4.9%) book chapters, 670 (50.56%) conference papers, 76 (5.73%) conference reviews, 31 (2.33%) reviews, one data paper (0.075%), and one retracted paper (0.075%). More than half of the total publications were in the form of conference papers followed by journal articles, which comprised more than one-third, and the rest of the publications constituted less than one-sixth of the total. The documents included 3,773 indexed keywords and 2,343 author's keywords. The number of references cited by these documents was 31,528. Concerning citations, the average years for a document to be cited was 7.36 years, the average citations per document were 5.112, and the average citations per year per document were 0.6576. In addition to that, the dataset included 2,839 authors with 3,896 author appearances, authors of single-authored documents were 176, and authors of multi-authored documents were 2,663. Finally, the author collaboration index was 2.53, single-authored documents were 271, documents per author were 0.467, authors per document were 2.14, and co-authors per document were 2.94. **Table 1** shows descriptive statistics of dataset.

As regards the language of publications, English was the absolute predominant language of published documents on e-learning accessibility (n=1,265, 95.4%), followed by Spanish (n=21, 1.58%), and Portuguese (n=18, 1.35%). **Table 2** shows the frequencies of languages of published documents on e-learning accessibility.

Table 2. Frequencies of languages of published documents on e-learning accessibility

Document language	Frequency
English	1,265
Spanish	21
Portuguese	18
English; Portuguese	7
Russian	4
French	3
English; Spanish	2
English; German	1
English; Croatian	1
Turkish	1
Korean	1
Serbian	1

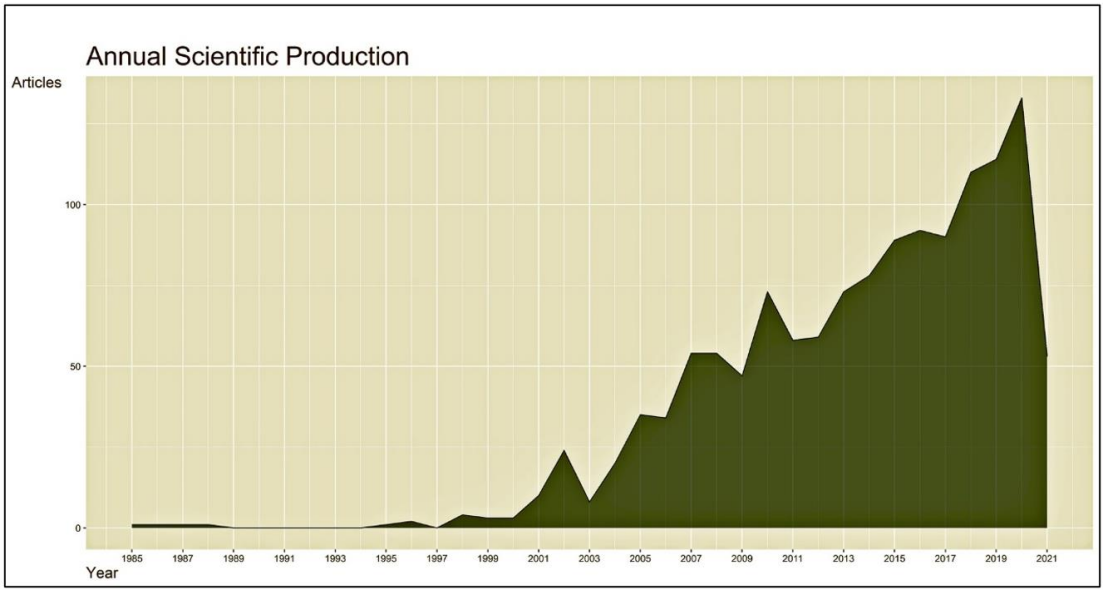

Figure 2. Annual scientific production of literature on e-learning accessibility

Annual Analysis of Documents

Figure 2 presents the annual scientific production of literature on e-learning accessibility from 1985 to 2021. Overall, the major trend of publications is that it increases over time. It shows that the publication rate from 1985 to 2000 was at a very low level, representing (n=17, 1.28%) of the total publications. Then the publication rate from 2001 to 2010 surged significantly compared to the years before, representing (n=359, 27.09%) of the total publications. However, the growth trend of publications from 2001 to 2010 followed an unsystematic pattern. From 2011 to 2020, the publication rate surged again dramatically compared to the years before, representing (n=896, 67.62%) of the total publications. In addition to that, the growth trend of publications from 2011 to 2020 followed almost a linear relationship. Finally, the year 2021 is not over yet but it seems that it is following almost the same trend as the years before, 2011 to 2020.

Sources with Most Documents

A total of 652 sources contributed to the 1,325 documents on e-learning accessibility. The top 10 sources, in terms of the number of publications, contributed 339 documents, 25.6%, of the total 1,325 documents. Of the 339 documents, 214 documents, 63.12%, were published in book series, 68 documents, 20%, were published in conference proceedings, and 57 documents, 16.82%, were published in journals. Three book series, three conference proceedings, and four journals composed the top 10 sources list. The Lecture Notes in Computer Science book series, (n=168,12.67%), ranked first in the top 10 sources list, followed by both the ACM International Conference Proceeding Series (n=28, 2.11%), and the Advances in Intelligent Systems and Computing book series (n=28, 2.11%). **Table 3** summarizes the sources which have published the largest number of documents on e-learning accessibility.

Table 3. Sources with the largest number of documents on e-learning accessibility

Sources	Source type	Documents
Lecture Notes in Computer Science	Book series	168
ACM International Conference Proceeding Series	Conference proceeding	28
Advances in Intelligent Systems and Computing	Book series	28
Universal Access in the Information Society	Journal	26
CEUR Workshop Proceedings	Conference proceeding	23
Communications in Computer and Information Science	Book series	18
Proceedings-Frontiers in Education Conference, FIE	Conference proceeding	17
Computers and Education	Journal	11
Studies in Health Technology and Informatics	Journal	11
Educational Technology and Society	Journal	9

Table 4. Top 10 most cited documents

Document	Year	Authors	DOI	DT	TC
Mobile learning technology based on iOS devices to support students with special education needs	2013	Fernández-López, Á., Rodríguez-Fórtiz, M. J., Rodríguez-Almendros, M. L., and Martínez-Segura, M. J.	10.1016/j.compedu.2012.09.014	Journal article	188
E-learning and disability in higher education: Accessibility research and practice	2006	Seale, J. K.	10.4324/9780203969595	Book	109
Remote experiments, re-versioning and re-thinking science learning	2004	Scanlon, E., Colwell, C., Cooper, M., and Di Paolo, T.	10.1016/j.compedu.2003.12.010	Conference paper	86
The potentials of virtual environments in the education and training of people with learning disabilities	1996	Cromby, J. J., Standen, P. J., and Brown, D. J.	NA	Review	78
Disabilities and e-Learning problems and solutions: An exploratory study	2009	Fichten, C. S., Ferraro, V., Asuncion, J. V., (...), Klomp, R., & Wolforth, J.	NA	Journal article	73
A longitudinal evaluation of accessibility: Higher education web sites	2005	Hackett, S., and Parmanto, B.	10.1108/10662240510602690	Review	72
Web accessibility at university libraries and library schools	2001	Schmetzke, A.	10.1108/07378830110384584	Review	71
The effective use of virtual environments in the education and rehabilitation of students with intellectual disabilities	2001	Standen, P. J., Brown, D. J., and Cromby, J. J.	10.1111/1467-8535.00199	Journal article	71
Not the right kind of 'digital capital'? An examination of the complex relationship between disabled students, their technologies and higher education institutions	2015	Seale, J., Georgeson, J., Mamas, C., and Swain, J.	10.1016/j.compedu.2014.11.007	Journal article	58
Students with disabilities and online learning: A cross-institutional study of perceived satisfaction with accessibility compliance and services	2011	Roberts, J. B., Crittenden, L. A., and Crittenden, J. C.	10.1016/j.iheduc.2011.05.004	Journal article	56

Note. DT: Document type; TC: Total citations

Most Cited Documents

Table 4 summarizes the most ten cited documents among the scholarly work on e-learning accessibility. These highly cited documents were published between 1996 and 2015. They are comprised of five journal articles, three reviews, one book, and one conference paper.

Contributions of Authors

The 1,325 documents on e-learning accessibility were written by 2,839 authors. Of the top 10 authors, in terms of the number of publications, there are four from Spain, and three from the UK. This might be

Table 5. Top 10 authors with the highest number of publications

Author	Documents	Affiliation	Country
Luján-Mora, Sergio	18	Universitat d'Alacant	Spain
Iglesias, Ana	15	Universidad Carlos III de Madrid	Spain
Moreno, Lourdes	15	Universidad Carlos III de Madrid	Spain
Pearson, Elaine J.	13	Teesside University	UK
Ulbricht, Vânia Ribas	13	Universidade Federal de Santa Catarina	Brazil
Hilera, José R.	13	Universidad de Alcalá	Spain
Jemni, Mohamed	12	École Nationale Supérieure d'Ingénieurs de Tunis	Tunisia
Green, Steve J.	11	Teesside University	UK
Draffan, E. A. B.	10	University of Southampton	UK
Acosta-Vargas, Patricia	10	Universidad de las Americas – Ecuador	Ecuador

Table 6. Top 10 countries with the highest number of publications

Country	Documents
USA	509
Spain	215
Brazil	183
UK	177
Italy	97
Australia	71
Canada	63
Portugal	51
Ecuador	49
Greece	49

attributed to the affiliation of these authors with projects and programs established to address e-learning accessibility in their institutions, regions, or the world.

It is interesting to note that USA has no authors in the top 10 authors list although it is the leading country in terms of quantity of publications on e-learning accessibility. **Table 5** presents the authors who published the largest numbers of research on e-learning accessibility.

Contributions of Countries

The 1,325 documents on e-learning accessibility were published by authors in 83 countries around the world. USA, Spain, Brazil, the UK, and Italy stand out as the leading countries in the generation and dissemination of knowledge on e-learning accessibility. This might be attributed to government-enforced legislation as well as a high number of students with disabilities in these countries. **Table 6** shows the leading countries in terms of the number of publications on e-learning accessibility.

Contributions of Institutions

A total of 1,138 institutions contributed to the 1,325 documents on e-learning accessibility. Of the top 10 institutions, in terms of the number of publications, there are three from Spain and two from the UK, and the University of Washington, from USA, is the leading institution. This might be attributed to the availability of resources in these institutions in the form of research funds from governmental bodies, industrial organizations, or others. **Table 7** presents the institutions, which published the largest numbers of research documents on e-learning accessibility.

Co-occurrence of Keywords

The 1,325 documents on e-learning accessibility included 2,343 different author keywords with a total of 5,344 occurrences. **Table 8** provides a summary of the top 10 frequently occurring author keywords.

To map the e-learning accessibility research area, a particular science mapping approach known as the co-word analysis was used. This technique measures the association strengths of terms extracted from publications' keywords, titles, or abstracts in a particular scientific field. Such that it analyses the co-occurrence frequency of strongly linked terms (Callon et al., 1983). As a result, it enables identifying the main research topics and trends of a scientific field and their inter-relationships (Coulter et al., 1998).

Table 7. Top 10 institutions with the highest number of publications

Institution	City	Country	Documents
University of Washington	Seattle, WA	USA	25
University of Alicante	Alicante	Spain	22
University of Southampton	Southampton	UK	17
Universidade Federal de Santa Catarina	Florianópolis	Brazil	16
Open University	Milton Keynes	UK	15
Universidad Carlos III de Madrid	Madrid	Spain	15
Silesian University of Technology	Gliwice	Poland	12
Universidad de Alcalá	Alcalá de Henares	Spain	12
Universiti Kebangsaan Malaysia	Bangi	Malaysia	12
Universidad de Las Américas	Quito	Ecuador	11

Table 8. Top 10 frequently occurring author keywords

Keyword	Frequency	% (N=5,344)
Accessibility	434	8.12
e-Learning	147	2.75
Disability	102	1.9
Web accessibility	82	1.53
Usability	63	1.17
Higher education	55	1.02
Assistive technology	54	1.01
Disabilities	51	0.95
Education	49	0.91
Universal design	43	0.80

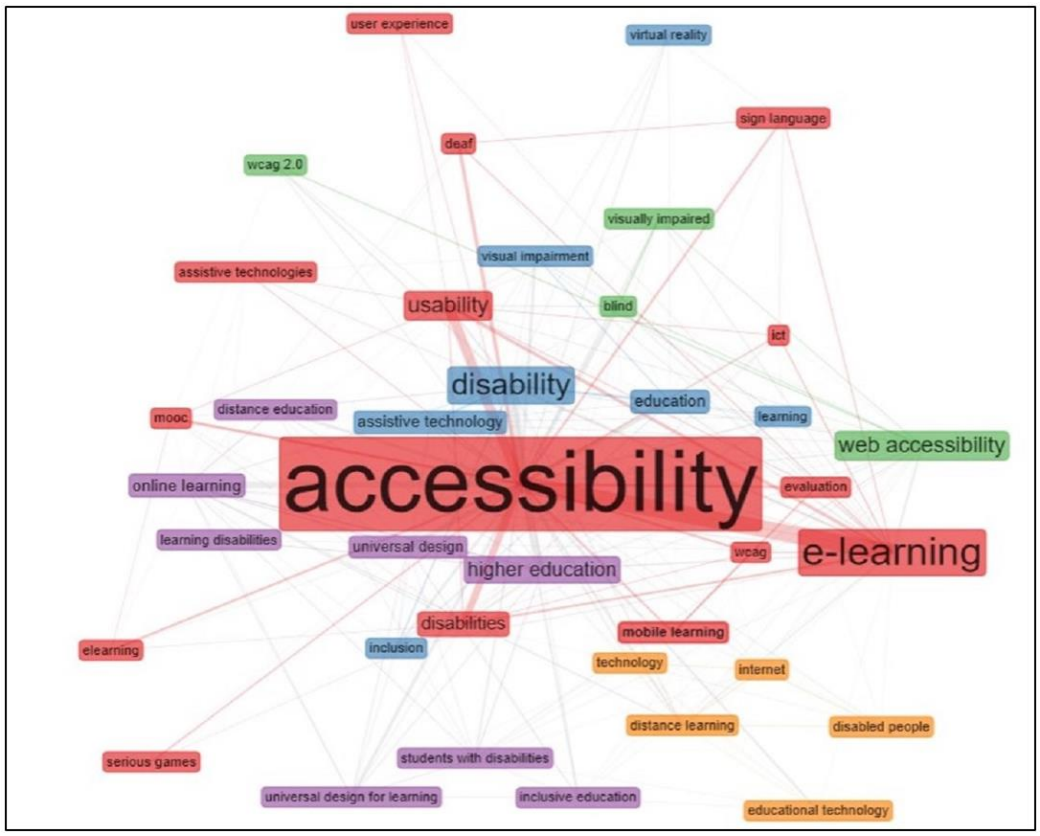

Figure 3. Author keywords co-occurrence network

In this study, an author keywords co-occurrence network was created. Author keywords are sufficient to capture the essence of a published document (Špiranec & Ivanjko, 2013). This network was determined based on the frequency of occurrences of author keywords and co-occurrence frequency of pairs of keywords in published documents on e-learning accessibility. Only author keywords occurring 15 or more times in the dataset were included in the analysis, leading to 39 author keywords. The author's keywords co-occurrence network is shown in **Figure 3**.

In this network, each node signifies an author keyword while the lines denote the co-occurrence network, or times each author keyword appears with other author keywords in the published documents. The node size reflects how often an author keyword occurs, and the thickness of the lines captures the strength of association among author keywords. The bigger the node, the more links the keyword has.

The analysis of the author keywords co-occurrence network revealed that there are five primary research topics, denoted by color-coded clusters, that have been explored in the literature on e-learning accessibility. Each cluster is labeled by the most frequently used keyword within that cluster. The first cluster, in red color, included 15 author keywords, including accessibility, e-learning, elearning, usability, user experience, disabilities, deaf, sign language, evaluation, WCAG, MOOC, assistive technologies, ICT, mobile learning, and serious games. The second cluster, in blue color, included seven author keywords including disability, assistive technology, education, inclusion, learning, visual impairment, and virtual reality. The third cluster, in green color, included four keywords including web accessibility, blind, visually impaired, and WCAG 2.0. The fourth cluster, in purple color, included eight keywords including higher education, universal design, online learning, inclusive education, universal design for learning, students with disabilities, distance education, and learning disabilities. The fifth cluster, in neon orange color, included five author keywords including distance learning, disabled people, technology, educational technology, and the Internet.

Research belonging to the first cluster is devoted to the accessibility, usability, and user experience of ICT applications for disabled learners. The focus within this cluster has been on a wide spectrum of ICT applications for students with disabilities including e-learning platforms and content–MOOC in particular, assistive technologies, mobile learning, and serious games. Meanwhile, special attention was given to deaf students and sign language. One possible explanation for that is that deaf students are among the most challenged students in e-learning environments, and they perceive it as more difficult than traditional learning (National Deaf Center, 2020). This might be due to the low self-esteem of deaf students in communication (Oleszkiewicz, 2021), which may affect how they learn in an e-learning environment (McKeown & McKeown, 2019). Deaf students rely on both assistive technology, hardware and/or software, and accommodations, sign language interpreters, and note-takers, to access e-learning platforms and content (Gugenheimer et al., 2017). Delivering the content and enabling access to e-learning platforms via alternative ways does not guarantee a satisfactory learning experience (Borgia et al., 2014; Moreno et al., 2012). Therefore, the rise of usability and user experience within this cluster might be attributed to the fact that meeting technical accessibility does not guarantee usability or satisfactory user experience for deaf students (Burgstahler, 2015; Godoi et al., 2020). Although assistive technology has revolutionized the learning processes for students with disabilities, they tend to be expensive and hard to obtain (Duhaney & Duhaney, 2000). However, with the emergence of mobile devices, smartphones, and smart tablets, which offer smart built-in assistive technology features and assistive technology downloadable applications, the disadvantages associated with assistive technologies began to weaken (Ismaili & Ibrahimi, 2017). That is, mobile devices are providing alternatives for stand-alone assistive technologies (Ok, 2018). Therefore, one possible reason for the occurrence of mobile learning within this cluster is the advantages it offers over stationary e-learning settings (Korucu & Alkan, 2011; Motiwalla, 2007). Concerning serious games, they are valued learning tools for students with disabilities, especially deaf students, who tend to have literacy delays (Cano et al., 2015; Paul & Roth, 2011; Wouters et al., 2013). That is, serious games have proven to promote meaningful learning and to overcome learning difficulties experienced by students with disabilities (García-Redondo et al., 2019). MOOC appeared as a trending topic in realm of accessibility of e-learning. MOOC offers several advantages over traditional or institutional e-learning. That is, when compared to traditional e-learning, MOOC incur cheaper or no tuition fees, has a higher enrolment capacity, and is credit-less (Mackness et al., 2010; Pappano, 2012). Therefore, MOOC has been attracting millions of people from around the globe (Impey & Formanek, 2021; Sandeen, 2013), including people with disabilities (Iniesto & Rodrigo, 2014; McMurray, 2019).

The second cluster explores the use of assistive technology, as inclusive education technologies, and virtual reality by students with disabilities in educational settings to support their learning. Meanwhile, special attention was devoted to visually impaired students. Students with disabilities have difficulties using mainstream technology for one reason or another (Forgrave, 2002). Hence, they rely on assistive technologies to access the general curriculum, social, and extracurricular activities (McNicholl et al., 2021; Okolo & Bouck, 2007). Thus, given their potential, assistive technologies accommodate the needs of students with disabilities

in inclusive educational settings (Chukwuemeka & Samaila, 2020; Zilz & Pang, 2021). Virtual reality has been used widely to support the learning of students with disabilities in multiple ways including attaining academic concepts, acquiring, and practicing social skills, and developing and improving communication skills (Jdaitawi & Kan'an, 2022; Ludlow, 2015). Virtual reality applications provide students with disabilities, visually impaired in particular, customizable learning environments (Buzio et al., 2017).

The third cluster deals with an accessibility evaluation of e-learning platforms and content as being a subset of web-based applications. The focus within this cluster has been on evaluating the accessibility of e-learning platforms and content for blind and visually impaired students. One possible explanation for this finding is that blind and visually impaired students are the most challenged group in accessing web-based e-learning platforms and content (Barreto & Hollier, 2019). "This is because the web has developed into a largely visual medium" (Edwards, 2008, p. 142). The studies within this cluster evaluated the accessibility of e-learning platforms and content against the WCAG 2.0. One possible explanation for that is that the WCAG 2.0 guidelines are the most comprehensive and widely used accessibility guidelines by practitioners (Cisneros et al., 2021; Harper & Chen, 2012; Lewis & Seeman, 2019; Parmanto & Zeng, 2005).

The fourth cluster encompasses research that explored the application of universal design in promoting inclusive education through online and distance learning in higher education for students with disabilities. Universal design for learning extends universal design (King-Sears, 2009). Whereas universal design aims at creating inclusive environments and has its roots in engineering sciences, universal design for learning aims at designing, creating, and delivering inclusive learning and teaching practices and content that address the idiosyncratic needs of all students within educational settings, including those with learning disabilities (Hitchcock et al., 2002; Pisha & Coyne, 2001). Therefore, universal design for learning serves as the framework to support inclusive education by providing all students with multiple means of accessing the curriculum and other learning materials and multiple means of communicating their knowledge and skills (Katz, 2013; Rose, 2000). In the context of online and distance learning, applying universal design for learning principles is expected to overcome challenges faced by all students including those with disabilities (Rogers-Shaw et al., 2018). Therefore, it is possible that this cluster emerged because of studies examining the effect of applying universal design for learning in e-learning settings as well as distance and online learning (Rao et al., 2015). Universal design for learning and web content accessibility guidelines are perceived as complementary to one another. That is, web content accessibility guidelines aim at creating accessible learning content, universal design for learning aims at creating an accessible learning experience (Gronseth, 2018; Houston, 2018).

The fifth cluster reflects the revolution in education because of incorporating educational technologies into education to aid the learning of students with disabilities (Fichten et al., 2000; Kim-Rupnow & Burgstahler, 2004; Okolo & Diedrich, 2014) Coinciding with the emergence of the Internet, distance and online learning have been empowering students with disabilities by providing them with successful alternative ways for learning (Fichten et al., 2020; Seale, 2013). Therefore, considering the advantages online and distance learning have compared to traditional learning settings, students with disabilities increasingly electing online learning programs (Cavanaugh et al., 2013).

To gain further insight into the knowledge base and intellectual structure of the e-learning accessibility domain, the betweenness centrality of each node within the author keywords co-occurrence network was calculated. Betweenness centrality is a network property that measures the extent to which a node is included in the shortest path between other pairs of nodes in the network (Borgatti & Everett, 2006). The higher the betweenness centrality of a node the more groups of keywords it connects, and, in turn, the higher the influence it has on the network (Fernández-Álvarez et al., 2021). **Table 9** presents the top 10 keywords with the highest betweenness centralities.

The further analysis revealed that accessibility, e-learning, disability, usability, and web accessibility are the top five core keywords that play the role of hub nodes that is more highly connected to other keywords. This result suggests an important future research direction which is examining and evaluating the usability, alongside the accessibility, of e-learning applications, mainly web-based. The usability of e-learning applications for learners with disabilities is a further step beyond accessibility. Whereas accessibility refers to the ability of learners with disabilities to access e-learning applications, usability refers to the ease of use of such applications (Pernice & Nielsen, 2001).

Table 9. Top 10 keywords with the highest betweenness centralities

Node	Cluster	Betweenness
Accessibility	1	400.8874508
e-Learning	1	33.38405293
Disability	2	15.61857827
Usability	1	9.143239274
Web accessibility	3	8.97160352
Higher education	4	8.292672543
Online learning	4	4.45275129
Universal design	4	3.367536417
Disabilities	1	3.03677122
Education	2	2.718364419

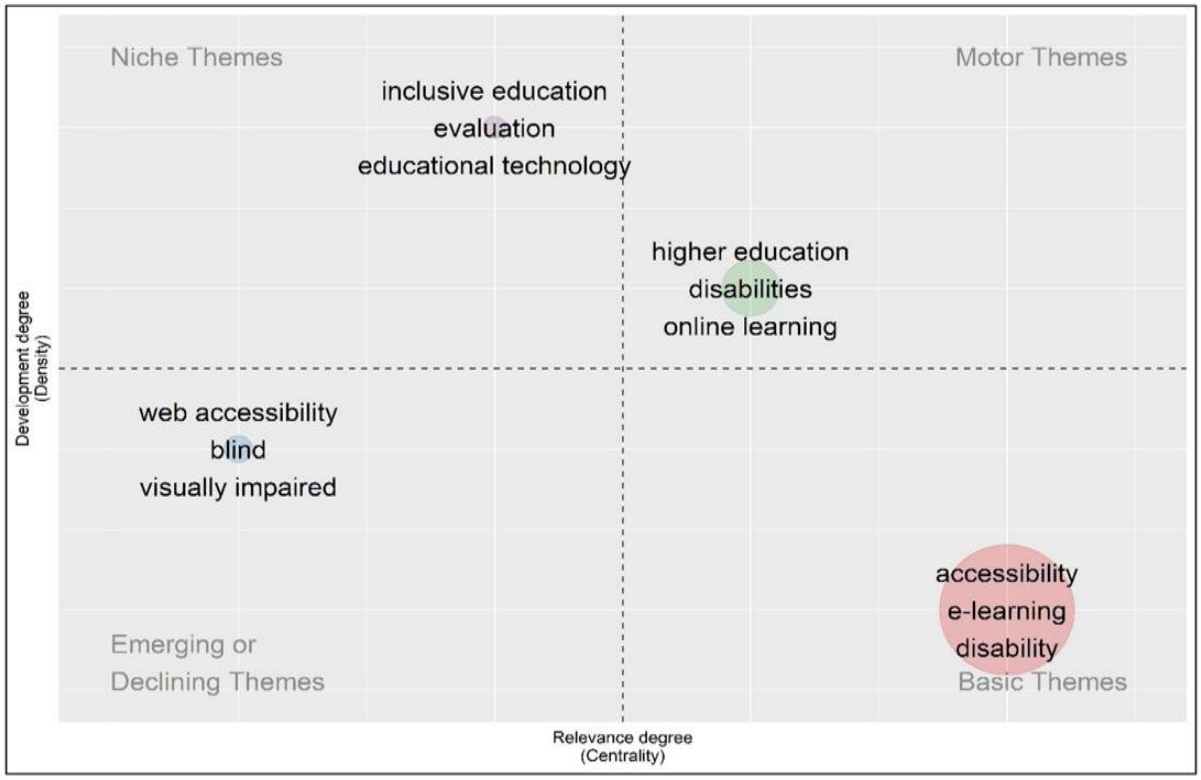

Figure 4. Strategic map of e-learning accessibility research themes

For a more exploratory approach for detecting the research themes of the e-learning accessibility domain, a thematic analysis was conducted. The thematic analysis allows a research field to be visualized as a set of research themes, mapped in a two-dimensional strategic map, and categorized into four different groups (Cobo et al., 2011). The strategic map presents the most important themes in terms of their centrality and density. Whereas density measures the Internal strength of the theme, centrality measures the degree of interaction of a theme with other themes (Callon et al., 1991). In this study, the centrality and density of the strategic map were calculated based on the co-occurrence of the author keywords. **Figure 4** presents the identified research themes in the field of e-learning accessibility, as follows:

1. **Motor themes (high centrality, high density):** These themes, within the upper-right quadrant, are well developed and highly related to other themes in other quadrants. As such, they are very strategical for the structure of the research field of e-learning accessibility.
2. **Basic themes (high centrality, low density):** These themes, within the lower-right quadrant, are not well developed but are highly related to other themes in other quadrants. As such, they are important for the research field of e-learning accessibility but are not developed.

3. **Niche themes (low centrality, high density):** These themes, within the upper-left quadrant, are well developed but do not have strong connections with other themes in other quadrants. As such, they are peripheral to the structure of the research field of e-learning accessibility but are well developed
4. **Emerging or declining themes (low centrality, low density):** These themes, within the lower-left quadrant, are neither developed nor highly related to other themes in other quadrants. As such, they are marginal for the structure of the research field of e-learning accessibility.

As shown in **Figure 4**, disabilities, higher education, and online learning are motor themes in the research on e-learning accessibility. They represent commonly addressed topics that constitute the research mainstream and therefore are essential to creating a disciplinary core online learning is becoming an integral part of higher education programs (Ali, 2020; Chang & Fisher, 2003; Hiltz & Turoff, 2005; Panigrahi et al., 2018), and their number is increasing rapidly (Glazier et al., 2021). Therefore, besides being a mandate by law, accommodating students with disabilities in online programs is required for the successful implementation of such programs (Evans et al., 2017; Fichten et al., 2020; Liasidou, 2014). In addition to that, ongoing advancement in ICT keeps the intersection of research on disabilities, higher education, and online learning anchored to new and changing technologies adopted in online programs (Burbules et al., 2020; Perera-Rodríguez & Moriña Díez, 2019;). That is being said, the studies that constituted the motor themes focused on students in higher educator rather than in K-12. Therefore, there is a need for more research that examines the accessibility of online learning and e-learning applications overall for K-12 students (Martin et al., 2021).

Moving on to basic themes that are important for a research field but not developed. Accessibility, e-learning, and disabilities are basic themes in the e-learning accessibility field. Improving the accessibility of e-learning for students with disabilities has been always a major concern for stakeholders in education (Stone, 2017). Yet, accessibility is a prerequisite to the success of e-learning for students with disabilities (Baldwin & Ching, 2021; Kurt, 2019). Moreover, accessible e-learning applications provide a better experience for all students including those without disabilities (Poore-Pariseau, 2010; Rogers-Shaw et al., 2018). Therefore, there is a trend of research-oriented approach proposes that improving the accessibility of e-learning for students with disabilities will promote best practices in digital learning environments for all students, and, in turn, supports successful online programs implementation in education (Tobin & Behling, 2018). Web accessibility, blind, and visually impaired are either emerging or declining themes. Those themes are neither developed nor highly related to other themes in other quadrants. They either tend to no longer attract major interest, or they have recently started to attract attention but have not yet been well developed. Despite significant advances in assistive technologies, blind and visually impaired users continue to encounter barriers when accessing web content (Ashraf et al., 2017; Shethia & Techatassanasoontorn, 2019). In addition to that, blind and visually impaired students are the most challenged group in accessing web-based applications including e-learning platforms and content (Barreto & Hollier, 2019). This is due to the nature of Web content which is highly visual (Edwards, 2008).

Inclusive education, evaluation, and educational technology are well-developed themes but do not have strong connections with other themes in other quadrants. Students with disabilities are educated in inclusive classrooms, mainstream settings, to a greater degree than ever before, and assistive technology is the major enabler of this phenomenon (Istenic Starcic & Bagon, 2014; Smith & Tyler, 2011). In addition to that, assistive technologies have proven to be effective tools in designing inclusive evaluation or assessment methods in inclusive learning settings (Loreman, 2017; Morton & Guerin, 2017).

Co-citation Network of Documents

Co-citation analysis is a science mapping technique that uses the frequency with which two documents, authors, or journals are cited together. It aims to connect documents, authors, or journals in a way that reflects the way they are used in a particular science field (McCain, 1990). In this study, a document co-citation analysis was performed. This is a very useful technique in identifying important documents in a research field (Walter & Ribière, 2013). Co-citation of two documents occurs when both are cited in a third document. **Figure 5** presents the documents' co-citation network. Only documents that have been co-cited with other documents were included in the network. Each node represents a document, and its size indicates the number of citations obtained by the respective work from other documents in the network. A link between two nodes indicates a co-citation relationship between two documents. The thicker the link, the stronger this

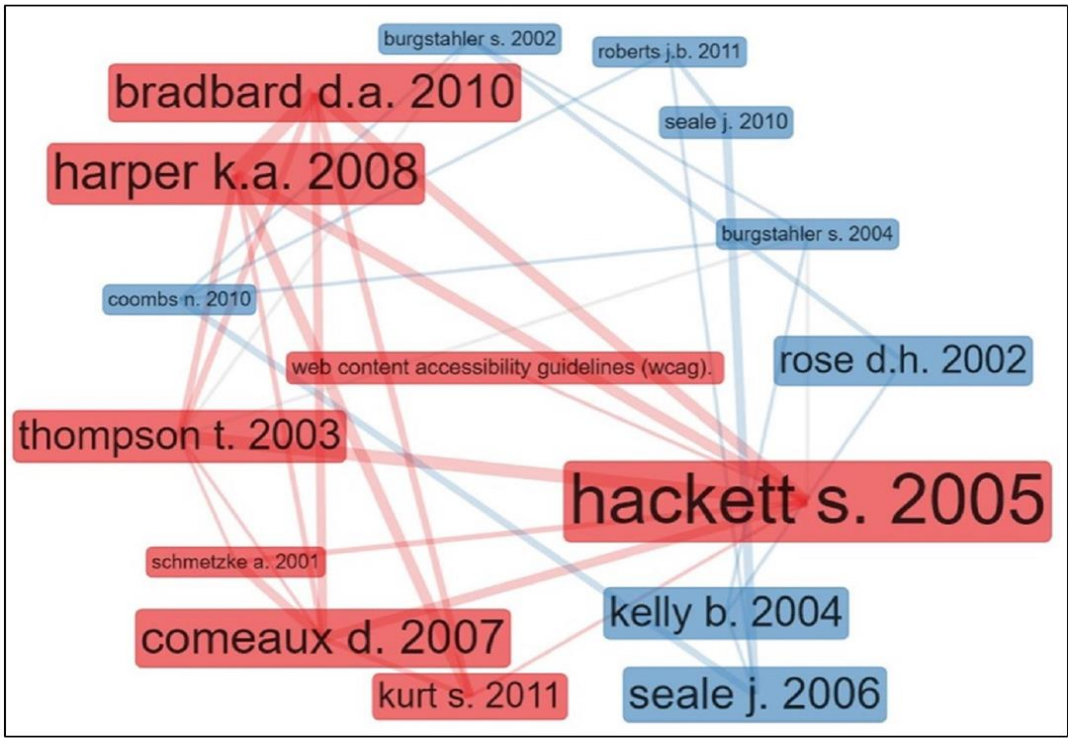

Figure 5. Documents co-citation network

Table 10. Top ten documents with the highest betweenness centralities

Document	Year	Authors	DOI	Cluster	Betweenness
Making distance learning courses accessible to students and instructors with disabilities: A Case study	2004	Burgstahler S., Corrigan B., and Mccarter J.	10.1016/j.iheduc.2004.06.004	2	36.3723087
A longitudinal evaluation of accessibility: Higher education web sites	2005	Hackett S., and Parmanto B.	10.1108/10662240510602690	1	34.62308392
Making online teaching accessible: Inclusive course design for students with disabilities	2010	Coombs N.	NA	2	25.84797667
Research on web accessibility in higher education	2003	Thompson T., Burgstahler S., and Comden D.	NA	1	24.37905823
Distance learning: Universal design universal access	2002	Burgstahler S.	NA	2	15.51506585
A contextualized model of accessible e-learning practice in higher education institutions	2006	Seale J.	10.14742/ajet.1302	2	13.02417812
Developing a holistic approach for e-learning accessibility	2004	Kelly B., Phipps L., and Swift E.	NA	2	7.850087849
Students with disabilities and online learning: A cross-institutional study of perceived satisfaction with accessibility compliance and services	2011	Roberts J., Crittenden L., and Crittenden J.	10.1016/j.iheduc.2011.05.004	2	2.042488543
Web accessibility trends in university libraries and library schools	2007	Comeaux D., and Schmetzke A.	10.1108/07378830710840437	1	1.854085451
A quest for website accessibility in higher education institutions	2008	Harper K., and Dewaters J.	10.1016/j.iheduc.2008.06.007	1	1.135

relationship. The nodes are also grouped into clusters according to their similarities. Thus, the documents in the same cluster have a stronger co-citation relationship.

The co-citation network consisted of two clusters. Each cluster is made up of eight documents. Overall, these 16 documents are the most influential and fundamental in the research area of e-learning accessibility. These 16 documents are not necessarily the most highly cited. However, they have been highly co-cited by other documents. **Table 10** presents the top ten documents with the highest betweenness centralities

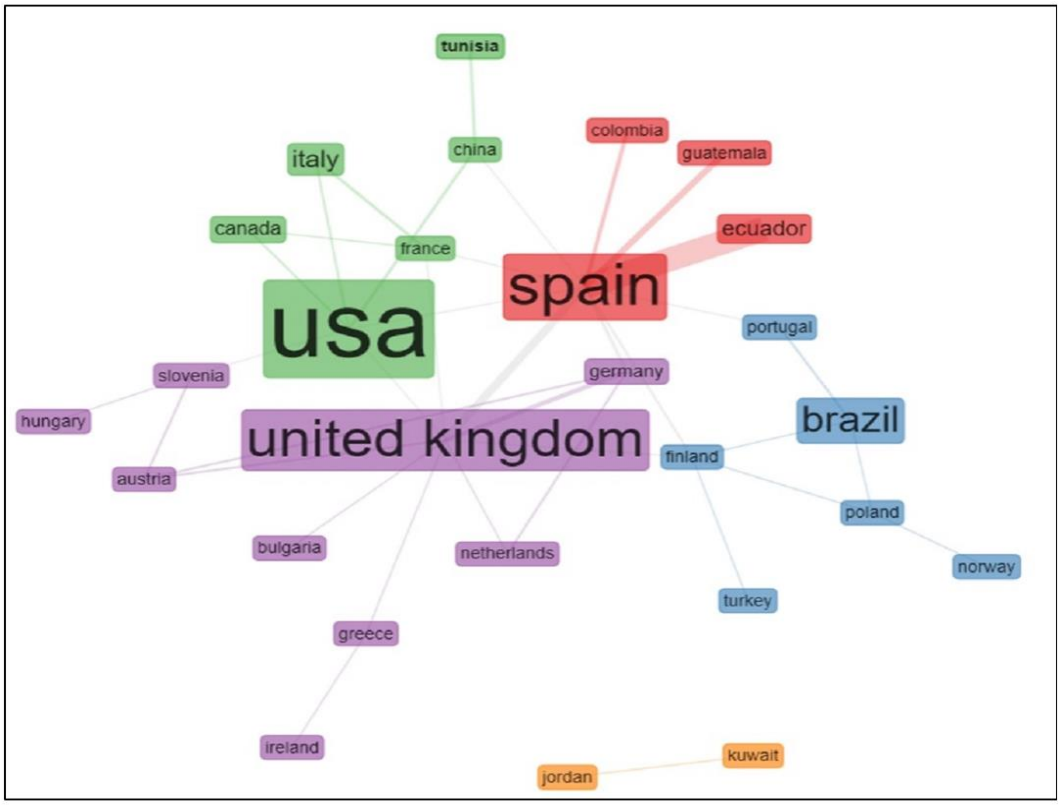

Figure 6. Collaborative research network on e-learning accessibility

The work by Burgstahler et al. (2004) titled "Making distance learning courses accessible to students and instructors with disabilities: A case study", received the highest betweenness centrality (36.37) in the co-citation network. Thus, this work has the most diverse citation relations with other documents of all the published documents on e-learning accessibility.

It is important to note that three documents happen to appear in the ten top ten cited documents and the top ten documents with the highest betweenness centralities within the co-citation network. This indicates that these three documents have had an essential and fundamental role and influence on the development of the e-learning accessibility field. The three documents were, as follows:

1. **A longitudinal evaluation of accessibility:** Higher education web sites. Authored by Hackett, S. and Parmanto, B., and published in 2005.
2. **Web accessibility at university libraries and library schools:** Authored by Schmetzke, A., and published in 2001.
3. **Students with disabilities and online learning:** A cross-institutional study of perceived satisfaction with accessibility compliance and services. Authored by Roberts J., Crittenden L., and Crittenden J., and published in 2011.

Analysis of Countries' Collaboration Network

Figure 6 presents the collaborative research network on e-learning accessibility at the country level. Only countries which have collaborative ties with other countries were included in the network. The network was composed of five clusters. Cluster 1 in red color, cluster 2 in blue color, cluster 3 in green color, cluster 4 in purple color, and cluster 5 in neon orange color included four, six, six, nine, and two countries, respectively.

Overall, the analysis demonstrates a weak international research collaboration in the field of e-learning accessibility. According to the betweenness centrality measures of the collaboration network, Spain is the most prolific and influential country on e-learning accessibility research, followed by the UK, Finland, USA, and Slovenia**.** **Table 11** presents the top 10 countries with the highest betweenness centralities in the international collaborative research network.

Table 11. Top 10 countries with the highest betweenness centralities in the collaborative research network

Node	Cluster	Betweenness
Spain	1	125.322413
UK	4	112.1190088
Finland	2	74.68666667
USA	3	53.48920749
Slovenia	4	24.53863636
Poland	2	23
China	3	23
Greece	4	23
France	3	16.66344538
Austria	4	14.26033414

CONCLUSION

This bibliometric study provides a comprehensive review of the development and structure of research on e-learning accessibility. A total of 1,325 documents, retrieved from Scopus database, were analyzed. The timespan of the documents was from 1985 to 2021. This indicates that the scientific publications on e-learning accessibility were commenced as early as the mid-80s in the last century which reflects the importance of this topic. Conference papers are the dominating source of scientific literature on e-learning accessibility followed by journal articles. As regards the language of publications, English was the absolute predominant language of published documents on e-learning accessibility. Concerning citations, the average years for a document to be cited was 7.36 years, the average citations per document were 5.112, and the average citations per year per document were 0.6576. In addition to that, the dataset included 2,839 authors with 3,896 author appearances, authors of single-authored documents were 176, and authors of multi-authored documents were 2,663. Finally, the author collaboration index was 2.53, single-authored documents were 271, documents per author were 0.467, authors per document were 2.14, and co-authors per document were 2.94.

Overall, the number of publications on e-learning accessibility is growing and is expected to continue to increase in the future. The number of publications on e-learning accessibility began to surge significantly since the year 2001. This could be attributed to the established legislation and standards and increased level of awareness among stakeholders on e-learning accessibility. The year 2020 witnessed the highest number of publications and this might be due to the COVID-19 pandemic where institutions around the world were obligated to adopt e-learning.

USA is the absolute leader in e-learning accessibility research. The University of Washington stands out as the most productive institution in the discipline. Concerning the international collaboration on e-learning accessibility research, it is weak, and Spain is the most collaborative country. Developed countries are contributing more than developing countries to e-learning accessibility research. Thus, international collaboration should be strengthened, and more focus on developing countries is warranted.

Research trends as shown by the analysis of author keywords elucidated that research on e-learning accessibility has predominantly addressed five research themes including accessibility, disability, web accessibility, higher education, and distance learning. The further analysis of author keywords revealed that accessibility, e-learning, disability, usability, and web accessibility are the top five core keywords and are highly connected to other keywords. This result suggests an important future research direction which is examining and evaluating the usability, alongside the accessibility, of e-learning applications.

The thematic analysis of the e-learning accessibility domain revealed that higher education, disabilities, and online learning are the motor themes. Accessibility, e-learning, and disability are the basic themes. Inclusive education, evaluation, and educational technology are the niche themes. Web accessibility, blind, and visually impaired are emerging or declining themes. Obviously, the focus of e-learning accessibility research has been on higher education, and therefore more focus should be given to primary, elementary, and secondary education.

This study contributed to the literature by providing useful information about the e-learning accessibility research status quo and, it should help policymakers to understand the complex interrelationship of e-learning accessibility research to achieve effective research planning. That is, it helps in objectively identifying

strengths and gaps in e-learning accessibility research in terms of its growth, development, themes, impact, and coverage.

Finally, although this study has contributed significantly to the literature by providing performance analysis and a science mapping of research on e-learning accessibility, it has a limitation. Namely, the documents that were analyzed in this study were limited to the sources indexed in Scopus database. Thus, future research should extend the analysis to include other documents published in other sources indexed in other databases. Web of science is a case in point.

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APPENDIX A

TITLE-ABS-KEY ({eLearning} OR {e-Learning} OR {electronic learning} OR {online learning} OR {online education} OR {online instruction} OR {online teaching} OR {on-line learning} OR {on-line education} OR {on-line instruction} OR {on-line teaching} OR {virtual learning} OR {virtual education} OR {distance learning} OR {distance education} OR {remote education} OR {remote learning} OR {web-based learning} OR {web based learning} OR {computer-based learning} OR {computer based learning} OR {internet-based learning} OR {internet based learning} OR {technology-based learning} OR {technology based learning} OR {technology-mediated learning} OR {technology mediated learning} OR {blended learning} OR {b-Learning} OR {bLearning} OR {educational technology} OR {computers in education} OR {computer education} OR {e-Education} OR {m-Learning} OR {mLearning} OR {mobile learning} OR {virtual campus} OR {virtual campuses} OR {massive open online course} OR {massive open online courses} OR {MOOC} OR {MOOCs} OR {online course} OR {online courses} OR {on-line course} OR {on-line courses} OR {virtual course} OR {virtual courses} OR {virtual classroom} OR {virtual classrooms} OR {online classroom} OR {online classrooms} OR {online class} OR {online classes} OR {on-line classroom} OR {on-line classrooms} OR {on-line class} OR {on-line classes} OR {virtual class} OR {virtual classes} OR {online lecture} OR {online lectures} OR {on-line lecture} OR {on-line lectures} OR {virtual lecture} OR {virtual lectures} OR {online school} OR {online schools} OR {on-line school} OR {on-line schools} OR {virtual school} OR {virtual schools} OR {online college} OR {online colleges} OR {on-line college} OR {on-line colleges} OR {virtual college} OR {virtual colleges} OR {online university} OR {online universities} OR {on-line university} OR {on-line universities} OR {virtual university} OR {virtual universities} OR {learning object} OR {learning objects} OR {learning content} OR {learning contents} OR {learning material} OR {learning materials} OR {educational material} OR {educational materials} OR {educational resource} OR {educational resources} OR {learning resource} OR {learning resources} OR {instructional material} OR {instructional materials} OR {teaching material} OR {teaching materials} OR {teaching resource} OR {teaching resources} OR {universal design for learning} OR {universal instructional design} OR {universal design of instruction} OR {instructional design} OR {computer-assisted instruction} OR {computer assisted instruction} OR {computer-based education} OR {computer based education} OR {computer-assisted learning} OR { computer assisted learning} OR {computer-facilitated learning} OR {computer facilitated learning} OR {computer-managed instruction} OR {computer managed instruction} OR {computer-assisted education} OR {computer assisted education} OR {computer support for collaborative learning} OR {rich environments for active learning} OR {rich environment for active learning} OR {self-directed learning} OR {self directed learning} OR {internet-based learning medium} OR {internet based learning medium} OR {adaptive learning} OR {mega-university} OR {mega-universities} OR {connective MOOC} OR {connective MOOCs} OR {c-MOOC} OR { c-MOOCs} OR {cMOOC} OR { cMOOCs} OR {x-MOOC} OR {xMOOC} OR {x-MOOCs} OR {xMOOCs}OR {little open online course} OR {LOOC} OR {little open online courses} OR {LOOCs} OR {small private online course} OR {small private online courses} OR {SPOC} OR {SPOCs} OR {virtual learning environment} OR {virtual learning environments} OR {artificial learning environment} OR {artificial learning environments} OR {interactive learning environment} OR {interactive learning environments} OR {interactive learning} OR {intelligent tutoring systems} OR {personal learning environments} OR {personal learning environment} OR {smart learning} OR {smart education} OR {learning management system} OR {learning management systems} OR {learning content management system} OR {learning content management systems} OR {course management system} OR {course management systems} OR {augmented reality} OR {virtual reality} OR {remote laboratory} OR {remote laboratories} OR {remote lab} OR {remote labs} OR {virtual laboratory} OR {virtual laboratories} OR {virtual lab} OR {virtual labs} OR {smart laboratory} OR {smart laboratories} OR {smart lab} OR {smart labs} OR {digital laboratory} OR {digital laboratories} OR {digital lab} OR {digital labs} OR {electronic laboratory} OR {electronic laboratories} OR {e-Lab} OR {e-Labs} OR {eLab} OR {eLabs} OR {eBook} OR {e-Book} OR {eBooks} OR {e-Books} OR {electronic book} OR {electronic books} OR {eTextbook} OR {e-Textbook} OR {eTextbooks} OR {e-Textbooks} OR {digital book} OR {digital books} OR {digital curriculum} OR {digital curricula} OR {educational game} OR {educational games} OR {Gamification} OR {game-based learning} OR {game based learning} OR {simulation} OR {e-Assessment} OR {eassessment} OR {e-Exam} OR {eexam} OR {e-Exams} OR {eexams} OR {electronic examination} OR {electronic examinations} OR {electronic exam} OR {electronic exams} OR {online examination} OR {online examinations} OR {on-line examination} OR {on-line examinations} OR {online exam} OR {online exams} OR {on-line exam} OR {on-line exams} OR {online test} OR {online tests} OR {on-line test} OR {on-line tests} OR {online testing} OR {on-line testing} OR {computer assisted assessment} OR {computer-assisted assessment} OR {computer based assessment} OR {computer-based assessment} OR {computer-based test} OR {computer based test} OR {computer-based tests} OR {computer based tests} OR {computer-based testing} OR {computer based

testing} OR {online library} OR {online libraries} OR {on-line library} OR {on-line libraries} OR {digital library} OR {digital libraries} OR {electronic library} OR {electronic libraries} OR {virtual library} OR {virtual libraries} OR {e-library} OR {e-libraries} OR {eLibrary} OR {eLibraries} OR ((school or university or universities or college or faculty or faculties or {academic institution} or {academic institutions} or { higher education}) and web)) **AND** TITLE-ABS-KEY (accessibility OR {e-Accessibility} OR {eaccessibility} OR {accessible}) **AND** TITLE-ABS-KEY (disability OR disabilities OR disabled OR impairment OR impaired OR handicap OR handicapped OR {special education} OR {special needs} OR deaf OR {hard of hearings} OR {hard of hearing} OR {hearing disorder} OR blind OR {low vision} OR {mute} OR {speech impediment} OR {speech disorder} OR autism OR autistic OR {cerebral palsy} OR dyscalculia OR dyscalculic OR dysgraphia OR dysgraphic OR dyspraxia OR dyspraxic) **AND** TITLE-ABS-KEY(student OR learner OR pupil OR teacher OR instructor OR tutor OR lecturer OR teaching OR learning OR studying OR tutoring OR education OR kindergarten OR school OR university OR universities OR college OR faculty OR faculties OR classroom OR {academic institution})