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INTEROPERABILITY IN SMART EDUCATION: A SYSTEMIC REVIEW BASED ON BIBLIOMETRIC AND CONTENT ANALYSIS METHODS

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ABSTRACT

The current educational system radically changed during the last years and has become the main theme of education development in the era where technology is changing education. The introduction of these technologies in education has been associated with a rise in the evolution of people's quality of life by improving teaching and learning. In the age of information technologies, developing with modern technology means growing and taking advantage of these new technologies: Mobile technology, Cloud Computing, Big Data, Internet of Things (IoT), Smart campus, Artificial Intelligence, Virtual reality (VR), Blockchain, Social Education, are some of the recent technologies which have been introduced recently in the solutions and infrastructures of the e-learning platforms. Based on a Bibliometric study, this article gives an overview of the research and application of Interoperability in Smart Education, from a bibliometric and content analysis on the use of interoperability in Smart Education over the years.

Keywords: *Smart Education, Interoperability, Bibliometric, E-Learning, Virtual reality (VR), Internet of Things (IoT)*

1. INTRODUCTION

Nowadays, recent technologies have changed the structure of education. The idea of ubiquitous technology has brought many benefits such as the ability to teach and learn anytime and anywhere [1]. This technology gives large data accessibility and that is why the traditional educational systems have been transformed into modern, intelligent systems to provides a smart education environment.

By using new technologies in e-learning, learners can interact with trainers, do online assessments, and get results in real-time [2]. His practical side is one of the main reasons why e-learning is so attractive. Another reason is the ability to personalize your learning experience with other innovations such as augmented reality and virtual reality (VR) [3]. Learners can freely choose content from various providers. The ability to improve quality and security with a diversified use of technologies requires the consistency and reliability of the data integrated into online platforms [4], The need to improve e-learning has become a critical issue. Today, students, teachers, and staff are confronted with different systems and different learning models. Each has its architecture, structure, and data, and we find ourselves unable to make systems communicate with each other to allow the exchange and exploitation of data, which leads us to study the implementation of interoperability in the education sector, which has been a problem for many years [5][6].

This study provides an overview of data collected and analyses performed on the use of interoperability in smart education from the perspective of bibliometrics analysis over years. Following this comprehensive bibliometric and content analysis of studies on interoperability in smart education, we hope that our findings will have an impact on existing and future knowledge by providing a better view of the evolution of interoperability in the smart education environment

over the years. In addition, the study will unveil information on current scientific achievements in this field in terms of advances in interoperability and education in different contexts, which will serve as a knowledge base for future researchers, and allow, new researchers, to benefit from these valuable resources for their future publications.

To carry out our bibliometric study we first analyzed the growth of articles publications and citations, then we addressed the authors, institutions, and the most active countries that publish articles on interoperability in education, we also analyzed existing co-occurrence patterns and the trend of keys-word and thematic result on the research methodology employed on articles that address the topic of interoperability in smart education.

2. INTEROPERABILITY IN SMART EDUCATION

Recently, using TIC in Education has been significantly changing the educational environment and has evolved in the last years. For example, there has been a drastic change in education [7][8], which has been defined as training on traditional boards to computer training, and today we are talking about mobile learning (m-learning) [9], which has been spurred by the evolution of wireless and mobile technologies. m-learning and e-learning are very similar [10], and both have evolved in terms of interoperability and the technologies used.

The evolution of technologies has brought new changes in the educational environment, now we talk about smart learning and smart education environment toward m-learning and e-learning [11]. This smart learning environment allows students to study anytime and anywhere through multiple online learning platforms, without the limitation of time, place, or environment [12]. The education field has also become interested in social learning, using smart technologies and Cloud services [13]. The evolution of smart education is expected to improve the learning environment to an advanced level regarding interoperability, new technologies, pedagogies [14], etc.

The interoperability in smart education is based on agreements and conventions adopted between partners who communicate and exchange data [15]. This interoperability governs both exchange protocols and procedures. This requires, however, a prerequisite: the interconnectivity of technical components based on compliance with and application of it using norms and standards in force [4][5]. This principle broadens the operating framework of interoperability, which now concerns all levels of interaction between technology applications [16], content, and operating procedures of digital information and smart systems at both the local and international levels [17], The design of distributed information systems and interoperable interfaces had strengthened these processes and replaced the old models based on the sectorization of services and the limitation of processes and standards [18]. The evolution of technologies and the challenges of using them have made the interoperability of systems a fundamental issue for companies and universities. Beyond its technical dimension, the real challenge of interoperability lies in the freedom that each user should have to choose the solutions that would best suit his needs and those of his environment so he can permanently have information resources regardless of the technology used.

3. BIBLIOMETRIC MAPPING ANALYSIS

Methods

This study focused on bibliometric mapping analysis using recommendations and workflows based on bibliometric mapping analysis (Aria and Cuccurullo, [19]). Our study is based on 3 phases: *Data Collection: Data Loading & Converting; Data Analysis & Synthesis; Data Result and Visualization from Bibliometric Mapping Analysis.*

3.1. Data collection: Data Loading & Converting

First, we started with the selection of our databases, we started by performing a literature search in the Scopus, Web of Science (WoS), PubMed, and ERIC databases. However, we focused on two databases Scopus and WoS which cover many articles and provide higher records in terms of citations. The advanced search parameters on both databases use binary operators such as "OR" and "AND". To carry out the huge data collection needed for this study, we defined search keywords such as smart education, e-learning, m-learning, and Interoperability, with multi-criteria, Table 1 shows the details of the research protocol and the combinations used, as well as the result obtained.

After extracting two databases, we used R-studio software which includes a set of bibliometric tools containing the R-package developed in the R language [19], which uses high-performance algorithms to perform statistical and scientific cartographic analyses as well as a "Biblioshiny"

Web Interface. This interface allowed us to import our merged data in BibTex format to perform our scientific analysis.

Table 1. Data advanced search with Criteria

Database	Criteria	Advanced Search	Results
Scopus	- Advanced search - Relevant articles - Documents are written in the English Language - Date of publication after 2001 - Articles in journals, and conferences. - Articles with publication stage "in press." - Articles limited to Computer Sciences, Education, and Engineering.	*(TITLE-ABS-KEY("Smart Education" OR "e-learning" OR "m-learning") AND TITLE-ABS-KEY("Interoperability")) AND PUBYEAR > 2001 AND (LIMIT-TO (DOCTYPE,"cp") OR LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"DECI")) AND (LIMIT-TO (LANGUAGE,"English"))*	**221**
Web of Science		*TS= ("Smart Education" OR "e-learning" OR "m-learning") AND TS=("interoperability") and Proceedings Papers or Articles (Document Types) and Computer Science or Education Educational Research or Engineering (Research Areas) and 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2012 or … (Publication Years)*	**268**
64 duplicated documents were removed for this study			**489**

Table 2. Data conversion and merging steps

Steps	Instructions on How to Merge Data Using R-Studio
1	Extract data in BibTex format from WoS and Scopus databases.
2	Save data in a file
3	Install Bibliometrix Packages by running the script > install.packages("bibliometrix")
4	run the script > library(bibliometrix)to import the Bibliometrix library
5	Open the file created in Step 2, running the script > setwd ("C:/…/Name of the file created in Step 2")
6	Save data in the same file created in Step 2

After completing the instructions in Table 2, we have run Scripts like in Figure 1:

```
> getwd()
> Scopus_BD=convert2df("Scopus.bib",dbsource = "scopus",format = "bibtex")
//* Script of data conversion
> View(Scopus_BD)
//* Script to View Data
> Web_of_Science_BD=convert2df("wos.bib",dbsource = "wos",format = "bibtex")
> View(Web_of_Science_BD)
>MergedDataBase=mergeDbSources(Scopus_BD,Web_of_Science_BD,remove.duplicated = TRUE)
//* Script of data merging + removing duplicated data
//*64 duplicated documents have been removed
> View(MergedDataBase)
> dim(MergedDataBase)
//* Script to show the dimension of our Merged Data
> library(openxlsx)
> write.xlsx(MergedDataBase,file = ("GlobalDataBase.xlsx")
//*Script for saving Merged Data
```

Figure 1. Detail of Scripts

Removing duplicated documents left the remaining data at 425 Figure 2, these data were uploaded to the "Biblioshiny" interface to perform our bibliometric mapping analysis.

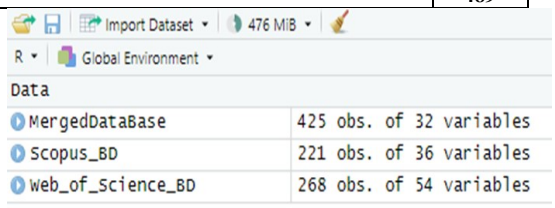

Figure 2. shows the output of the executed script

3.2. Data Analysis & Overview

Table 3 presents the summary information of the bibliometric analysis dataset. It reveals the number of document types in the collected data. Conference documents (n = 167) are the highest number of document types. This is followed by articles (n = 89). Other types of documents accounted for the remaining 169. To analyze the content, we examined all the data based on advanced shears in Table 1.

Table 3. Main Information overview

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2002:2022
Sources (Journals, Books, etc)	310
Documents	425
Average years from publication	11,6
Average citations per document	4, 692
Average citations per year per doc	0,4386
References	7984
DOCUMENT TYPES	
Article	89
Article; proceedings paper	18
Conference paper	167
Proceedings paper	150
Review	1
DOCUMENT CONTENTS	
Keywords Plus (ID)	1639
Author's Keywords (DE)	1017
AUTHORS	
Authors	1056
Author Appearances	1335

Authors of single-authored documents	37
Authors of multi-authored documents	1019
AUTHORS COLLABORATION	
Single-authored documents	38
Documents per Author	0,402
Authors per Document	2,48
Co-Authors per Documents	3,14
Collaboration Index	2,63

This section presents our results of bibliometric analysis based on data from the databases of indexed journals including Web of Science (WoS) and Scopus. This result provides a global overview of the evolution of interoperability in smart education over the years 2002 to May-2022. Moreover, the result shows the most active authors, institutions, and countries that have marked their contribution in terms of publications related to interoperability and smart education.

3.3. Data Result and Visualization from Bibliometric Mapping Analysis

3.3.1 Annual Scientific production Publishing on this Study

Interoperability in smart education seems to begin in 2002 with the contribution of ANIDO L & HATALA M, being the first two and only papers published that year. Bibliometric analysis shows that the field of smart Education and interoperability had an annual growth rate of 47.52% in scientific output from 2002 to 2010, this annual growth has seen a decrease between 2011 and 2021 (Figure 3), however, the year 2022 saw the publication of a single article by KIM H being the only article and the last contribution published until May-2022 in the field of Interoperability in smart education.

In 2009 and 2010, 52, 48 articles were published, making them the highest number of publications per year recorded to date, indicating the impressive evolution of publications in the field of smart education and interoperability. This growth became drastic after 2010 when a total of 198 articles were published. This regression has probably occurred because current research addresses new technology trends in smart education, however, interoperability remains the focal point that connects all these technologies and allows smart systems to be interoperable with each other. Without forgetting that our study is based on a selection of articles from Scopus and WoS databases and was limited to education and computer science, leaving aside other areas, such as health, business, sociology, and media...

In 2019 15 articles were published compared to 2018 which saw just the publication of 7 articles, this evolution between 2018 and 2019 is explained by the enormous need that has known the world in terms of e-learning caused by the COVID-19 pandemic. Given that the field of Interoperability in smart education tends to evolve using new technologies, it is expected that the scientific contribution will continue to grow every year, especially in the use of emergent technologies in this field. Also noting that the years between 2010 and May-2022 have seen an evolution in terms of online learning systems (LMS, MOOC, etc.) and progressive evolution in terms of interoperability [20].

For the number of citations of interoperability in smart education publications, Figure 4 shows the average citation of articles per year. The result shows that the year 2002 which stands out for the publication of two articles, which seem to be the beginning of research on the field of interoperability and smart education, received an average of 1.13 citations. This means that the contribution of the authors ANIDO L and HATALA M [21], had a good impact in this area. The average citation experienced a sharp drop in the year 2003 until 2007 which saw a slight increase of 0.57, which suddenly dropped to 0.16 in 2008 for an increase again in 2009 of 0.58. However, the average number of citations per year increased to 1.18 in 2018 and 2.24 in 2019, which remains the highest number of citations recorded so far. This number decreased sharply to 0.36 in 2020 and increased to 1.31 in 2021. However, we could explain why this decrease in 2020 is due to the COVID-19 pandemic, during which annual scientific output during that year did not increase as much (Figure 3).

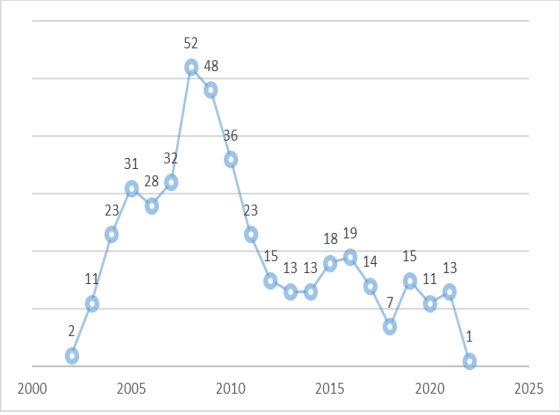

Figure 3. Annual scientific production of articles on Interoperability in smart education

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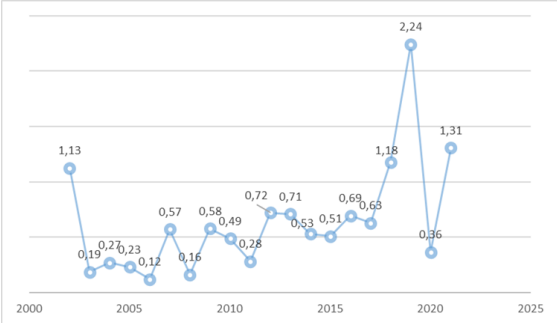

Figure 4. Average Citations per Year

3.3.2 Most Active Authors, Institutions, and Countries Publishing Articles on the use of interoperability in smart education.

The results of the top 20 prolific researchers in the field of smart education and interoperability from 2002 to May-2022 it's based on the processing in Figures 5 and 6. These researchers have shown a stable contribution to scientific production in this field. The result revealed that LEAL J and QUEIROS R of Portugal had produced a total of 12,11 documents respectively, LEAL J, obtained the highest h-index (Figure 6), suggesting that LEAL J, remains the most impactful author in the area of smart education and interoperability. The first article of LEAL J was published in 2010 [22], with an average of citations per year of 0.38, his latest article was in 2019 [23] had an average citation per year of 0,25. Although the result shows that LEAL J does not yet have a publication after 2019, he had a regular contribution in this area between 2010 and 2019. The second most prolific researcher in this area is DEHBI R from Morocco, which has a total of 6 publications, DEHBI R started publishing in the field of interoperability in smart education in 2016, where he published his first article in 2016 and another in 2017, then 3 articles in 2019 and the last one was in 2020, DEHBI R scored 3 in h-index (Figure 6), he is still the most recent author in this field.
MARTINEZ J from Spain, which has a total of 8 publications, become inactive for a langue period (2013-2022). Finally, the year 2022 shows that only one work has been published, that of KIM H from Korea, these articles were published respectively in 2006, 2008, 2014, and 2022.

However, most of these authors did not have any publications between the last two years 2020 to May-2022. Other leading researchers in this field and their scientific outputs are shown in Figures 5 and 6.

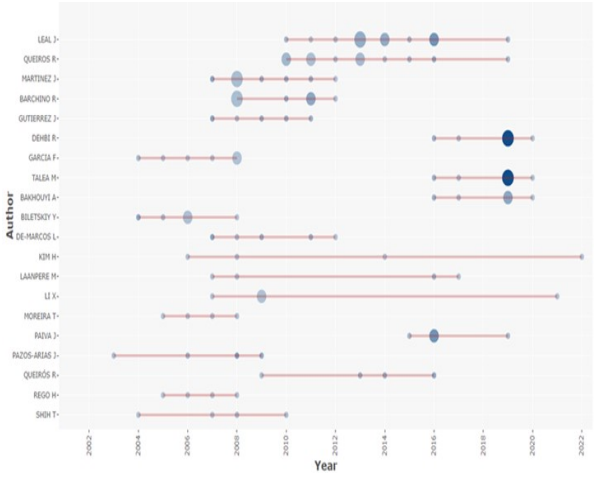

Figure 5. Top 20 authors' productions over years; the number of articles is indicated by the size of the circles

Figure 6 shows that the top 20 authors are between the years 2015 to 2021. The average of the m-index during this period is 0,41, the authors having an average greater than 0.41 respectively (CAEIRO R M, DÍAZ R R, FERNÁNDEZ V A, GIANNAKOS M, KOSTAKOS P, LÓPEZ E J, MANGAROSKA K, VESIN B, DEHBI R, TALEA M).

The result also shows us the assignment between the authors and the most frequent keywords of our research as well as their countries of origin, however, the analysis shows us that the keywords most used by the authors are "interoperability" and "e-learning" and the country that contains multiple authors in this area is Spain (Figure 7).

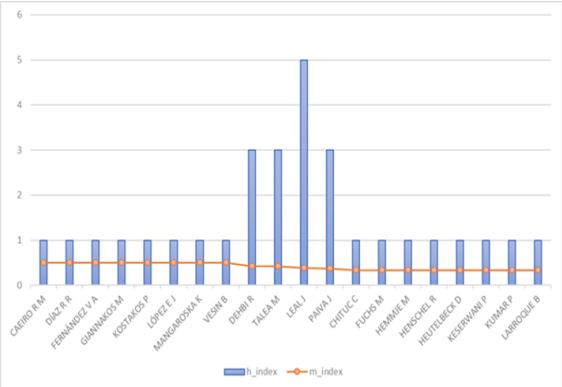

Figure 6. Top-20 authors' impact by H&M-index analysis within 20 years

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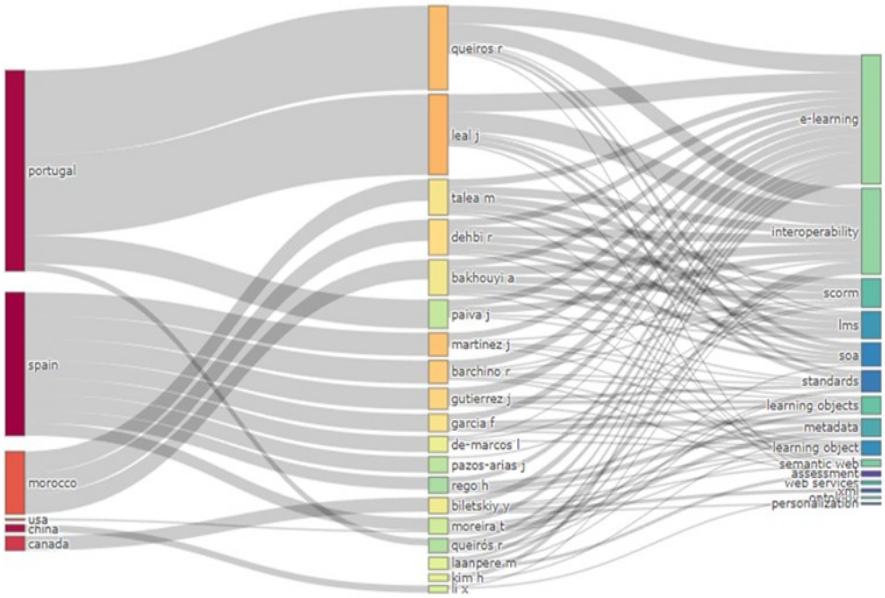

Figure 7. Three-Fields Plot of active Auteurs and countries publishing articles related to Keywords

This analysis also shows some top institutions and countries fronting Interoperability and E-learning. As shown in Figures 7 and 8, some of these universities, were the Hassan II University (Morocco), University of Porto (Portugal), and University of Salamanca (Spain).

This study has shown an advanced analysis of scientific production in the field of smart education and Interoperability in all the most active countries. Figure 8 shows that Spain and Portugal have the highest number of publications in Europe, followed by Morocco, the only active country in Africa that also contributes to this field. However, Ireland, France, and the Netherlands contribute substantially to this area. Canada and the USA in their turn contributed to the field of smart education and Interoperability, without forgetting China, which is also contributing.

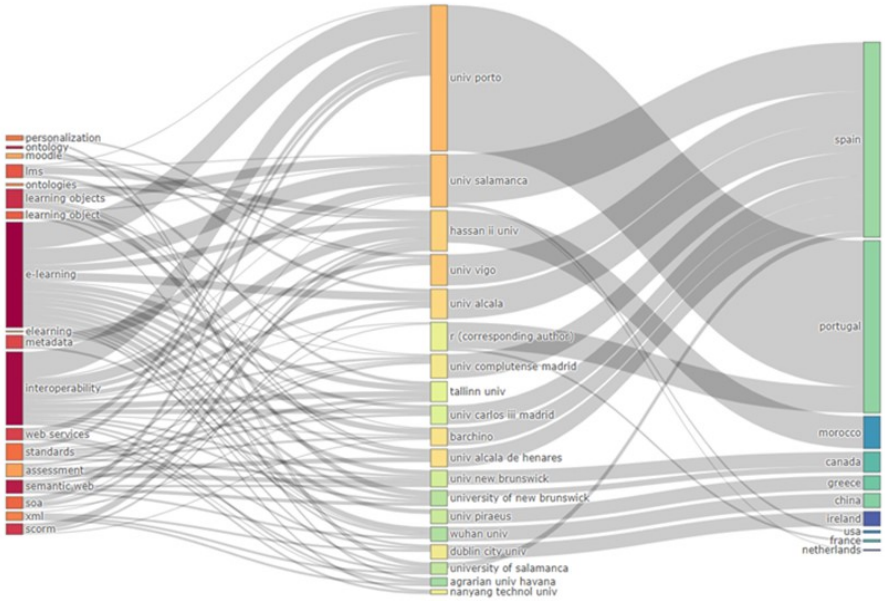

Figure 8. Three-Fields Plot of active institutions and countries publishing articles related to keywords

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The analysis also shows the top 10 most active universities in this field, we will mention the first three Universities that contributed to smart education and interoperability respectively the University of Porto in Portugal, the University of Salamanca in Spain, and Hassan II University in Morocco (Figure 9).

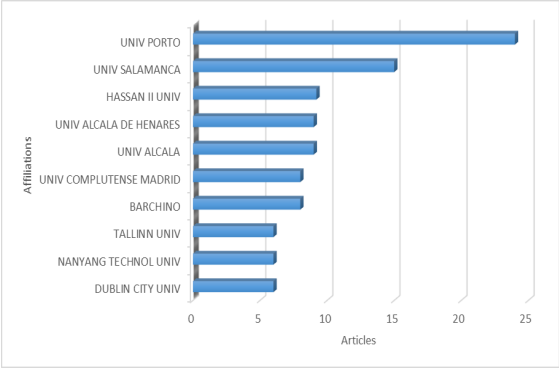

Figure 9. Top-10 Most Relevant Affiliations

3.3.3 Keywords Analysis, Networks Mapping, and Trending topics of this Study

The network map between keywords focuses on understanding a scientific field's knowledge components and structure by examining the relations between keywords in the same field. Figure 10 reflects the relations generated between keywords from studies on the use of interoperability in smart education. Figure 10 shows three distinct clusters, each with a different color and size "Interoperability & e-learning red, Education blue, and Learning systems green".

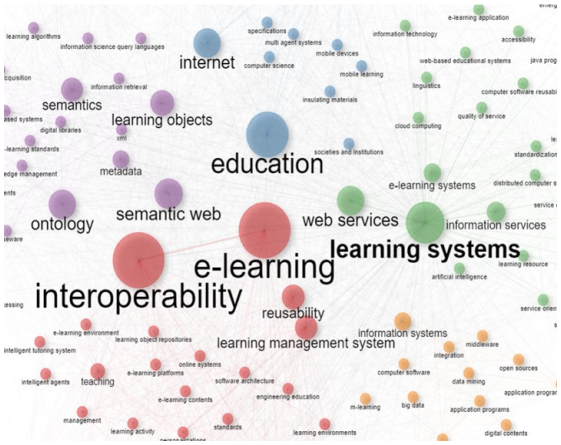

Figure 10. keywords co-occurrence Network: show the highest number of using repetitive keywords

The analysis also shows us the result of thematic evolution over years figure 11, we can see that some thematics have disappeared over the years like "distributed environment", and "metadata" and others have remained stable us "interoperability" and "e-learning".

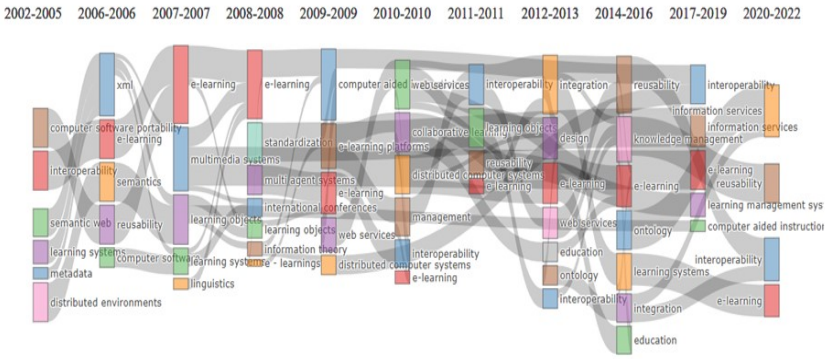

Figure 11. Thematic Evolution

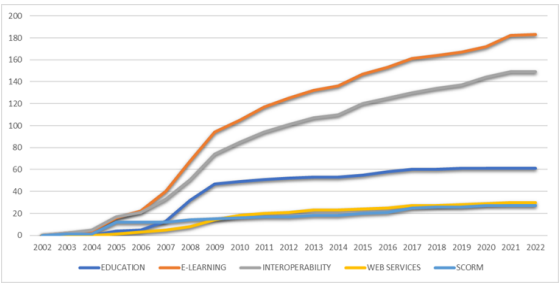

Figure 12. Top 5 Dynamic keywords evolution over time

The analysis of the most frequent Keywords in publications is an essential tool for studying trending topics. The use of these keywords allows us to identify and focus on the purpose of this study. The Word Cloud in Figure 13 shows the most frequent keywords used for interoperability in smart education.

However, interoperability and e-learning have become the most used keywords from 2002 until 2022. This finding means that interoperability and education environment analysis was and will be the

trending topic as an aspect of smart education. In addition, the network mapping presents the relations between keywords in this study, which gives a global overview of the knowledge base in this field. Therefore, our result shows that beyond identifying frequent keywords, as shown in the Word Cloud (Figure 13), Network mapping revealed the connections between them (Figure 10).

By carefully examining these keywords from their color-coding, dimension, and connections, we can deduce three focal points namely e-learning, interoperability, and education. E-learning and interoperability connect directly to education, relying on different standards and different emerging technologies, such as Cloud Computing, Web services, Scorm, Semantic Web, Artificial intelligence, Bigdata, Data mining, and m-learning…, This finding suggests that the field of intelligent learning will continue to be studied around these dominant aspects.

Figure 13. Word cloud of a trending topic

The analysis of these keywords has shown that most of the articles only talk about e-learning more than m-learning, which shows the lack of contribution concerning m-learning.

3.3.4 Relevant Sources and Documents of this Study

About the relevant articles registered in the field of interoperability and smart education, this study focused on the overall citation that measures the number of citations for an article in all the databases of our study. The overall citation also examines the impact of an article, that could receive citations in other disciplines as well [19]. The analysis has also shown that the most cited article in the world between 2002 and May-2020 comes from the article published by Dagger, O'Conner, Lawless, Walsh, and Vincent P with a total of 200 world citations. The work of these authors focused on the use of Web services in e-learning Platforms, they studied the evolution of standards and online learning platforms with a focus on interoperability challenges [24]. In addition, the result shows the 10 most cited articles in these study datasets (Figure 14).

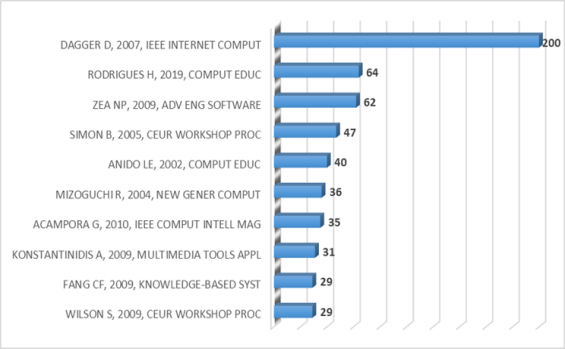

Figure 14. Top 10 distribution of articles by relevant sources from 2002 to May-2022

About the most relevant sources registered in the interoperability and smart education field. Figure 15 shows that "Ceur Workshop Proceedings" is on the top of the relevant sources in this field, flowing by the "Communications In Computer And Information Science".

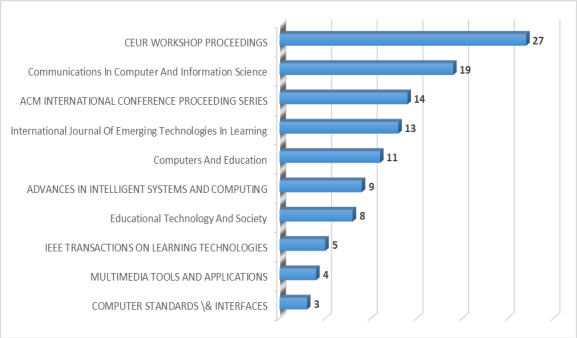

Figure 15. Top 10 distribution of relevant sources from 2002 to May-2022

4. DISCUSSION

An unprecedented study on an in-depth review of scientific publications in the field of interoperability in smart education over time using bibliometric analysis examined all publications from 2002 to May-2022 have been carried out. On the area of using interoperability in education, an analysis of scientific output and authors' contributions was explored, with a focus on the most active authors, institutions, countries, and regions. Subsequently, an analysis of keywords and trends topics was presented, then a thematic analysis of smart education and interoperability showing the status of publications and their prospects.

A total of 425 documents were extracted from two WoS and Scopus databases for this study. This work makes several important contributions to

scientific production. First, the study found that the first two papers on interoperability in smart education were published in 2002, which perhaps means the beginning of research on interoperability in smart education. Relevant publication points were identified in this study. At the forefront of the publication sources revealed by the study is the "*Ceur Workshop Proceedings*" followed by the "*Communications In Computer And Information Science*" This result allows researchers to identify the appropriate publication source for their research articles in this field.

In addition, a survey of relevant published articles revealed that the work of LEAL J, QUEIROS R, and DEHBI R, stands out; these authors mainly work around interoperability and a smart education environment. Their work will perhaps pave the way for discussions, and collaborations on interoperability characteristics from the point of view of technology and education.

Similarly, our result indicates that Spain and Portugal followed by Morocco have the highest number of scientific productions in the field of interoperability and smart education over the years. This suggests that Spain, Portugal, and Morocco have remained the most relevant countries in this area. In terms of contributions and relevance of institutions, the University of Porto in Portugal is at the top of the list followed by the University of Salamanca in Spain, and Hassan II University in Morocco. When it comes to active researchers who make a huge production to the field of interoperability in smart education, Portugal's LEAL J is at the top of the list with an h-index of 5. In addition, researchers such as DEHBI R, TALEA M, PAIVAJ, and QUEIROS R have established a broad contribution.

As well, the study revealed that the field of interoperability and smart education is related to several emerging and growing aspects and technologies such as "Cloud Computing", "Artificial intelligence", "Big data", "Data mining", "Web services", "Semantic Web", "Scorm", and "m-learning". The thematic analysis results show that the predefined themes can be the subject of future publications in the field of interoperability in smart education, especially in this field linked by TIC technologies and emerging technologies, these technologies need to be further developed for better interoperability in smart environments including mobile as an example. The study also showed that over the years, "interoperability & e-learning" remains a trending topic. Interestingly, new topics related to interoperability in the air of smart education, such as Scorm, and the Semantic Web, have emerged and have become research hotspots in interoperability in smart education. These findings underscore the importance of further research to leverage the Semantic Web and Scorm in the future. As part of our conclusion, the studies also show a lack of collaboration between researchers and institutions. In this sense, international collaboration remains an essential vector for the visibility and quality of scientific production, thus creating a more global impact on the potential of interoperability in smart education for an improved learning experience. It is also suggested that researchers invest more effort in the study of interoperability with relevant analyses on new standards and technologies dedicated to smart education that will surely make topics for future research.

5. LIMITATIONS

The study has some limitations. The main weakness of the study concerns the collection of sample data. It should be acknowledged that the results are rooted in merging the two databases, WoS & Scopus and that only publications in these journals were considered. This may result in absence of some relevant data. Despite the limitations, our work hopes to have an impact on scientific production in the field of smart education.

6. CONCLUSIONS

This is the first in-depth study on progress in this area from an interoperability perspective. Trend analyses of publications and citations indicate a huge need for interoperability research and its great value in the evolution of smart education. The findings from active authors, institutions, countries, and journals will help researchers identify appropriate focal points and channels for their future publications and opportunities for future collaborations. Our study also contributes by displaying the state of research and development in the field over the years, which will allow researchers to become more aware of research hotspots while making decisions about the topic to be addressed.

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