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Global research on ubiquitous learning: A network and output approach

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Abstract

Ubiquitous learning refers to the advancement of online learning, adapted to the development of communication and informatics. The study aimed to carry out a bibliometric approach to ubiquitous learning worldwide indexed in Scopus from 2003 to 2023. Methodologically, it was a quantitative, bibliometric study. Scientific output indicators were generated from 2668 selected Scopus papers using English keywords ("ubiquitous" AND "learning"). From 2007 to 2023, the number of published documents increased (90.9%), indicating a growing interest in the subject of study. The United States has the highest scientific production (21%), and the CNRS Centre National de la Recherche Scientifique has the most publications (n=39). The journal IEEE Access received 2514 citations, with the author Cook, D.J. (n=532) being the most cited. It is concluded that the orientation on ubiquitous learning is dynamic and increasingly linked to the development of information and communication technologies (ICT), as this learning style uses technology to give students more independence over their learning process.

Keywords: ubiquitous learning, u-learning, bibliometrics, scientific output

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1. Introduction

The advent of the Internet and other forms of digital technology in recent decades has led to significant social changes that have contributed to shaping a new cultural paradigm.[1] Consequently, the digital era can be defined as a technological civilization in which the continuous and irreversible advancement of digital technology and the Internet has altered human behavior and organizational and productive paradigms.[2]

In that order of ideas, a new way of life in a networked society has emerged due to technological advances.[3] In this sense, the extension of the digital revolution has had an impact on education as a process based on knowledge, social interactions, and communication, causing modifications and transformations in the educational environment and the actors that compose it, such as teachers, students, and the educational institution.[4–6]

On the other hand, the advantage of mobile devices over previous technologies for learning is important. Thanks to their connectivity, they can be used in formal and informal educational contexts, alone or in collaboration with others.[7] Due to this portability, new pedagogical approaches and lines of research have emerged, such as ubiquitous learning (u-learning).[8,9] Firstly, ubiquity in learning is recognized

when the same student can be virtually present in different places simultaneously.[10,11] Similarly, the importance of decentralization and timelessness in ubiquitous learning has been emphasized since it opposes the linear vision of learning because it not only optimizes different times but also uses a variety of technologies and modalities to achieve its objectives.[12–14]

Due to the widespread availability of information and communication technologies (ICT), ubiquitous learning can be considered an educational model that characterizes societies whose access to information is not restricted, which in turn are well-informed and equitable, and balanced.[15–17] Thus, ubiquitous learning, in all its forms (e-learning, m-learning, b-learning, and u-learning), is the dominant educational model in knowledge societies due to the importance of ICT as didactic means, learning resources, and basic components of virtual learning environments.[18–21]

Given the importance of the topic, various research studies have been conducted to establish the foundations or provide answers regarding ubiquitous learning and the changes that will facilitate the introduction of new learning forms in the current model of activities.[22–25] As a result, bibliometric indicators have been developed to provide numerical measures of the data collected through the metric analysis of scientific production linked to various academic disciplines.[26–28]

In this context, "bibliometrics" refers to calculating and analyzing quantitative data on literary works and other forms of published material.[29–32] That is, bibliometric analysis allows researchers to track the evolution of scientific literature, draw conclusions about the influence of published documents, and, more importantly, allocate resources appropriately.[33–35] Additionally, scientific data collected and preserved in databases are analyzed through meta-analysis to reveal patterns, relationships, trends, and indications in this field and to provide reliable data about the people and procedures involved in scientific discovery.[36,37]

Considering the changes that occur due to the emphasis on localized and contextualized learning, shortly, teachers and students are expected to be present across multiple digital platforms.[38,39] Therefore, it is important to explain and represent the academic community's understanding of trends in ubiquitous learning by categorizing information according to the year of publication, country, thematic area, document type, source, and authorship. Based on this premise, the study aims to conduct a bibliometric approach to ubiquitous learning worldwide indexed in Scopus from 2003 to 2023.

2. Methods

A bibliometric study was conducted on scientific papers published worldwide on ubiquitous learning in the last twenty years (2003-2023). Bibliometrics was used for this data analysis to present qualitative and quantitative results.[40–44] Additionally, the information used was extracted from Elsevier's Scopus database.

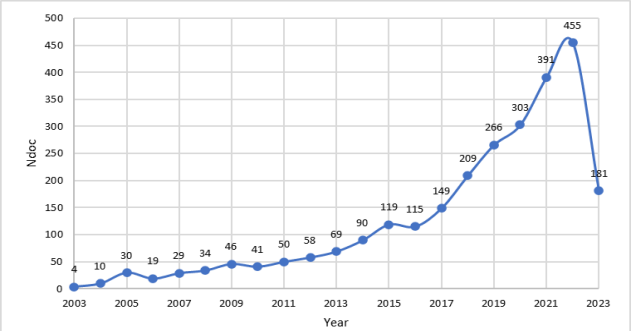
Regarding the information selection process, an exhaustive search was performed on the abstract, title, or keywords of articles using the search terms "ubiquitous" AND "learning".[28,45] Subsequently, the resulting metadata was extracted after applying filters based on various descriptors, such as publication year (2003-2023) and document type. In this way, a subset of 4020 documents was obtained, from which a sample of 2668 documents was extracted for analysis after duplicate exclusion and metadata normalization.

Finally, a co-occurrence analysis was conducted, examining the relationships between keywords and other general categories of scientific production. In this regard, the focus is on the quantitative analysis of bibliometric data,[46] providing details such as publication year, source or journal, country of origin, author, document type, thematic area, and institutional affiliation of the author, all related to ubiquitous learning at a global level. Descriptive statistics were also collected and analyzed in Excel, and the co-occurrence map data was visualized using VOSviewer V_1.6.19.

3. Results

For the development of the bibliometric analysis, 2668 documents from Scopus on ubiquitous learning published between 2003 and 2023 were chosen. As shown in Figure 1, from 2007 to 2022, the scientific community had exponential growth in producing 2424 documents, representing 90.9%. Likewise, the years with the highest publication were 2022 (n=455), 2021 (n=391), and 2020 (n=303), which together represent 43.1% of all worldwide publications during the chosen period.

Figure 1. Documents published by year



Source: Scopus data (2023)

Table 1 summarizes the contributions of 105 countries in scientific production, highlighting the regions where the largest number of studies on the subject have been published. The United States ranks first with 21% (n=850) of the published papers, followed by the United Kingdom (10%) and China (10%). In addition, the predominant language of publication in 96% was English, while only 4% were in Spanish and Portuguese.

Table 1. Publication of documents by country

N°	Country	Ndoc	%Ndoc	N°	Country	Ndoc	%Ndoc
1	United States	830	21%	18	Portugal	48	1%
2	United Kingdom	401	10%	19	Singapore	47	1%
3	China	388	10%	20	Malaysia	42	1%
4	Germany	187	5%	21	Brazil	40	1%
5	Spain	152	4%	22	Pakistan	38	1%
6	Australia	139	4%	23	Belgium	35	1%
7	Canada	127	3%	24	Finland	34	1%
8	India	101	3%	25	Ireland	34	1%
9	Italy	98	3%	26	Norway	33	1%
10	France	97	2%	27	Austria	31	1%
11	Japan	85	2%	28	Greece	27	1%
12	South Korea	76	2%	29	Turkey	26	1%
13	Switzerland	75	2%	30	South Africa	25	1%
14	Switzerland	70	2%	31	Egypt	24	1%
15	Saudi Arabia	58	1%	32	Hong Kong	24	1%
16	Taiwan	54	1%	33	Indefinite	393	10%
17	Sweden	51	1%	**Total country**		**105**	

Source: Scopus data (2023)

This study's sample of scientific papers comes from 160 different data sources. Table 2 shows the top journals regarding the number of articles on the topic studied. With 169 articles, Lecture Notes in Computer Science outnumbered most of the journals, compared to IEEE Access (n=109), Plos One (n=49), Sensors Switzerland (n=47), and Sensors (n=43). In addition, there is a preponderance of journals published in the United States and the United Kingdom, which have a high impact factor, and the vast majority are in the top two quartiles.

Table 2. Publication of documents by source or journal

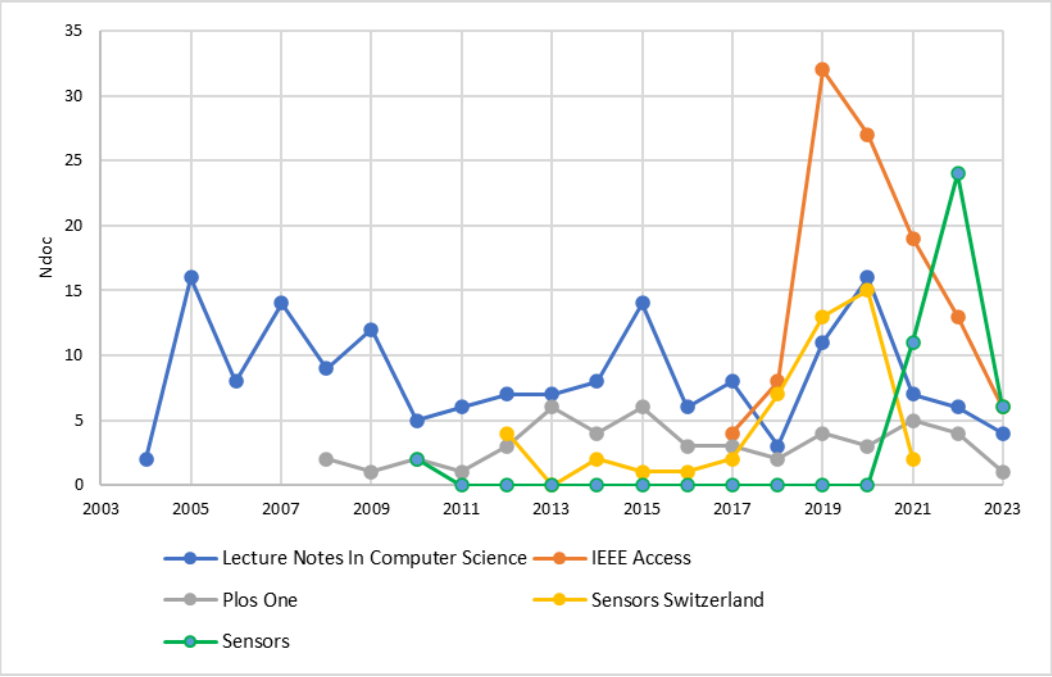
Source	Ndoc	Source	Ndoc	Source	Ndoc
Lecture Notes in Computer Science	169	Education Sciences	16	Lecture Notes in Electrical Engineering	11
IEEE Access	109	IEEE Internet of Things Journal	16	Neurocomputing	11
Plos One	49	IEEE Transactions on Learning Technologies	16	Elife	10
Sensors Switzerland	47	International Journal of Interactive Mobile Technologies	16	International Journal of Advanced Computer Science and Applications	10
Sensors	43	Plos Computational Biology	15	Pervasive and Mobile Computing	10
Scientific Reports	38	Proceedings of the ACM on Interactive Mobile Wearable and Ubiquitous	15	BMC Medical Education	8

International Journal of Emerging Technologies in Learning	28	Technologies IFIP Advances in Information and Communication Technology	14	IEEE Sensors Journal	8
Sustainability Switzerland	26	Nature Communications	14	Communications in Computer and Information Science	7
Applied Sciences Switzerland	21	Personal and Ubiquitous Computing	12	Computational Intelligence and Neuroscience	7
Proceedings of the National Academy of Sciences of The United States of America	21	Wireless Communications and Mobile Computing	12	Comunicar	7
Electronics Switzerland	20	Advances in Intelligent Systems and Computing	11	Education and Information Technologies	7
Frontiers in Psychology	20	Computers Materials and Continua	11	Otras fuentes	537
Journal of Neuroscience	17	Current Biology	11	**Total sources**	**160**

Source: Scopus data (2023)

On the other hand, Figure 2 shows the trend of global articles published in the five most prominent journals on ubiquitous learning. In particular, the journal Lecture Notes in Computer Science records a steady publication of papers from 2004 to the present, with 2020 having the most published papers (n=16). Similarly, between 2017 and 2023, 109 scientific papers were published in the IEEE Access Journal, with 2019 being the year with the most scientific production (n=32).

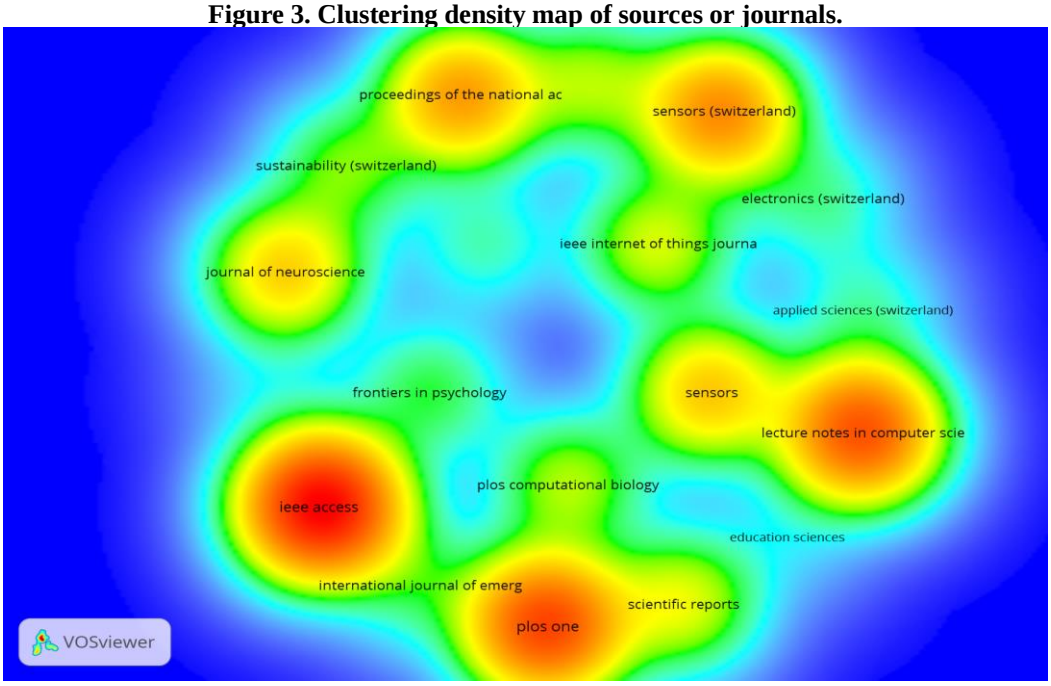
Figure 2. Publication of papers in the main sources.



Source: Scopus data (2023)

From the data collected from the selected sources, a bibliographic clustering analysis was performed to establish the sets of sources or journals (Figure 3). Consequently, six different main clusters were identified: a first focus was the journal IEEE Access with 2514 citations, followed by Plos One (1825 citations), Lecture Notes in Computer Science (1688 citations), Sensors Switzerland (1208 citations), Proceedings of the National Academy of Sciences of the United States of America (1078 citations) and Journal of Neuroscience (777 citations). That is, the bibliographic clustering analysis showed a strong correlation between sources with many citations in common with these journals.

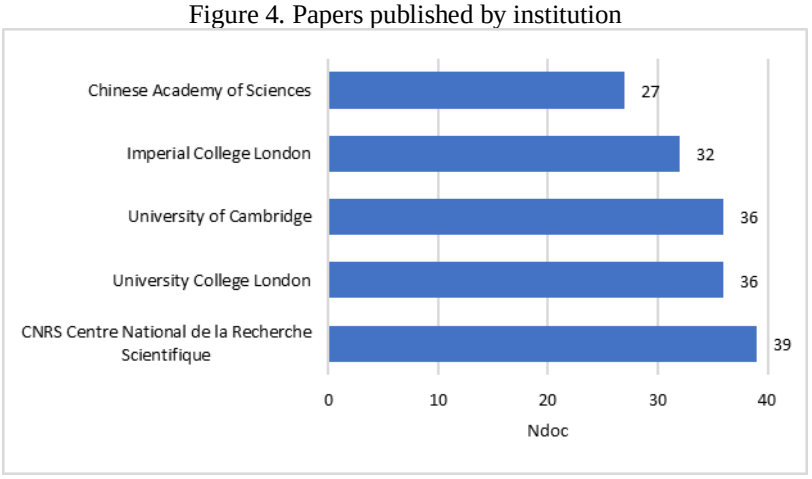
Figure 3. Clustering density map of sources or journals.



Source: Results in VOSviewer (2023).

For their part, academics from 160 institutions contributed to 2668 papers. Figure 4 shows that, over the chosen study period, most of the papers on ubiquitous learning were published by the CNRS Centre National de la Recherche Scientifique (n=39), followed by University College London (n=36) and Cambridge (n=36). In contrast, Imperial College London has 32 developed papers, compared to the Chinese Academy of Sciences, with 27 published scientific papers.

Figure 4. Papers published by institution



Source: Scopus data (2023)

The publications were written by 160 authors from 160 different academic institutions. Table 3 shows that Cook, D.J. is the author who has written the most scientific papers (n=9). He is followed in several publications by Asensio-

Pérez, J.I. (n=8), Muñoz-Cristóbal, J.A. (n=7), and finally Barbosa, J.L.V. and Martínez-Monés, A. with six publications each.

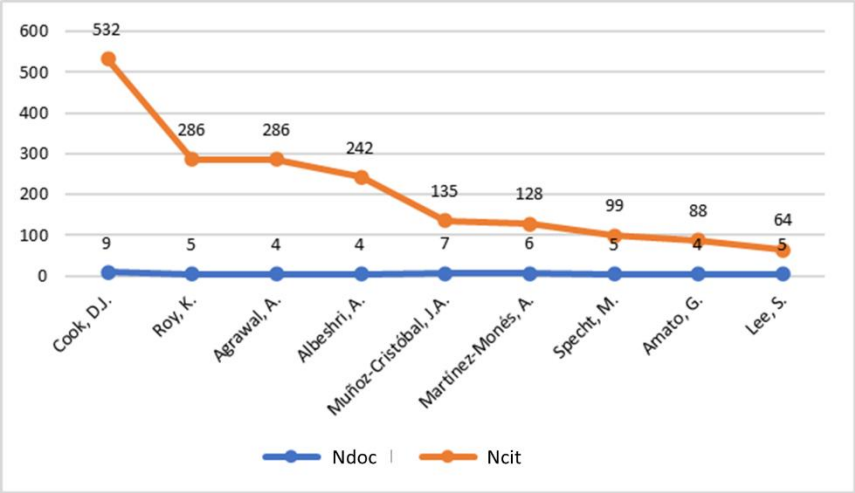
Table 3. Papers published by the author

Author	Ndoc	Ncit	Author	Ndoc	Ncit
Cook, D.J.	9	532	Roy, K.	5	286
Asensio-Pérez, J.I.	8	67	Ruiz-Calleja, A.	5	45
Muñoz-Cristóbal, J.A.	7	135	Serrano-Iglesias, S.	5	45
Barbosa, J.L.V.	6	51	Specht, M.	5	99
Martínez-Monés, A.	6	128	Agrawal, A.	4	286
Arribas-Cubero, H.F.	5	63	Albeshri, A.	4	242
Gallego-Lema, V.	5	63	Amato, G.	4	88
Lee, S.	5	64	Bote-Lorenzo, M.L.	4	15

Source: Scopus data (2023)

To complement the analysis of publications by the author, Figure 5 presents the three most cited authors with papers on ubiquitous learning: Cook, D.J., with 532 citations. While in second place, Roy, K. and Agrawal, A. stand out, each with 286 citations in published papers.

Figure 5. Most cited papers by the author



Source: Scopus data (2023)

Table 4 shows all the papers published during the research period (2003-2023) that address ubiquitous learning, broken down by subject area and type of publication. Data analysis shows that, of the 28 subject areas analyzed, computer science, engineering, and social sciences account for more than 48% of all the literature published.

Table 4. Publication of documents by subject area and type of publication

Subject area	Ndoc	%Ndoc
Computer Science	1340	25%
Engineering	710	13%
Social Sciences	538	10%
Mathematics	410	8%
Biochemistry, Genetics and Molecular Biology	326	6%

Physics and Astronomy	234	4%
Medicine	219	4%
Neuroscience	191	4%
Materials Science	178	3%
Psychology	162	3%
Other	1113	21%
Total	**5421**	**100%**
Document Type	**Ndoc**	**%Ndoc**
Article	2356	88%
Conference-Paper	247	9%
Book Chapter	39	1%
Book	26	1%
Total	**2668**	**100%**

Source: Scopus data (2023)

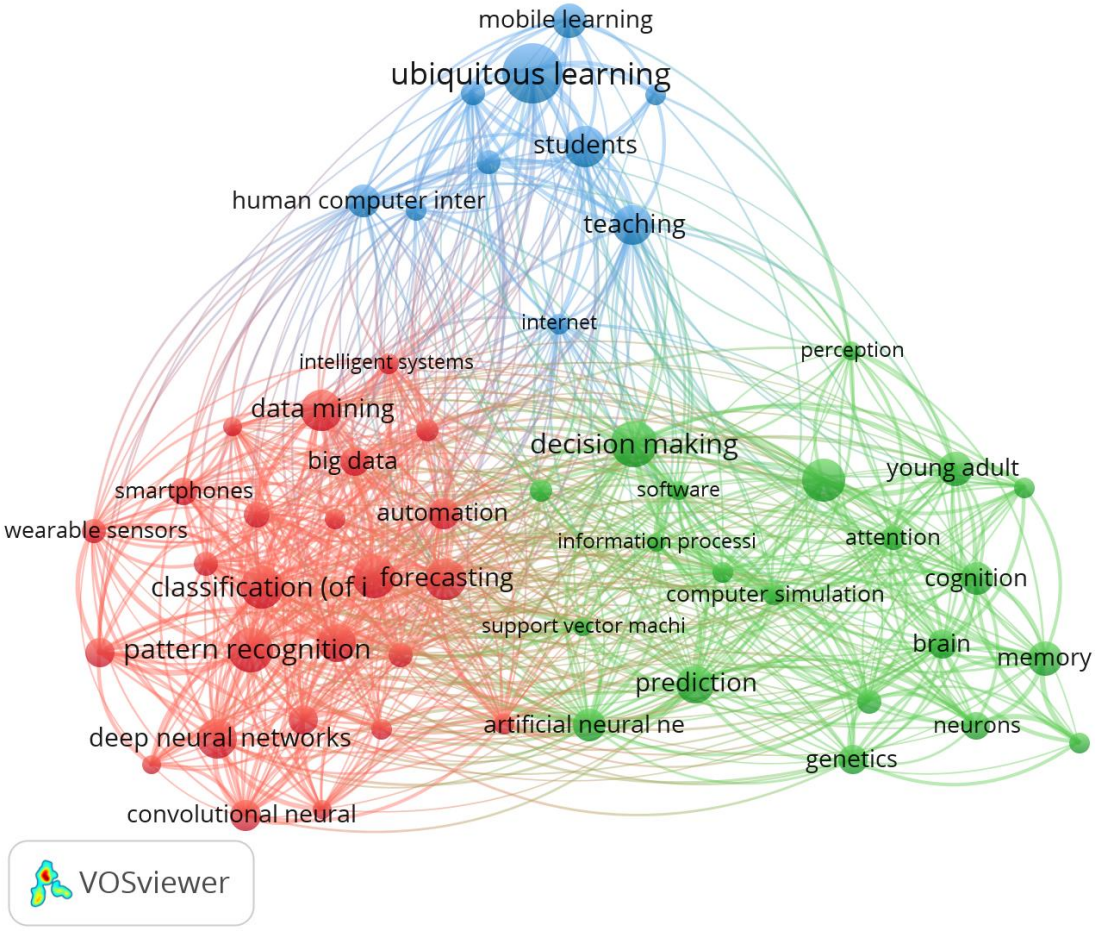
Likewise, as shown in Figure 6, computer science represents 25% of scientific production, engineering 13%, and social sciences 10%. On the other hand, when analyzing the production according to the different types of documents created, it can be seen that scientific articles represent the largest part of the production (88%), followed by conference-paper (9%). In comparison, book chapters and books only represent 2%.

Figure 6 shows the study results on keyword co-occurrence by selecting terms with more than three occurrences in the title, keyword, and abstract fields. The degrees of connectedness estimated by VOSviewer were used to designate each color to the set of words related to each other.

- Blue cluster. "ubiquitous learning" (n=118 occurrences) is associated with the words: students, mobile learning, teaching, higher education, human-computer interaction, and internet.
- Green cluster. "decision making" (n=88 occurrences) refers to related words, including perception, software, brain, memory, young adult, attention, prediction, genetics, neurons, cognition, support vector machine, and information processing.
- Red cluster. "pattern recognition" (n=85 occurrences) clusters the following words: big data, data mining, intelligent systems, wearable sensors, smartphones, forecasting, deep neural networks, and convolutional neural networks.

The clusters highlight that the most commonly used terms are those that are intrinsically related to the topic of the study.

Figure 6. Keyword co-occurrence map.



Source: Results in VOSviewer (2023).

4. Discussion

The results demonstrate a growing trend in the number of scientific articles addressing the topic of ubiquitous learning each year, with the highest total number of publications in 2020, 2021, and 2022 (n=1149; 43.1%). According to Berrones et al. (2023),[21] there has been an increase in the volume of publications on the topic in recent years. This is due to the widespread adoption of ICT in classrooms, enabling significant changes in pedagogy. As a result of the development of ICT and its inclusion in pedagogical practices, ubiquitous education emerges, aiming to incorporate more accessible learning for students in their immediate environments.[45,47–49]

On the other hand, the most relevant institution in terms of the number of publications was the CNRS Centre National de la Recherche Scientifique, with thirty-nine publications. Additionally, the United States ranks first in scientific production with 21%, with English as the predominant language in most publications (96%). Furthermore, the author with the most publications (n=9) was Cook, D.J. from Washington State University Pullman. It was also evident that most articles were published in Lecture Notes In Computer Science (n=169) and IEEE Access (n=109). However, IEEE Access, Plos One, Lecture Notes in Computer Science, and Sensors Switzerland were the journals with the highest impact.

Academic progress is impossible without international cooperation.[50] New paradigms for the design, use, implementation, and evaluation of educational technologies emerge as their incorporation in the classroom is considered.[51,52] Due to this development, the education paradigm has shifted from traditional e-learning to m-learning (mobile learning) and ultimately to u-learning or ubiquitous learning.[53–55] This helps researchers tackle the challenge of scientific production and define ubiquitous learning as learning that incorporates the elements above and all the technological tools available today for instruction and learning.[56]

Interdisciplinarity is also observed in fields such as engineering, social sciences, mathematics, and others, but the documents studied here stand out in computer science. Additionally, scientific articles accounted for 88% of the total document production. The most co-occurring keyword was "ubiquitous learning," which forms the basis of the study. Apart from this term, the other keywords, such as "decision making" and "pattern recognition," do not deviate too much from what the authors investigated.[57–59]

Therefore, the purpose of ubiquitous learning is to improve students' performance and expand their capabilities in their learning process through technology-mediated contextual teaching. Lastly, the keywords surrounding ubiquitous learning point towards a multidisciplinary strategy, as demonstrated by its applications in computer science, education, and mathematics.[14,60,61] Consequently, the term co-occurrence network provides a visual representation of the most important aspects of the articles and the overall study topics in the form of clusters.[62–64]

5. Conclusions

According to the purpose of the study, based on the bibliometric approach to ubiquitous learning literature worldwide indexed in the Scopus database between 2003 and 2023, an exponential trend is evident from 2007 to 2022, representing 90.9% (n=2424) of the published works in the studied period. Additionally, out of the entire scientific production from 105 countries, 21% (830 documents) can be attributed to the United States.

Furthermore, Lecture Notes In Computer Science has published more articles than any other journal (n=169), while the CNRS Centre National de la Recherche Scientifique has produced 39 academic works. Cook, D.J. is the author with the most scientific publications on ubiquitous learning (n=9) and citations in their works (532 citations). It was also observed that the majority of the works were scientific articles (88%) in the field of computer science (25%), engineering (13%), and social sciences (10%). Moreover, based on the keyword analysis results conducted using the VOSviewer program, "ubiquitous learning" was the most frequently used term (n=118 occurrences).

Based on the analysis of the 2668 documents comprising the study sample, it is concluded that the research orientation on ubiquitous learning is dynamic and increasingly linked to the development of information and communication technology (ICT), as this learning style utilizes technology as a tool for students to access the information they need at any time, providing them with greater independence in their learning process.

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