Contemporary Educational Technology, 2023, **15**(4), ep471
ISSN: 1309-517X (Online)

OPEN ACCESS

Review Article

A cross-database bibliometric analysis of ubiquitous learning: Trends, influences, and future directions

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Citation: Abayeva, G. A., Orazayeva, G. S., Omirbek, S. J., Ibatova, G. B., Zakirova, V. G., & Vlasova, V. K. (2023). A cross-database bibliometric analysis of ubiquitous learning: Trends, influences, and future directions. *Contemporary Educational Technology, 15*(4), ep471. https://doi.org/10.30935/cedtech/13648

ARTICLE INFO

Received: 28 Jul 2023
Accepted: 2 Sep 2023

ABSTRACT

The concept of ubiquitous learning has emerged as a pedagogical approach in response to the advancements made in mobile, wireless communication, and sensing technologies. The domain of ubiquitous learning is distinguished by swift progression, thereby presenting a difficulty in maintaining current knowledge of its developments. The implementation of bibliometric analysis would enable the tracking of its development and current status. The objective of the present investigation is to perform a thorough bibliometric examination of the domain of ubiquitous learning. This research aims to discern significant attributes, patterns, and influencers within the discipline by analyzing scholarly works. The primary objective of this study is to provide a comprehensive depiction of the salient characteristics and patterns exhibited by the datasets employed in ubiquitous learning research, namely Scopus, Web of Science (WoS), and merged datasets. Additionally, the study seeks to trace the historical development of publications in this domain and to ascertain the most noteworthy publications and authors that have exerted a significant impact on this field. This study provides an extensive bibliometric analysis of ubiquitous learning, examining output from Scopus, WoS, and a merged dataset. It highlights the field's growth and the rising use of diverse data sources, with Scopus and the merged dataset revealing broader insights. The analysis reveals an interest peak in 2016 and a subsequent decline likely due to incomplete recent data. Documents, predominantly articles, differ across databases, underscoring the unique contributions of each. The study identifies "Lecture Notes in Computer Science" and "Ubiquitous Learning" as major research sources. It recognizes Hwang, G.-J. as a highly influential author, with Asian institutions leading in research output. However, Western institutions also show strong representation in WoS and merged databases. Despite variations in total citation counts, countries like China, Switzerland, and Ireland contribute significantly to the field. Terms like "mobile learning" and "life log" have vital roles in bridging research clusters, while thematic maps reveal evolving trends like mobile learning and learning analytics. The collaborative structure and key figures in ubiquitous learning are illuminated through network analysis, emphasizing the importance of cross-database analysis for a comprehensive view of the field.

Keywords: bibliometric analysis, Scopus, ubiquitous learning, WoS

INTRODUCTION

The advent of digital resources and tools has revolutionized the way we learn, as underscored by numerous studies (Fakomogbon, & Bolaji, 2017; Fernández-Batanero et al., 2022; Guillén-Gámez et al., 2019; Lin et al., 2017). Educators, recognizing the importance of authentic learning activities, emphasize engaging students with real-world problems (Alioon & Delialioglu, 2019; Roach et al., 2018; Sotiriadou et al., 2019). This has led researchers to advocate for designed lessons that seamlessly merge both real and virtual learning environments (Allcoat et al., 2021; Díaz, 2020). A concept central to this approach is ubiquitous learning, which involves using digital technologies to design authentic learning environments. It is a learning approach developed alongside the rapid progress of mobile, wireless communication, and sensing technologies (Hwang, 2014; Hwang et al., 2009). This enables learning environments, where students can perceive real-world situations and environmental contexts (Chu et al., 2010a), providing appropriate information to individual students at the right place and time.

The term 'ubiquitous learning' is rooted in ubiquitous technology and computing (Hua, 2010), facilitating seamless integration into the educational process using mobile gadgets, embedded digital components, and sensor technologies (Hwang et al., 2008). There is some confusion around the term, as it is often used interchangeably with mobile, augmented, and seamless learning, all of which describe the pervasive nature of learning (Virtanen et al., 2018).

The integration of ubiquitous learning technologies has become increasingly significant in contemporary education, revolutionizing the acquisition and dissemination of knowledge (Marinagi et al., 2013). Mobile technologies have made a noteworthy contribution to the notion of ubiquitous learning among various technologies (Chu et al., 2010a). The widespread use of smartphones and tablets in contemporary society facilitates the possibility of ubiquitous learning, thereby transcending the conventional limitations of temporal and spatial boundaries (Pimmer et al., 2016). The utilization of mobile technologies facilitates the ability of learners to access educational resources at their convenience, participate in interactive learning experiences, and engage in collaborative efforts with fellow learners, without being limited by geographical constraints.

Cloud-based learning is a crucial element of ubiquitous learning. The platform offers a pliant and expandable infrastructure for the storage and retrieval of educational materials (Wannapiroon et al., 2019). The emergence of the Internet of things (IoT) (Davies et al., 2020) is beginning to influence the development of Ubiquitous Learning environments (Wang et al., 2020). IoT facilitates the interconnection of commonplace objects in a digital manner (Kaur & Kaur, 2017), thereby enabling the generation of data that can be utilized to enrich and augment the learning process (Weeber et al., 2016). IoT devices have the potential to facilitate experiential learning by gathering environmental data and delivering instantaneous feedback to learners (Fidai et al., 2019). The amalgamation of tangible and virtual surroundings enables a holistic educational encounter that mirrors the omnipresence of technology in contemporary society.

Ubiquitous learning facilitated by contemporary technology influences learner's performance (Cárdenas-Robledo & Peña-Ayala, 2018; Thongkoo et al., 2019). One of the significant impacts of ubiquitous learning is its influence on student achievement (Liu & Chu, 2010; Suartama et al., 2021). Studies have shown that the flexibility and accessibility provided by ubiquitous learning can enhance students' academic performance (De Lourdes Martínez-Villaseñor et al., 2014; Suartama et al., 2021). This is largely due to the personalized learning environment that ubiquitous learning creates, allowing students to learn at their own pace and style (De Lourdes Martínez-Villaseñor et al., 2014). Moreover, the immediate feedback provided through digital platforms can help students identify their strengths and weaknesses, leading to improved academic outcomes (Chen et al., 2013).

Another profound effect of ubiquitous learning is its impact on motivation (Cárdenas-Robledo & Peña-Ayala, 2018; Liu & Chu, 2010). The use of digital devices and interactive applications in ubiquitous learning can make learning more engaging and enjoyable for students, thereby increasing their motivation to learn (Hwang & Wu, 2014; Lin et al., 2017). Furthermore, the autonomy that ubiquitous learning provides can foster a sense of responsibility and self-determination among students, which are key factors in intrinsic motivation (Nikou & Economides, 2021). The ability to access learning materials anytime and anywhere can also reduce the pressure and anxiety associated with traditional time-bound and location-specific learning, further enhancing students' motivation (Makodamayanti et al., 2020).

Ubiquitous learning significantly contributes to the learning process (Chu et al., 2010a; Liu & Chu, 2010). It promotes active learning by encouraging students to interact with the learning materials, rather than passively receiving information. This interaction can lead to deeper understanding and better retention of knowledge (Graf & Kinshuk, 2008). Additionally, ubiquitous learning supports collaborative learning by providing platforms, where students can share ideas and work together on projects, fostering a sense of community and enhancing social learning (Ogata & Yano, 2004; Yang, 2006). The integration of real-world contexts into the learning process, another feature of ubiquitous learning, can make learning more relevant and meaningful for students (Chen & Huang, 2012; Hwang, 2014; Hwang et al., 2011). Overall, Ubiquitous Learning can transform the learning process into a more effective, engaging, and personalized experience.

The future of ubiquitous learning holds significant implications for future educational models. It posits a more learner-centric, flexible, and personalized education model, where learning occurs seamlessly, integrated into our daily lives (De Lourdes Martínez-Villaseñor et al., 2014; Graf & Kinshuk, 2008; Nikou & Economides, 2021). This transformation could potentially shift our understanding of traditional classroom environments, broadening the scope of learning beyond the confines of physical institutions and fixed schedules. However, the actualization of ubiquitous learning is not without its challenges. It presents potential obstacles such as digital divide, privacy and security concerns, and the need for significant infrastructural investment (Bdiwi et al., 2018; Cope & Kalantzis, 2010; Matthew et al., 2018). Furthermore, the ubiquitous nature of this learning model necessitates pedagogical changes and further exploration of teaching methodologies that can maximize its potential (Panjaburee & Srisawasdi, 2018). Research directions for the future could involve studying the impact of ubiquitous learning on different learning styles, exploring how it can support different sectors of learners, such as those with special needs, and understanding how to ensure equity in access and use of these technologies. The aim is to effectively harness the power of ubiquitous Learning to enhance educational outcomes and foster a culture of lifelong learning.

A bibliometric analysis is a method of examining scholarly research through empirical and quantitative means, which can uncover patterns and trends that may not be readily discernible through a conventional literature review. The present investigation aims to offer valuable perspectives on the prevalence of ubiquitous learning in scholarly literature, the primary topics and themes that are being explored, and the temporal evolution of these themes. The analysis has the potential to discern significant contributors, periodicals, and establishments in this domain, in addition to identifying areas in the literature that require further investigation. Consequently, this analysis would be a highly valuable asset for scholars and instructors who aim to comprehend the current state of the discipline and its prospective trajectory.

The field of ubiquitous learning is characterized by rapid evolution, posing a challenge to staying up-to-date with its advancements. Utilizing bibliometric analysis would facilitate the monitoring of its progression and present state. Given that ubiquitous learning is inherently multidisciplinary, incorporating insights from fields such as education, computer science, and cognitive psychology, a bibliometric analysis would offer a comprehensive overview that considers these varied perspectives. The comprehension of the research landscape in the field of ubiquitous learning is imperative for educators, policymakers, and researchers to make well-informed decisions and formulate efficacious strategies, given the rising implementation of this approach in educational settings.

The aim of this study is to conduct a comprehensive bibliometric analysis of the field of ubiquitous learning. The study seeks to identify key characteristics, trends, and contributors to the field through the examination of academic literature. Specifically, the study aims to describe the key features and trends of the datasets (Scopus and Web of Science [WoS]) used in ubiquitous learning research, to chart the evolution of publication in this field over time, and to identify the most influential publications and authors. Research questions are determined, as following:

1. What are the key features and trends in the datasets used in ubiquitous learning research?
2. What is the trend in the publication of research on ubiquitous learning over time, and how has it evolved?

3. What are the most influential publications in the field of ubiquitous learning, and what makes them significant?
4. Who are the top authors contributing to the field of ubiquitous learning, and what are their specific areas of focus or contribution?
5. Which countries and institutions have made significant contributions to research in the field of ubiquitous learning, and what are the characteristics or focus areas of their contribution?
6. What are the current research fronts and intellectual bases in the field of ubiquitous learning, and how have they shaped the direction and focus of research in this field?

METHODOLOGY

This study employs a robust bibliometric analysis to examine the expansive landscape of ubiquitous learning, a research area of increasing prominence in the era of digital transformation. By utilizing comprehensive data from two globally recognized databases, Scopus and WoS, as well as a merged dataset from both platforms, we aim to provide a rich, multi-faceted understanding of the field's growth, its key contributors, thematic underpinnings, and the global reach of its research output. Bibliometric analysis, a quantitative approach to the evaluation of academic literature, allows for an in-depth exploration of the trends, collaborations, and influential works within a specific discipline. This methodology offers a scientific approach to analyze various aspects of publications, including their temporal distribution, citation counts, co-authorship networks, and keyword usage patterns. It thereby assists in elucidating the evolution, the status, and potential future directions of a field.

Data Collection Process

The methodology for selecting publications for this study was meticulously designed to ensure a comprehensive and inclusive analysis. The inclusion criteria were that the publications had to be written in English and pertain to the subject of "ubiquitous learning." These criteria were established to ensure that the study encompassed a broad range of perspectives while maintaining a focus on the designated subject. No additional criteria were applied, and no time constraints were imposed on the studies included in the analysis.

The first phase involved conducting an initial search in Scopus database, which yielded 1,606 publications. These data were downloaded in the BibTeX file format. Upon reviewing the file in a text editor, studies without identifiable authors were excluded from the analysis, resulting in 1,543 publications ready for bibliometric analysis.

In the second phase, an initial search was conducted in WoS database, yielding 1,242 publications. The relevant information for these studies was also downloaded in the BibTeX file format. As with Scopus phase, a text editor was used to identify and exclude studies with unidentifiable authors, leaving 1,238 publications remaining.

The 'bibliometrix' package (Aria & Cuccurullo, 2017) was utilized for the analysis. After analyzing the datasets from both Scopus and WoS, the data was exported in Excel format. The Excel files from Scopus and WoS were then merged, and any duplicate publications were removed. Following this final refinement, there were 1,922 unique data points remaining for the study.

The exclusion of studies without identifiable authors was a necessary step in the data curation process to maintain the integrity and reliability of the analysis. This decision aligns with the study's aim to provide a comprehensive and trustworthy overview of the current state of ubiquitous learning literature. Despite this exclusion, the analysis encompasses a wide array of studies, ultimately yielding 1,922 unique data points that provide a robust foundation for the bibliometric analysis. This approach ensures clarity in the data collection process while acknowledging the limitations associated with excluding certain studies.

Data Analysis

The analysis process for each dataset occurred independently. The tool employed for this purpose was the Bibliometrix package, which is part of the R Programming language suite (Aria & Cuccurullo, 2017). In the field of bibliometric analysis, two main categories of analysis were conducted (Sudakova et al., 2022). The

Table 1. Descriptive information on Scopus, WoS, & merged datasets

Description	Scopus	WoS	Merged
Main information about data			
Timespan	2002:2023	2002:2023	2002:2023
Sources (journals, books, etc.)	709	644	933
Documents	1,543	1,238	1,922
Annual growth rate %	15.86	12.1	16.34
Document average age	8.75	8.73	8.76
Average citations per document	13.89	11.02	10.26
References	40,384	25,835	45,418
Document contents			
Keywords plus (ID)	4,485	670	3,929
Author's keywords (DE)	3,080	2,704	3,802
Authors			
Authors	2,858	2,483	3,583
Authors of single-authored documents	184	159	247
Authors collaboration			
Single-authored documents	210	189	293
Co-authors per document	3.17	3.01	3.06
International co-authorships %	13.87	15.43	6.972
Document types			
Article	612	482	701
Article; book chapter		94	76
Article; early access		7	6
Article; proceedings paper		10	3
Book	12	4	13
Book chapter	97		76
Conference paper	787		618
Proceedings paper		600	377
Review	27	17	29
Others	7	24	23

initial category encompasses descriptive and performance analysis (Garzón, 2021). This portion of the analysis involved reviewing general information pertaining to the sources and types of documents included in the data sets. Further examination of the data produced statistical information related to the annual frequency and total number of studies, as well as the accumulated citations for these studies. Among these, the most cited works were singled out, with a focus on the top ten. The final part of this initial analysis focused on identifying the most productive contributors, which included authors, sources, institutions, and countries. The second category of analyses dealt with the creation of scientific maps and network analyses. One of the methods utilized was the analysis of clusters formed by document coupling, which was based on the keywords used by the authors. From this analysis, thematic maps relating to ubiquitous learning were derived and presented (Zammarchi & Conversano, 2021). Another aspect of the second category involved a network approach, whereby the co-occurrences network, co-citations network, and country participation were thoroughly analyzed (López-Belmonte et al., 2020). Co-occurrences networks represent the frequency of two events occurring simultaneously. In this context, it could indicate the common appearance of two keywords in the same document. Co-citations networks, on the other hand, represent the frequency of two works being cited together, indicating their thematic connection. Country participation provided a measure of the global engagement in the studies' topics, thus providing a broader perspective of the research environment.

FINDINGS

Scopus and WoS databases were used for the bibliometric analysis of ubiquitous learning. Scopus and WoS data will be presented for each research question in presenting the study's findings. The findings on the merged data of both databases will also be presented.

Descriptive Information on Datasets

This data is about the scientific output concerning ubiquitous learning from Scopus database, WoS, and a merged dataset combining both (**Table 1**). The timespan analyzed for all databases is from 2002 to 2023. The number of different sources, including journals, books, etc., used in Scopus is slightly higher (709) compared to WoS (644). However, when both datasets are merged, the number of sources increases to 933, indicating a diversity of the data sources in the field of ubiquitous learning. Scopus has more documents (1543) related to the topic than WoS (1238). The merged result shows an increase in the number of documents (1922), signifying a larger corpus of work.

The annual growth rate signifies the rate at which new documents are added each year. This rate is higher in the merged data (16.34%) compared to Scopus (15.86%) and WoS (12.10%). This suggests a progressively increasing interest in ubiquitous learning. The average age of documents is almost the same across all three databases (~8.75 years), indicating that the field has been active for some time. Scopus has the highest average citation per document (13.89), indicating that the work in this database tends to be more cited or influential than those in WoS (11.02) and the merged data (10.26). The number of references is significantly higher in the merged data (45,418) and Scopus (40,384), demonstrating a larger academic discourse in these databases.

The number of keywords used by authors is relatively lower in WoS compared to Scopus and the merged data. This might indicate a narrower range of topics covered in WoS or less keyword tagging by authors in this database. Scopus has more authors (2,858) compared to WoS (2,483), indicating a broader scholarly base. The merged data shows an increase in the number of authors (3,583) as expected. The number of authors who have single-authored documents is quite low across all three datasets, suggesting a trend toward collaborative research in the field. The number of single-authored documents is relatively low across all databases, supporting the suggestion of collaborative research. However, the merged dataset has slightly more single-authored documents (293). The number of co-authors per document is around three for all databases, again indicating high collaboration. The percentage of international co-authorships is highest in WoS (15.43%), indicating a broader geographic diversity in the collaboration compared to Scopus (13.87%) and the merged data (6.97%).

The most common document type across all databases is the 'article,' with the highest number in the merged dataset (701) and Scopus (612). This document type is highly prevalent in Scopus (787) but absent in the data for WoS. The merged data shows a substantial number of conference papers (618), indicating the importance of conference proceedings in the field. They appear in significant numbers in Scopus (97) and in the merged data (76) but are not listed for WoS. WoS has many 'proceedings papers' (600), which do not appear in Scopus dataset. The merged data contains fewer 'proceedings papers' (377). The type of documents varies between databases, which may be due to the different focus or coverage of each database.

Trend in the Publication of Ubiquitous Learning

The data shown in **Figure 1** starts from 2002, with only one document found in each of Scopus and WoS databases. This could indicate the beginning of the academic discussion on ubiquitous learning or the limitations of the databases to track earlier work. From 2003 to 2008, there is a steady growth in the number of documents across all databases, with the merged dataset always having the highest number. The growth was quite significant in 2008, with Scopus and the merged dataset almost doubling their figures from the previous year. In 2009, the number of documents in WoS increased significantly, matching closely with the number in Scopus. The merged dataset shows an even higher number, showing the growth in the academic output in ubiquitous learning. The most productive year across all databases was 2016. The merged data had the highest number of documents (179), with a significant increase in WoS data (156). This could be seen as the peak year for ubiquitous learning research in this period. Post-2016, there is a general decrease in the number of documents across all databases. This might be due to a variety of reasons including changes in research focus, funding, or global events. However, Scopus tends to have slightly more output than WoS in most years. For the most recent years (2022 and 2023), there is a further decrease in the number of documents. However, it is essential to note that data for these years might not be complete, especially for 2023. This is due to the delay between when research is conducted, written up, submitted, and finally published. In summary, **Table 1** shows a growing interest in ubiquitous learning from 2002, with a peak in 2016, and then a slow decrease thereafter. It is important to consider that the decrease in recent years might be due to incomplete data for those years at the time of this analysis. This trend shows the evolving nature of research interests and highlights the importance of monitoring the current research trends.

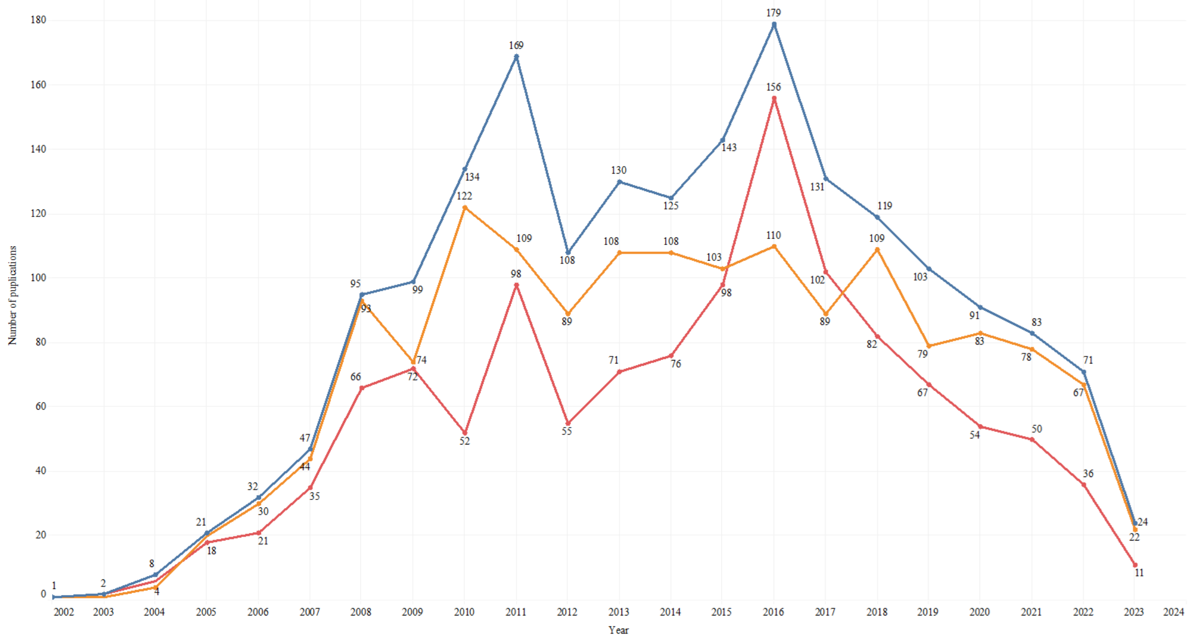

Figure 1. Annual scientific production in ubiquitous learning (Source: Authors)

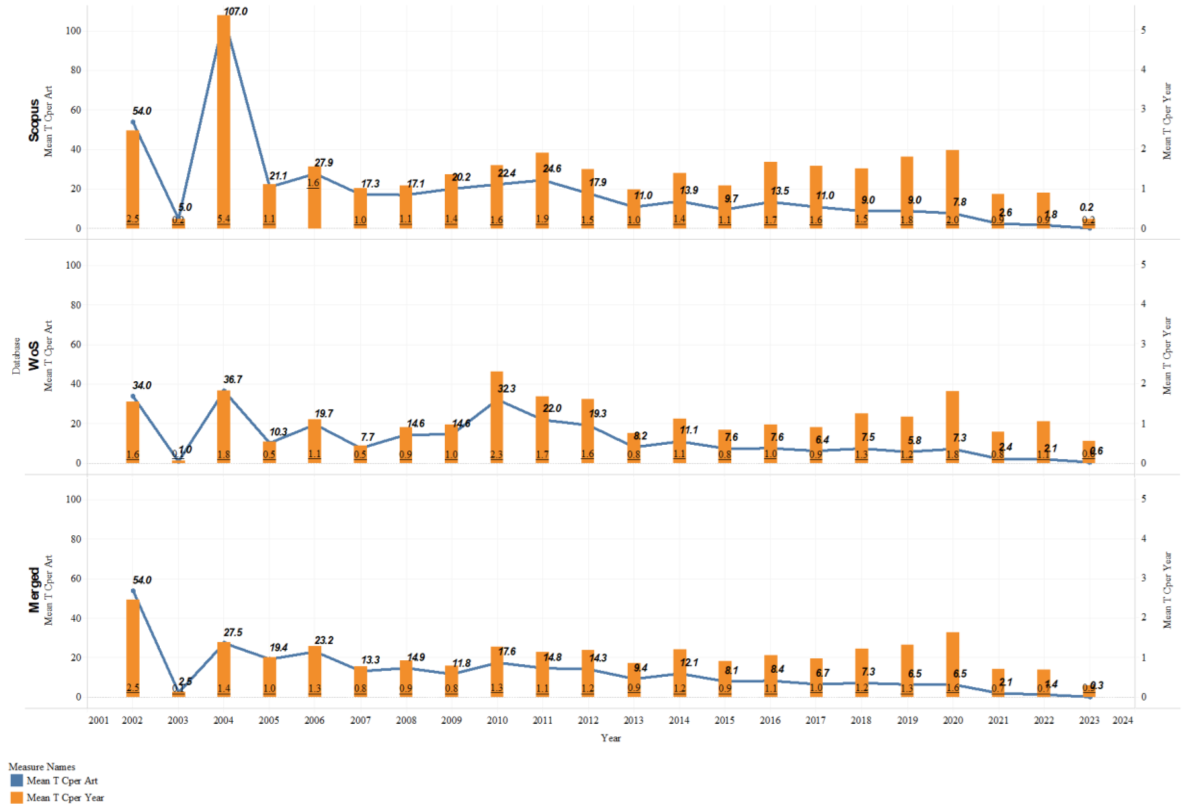

Figure 2. Mean total citation over year & article each dataset (Source: Authors)

The year 2002 shows the highest total citation per article (TCPA) for Scopus and the merged database, while 2004 shows the highest for WoS, as shown in **Figure 2**. This means that on average, articles from these years have the highest total number of citations. It could indicate that seminal works or key papers on ubiquitous learning were published in those years. For Scopus and the merged data, TCPA drops considerably in 2003, then rises again in 2004. **Figure 2** remains relatively stable until 2009, after which it gradually declines with some fluctuations. This trend might suggest that papers from these years might not have been as impactful as those in earlier years. For WoS, TCPA shows more fluctuation, with peaks in 2004 and 2010, but

Table 2. Top-10 sources based on total publication

Scopus		WoS		Merged	
Sources	n	Sources	n	Sources	n
Lecture Notes in Computer Science (including subseries)	74	Towards Ubiquitous Learning, EC-TEL 2011	52	Ubiquitous Learning	63
International Journal of Mobile Learning & Organization	54	Educational Technology & Society	47	International Journal of Mobile Learning & Organization	54
Ubiquitous Learning	48	Handbook of Research on 3-D Virtual Environments & Hypermedia for Ubiquitous Learning	25	Lecture Notes in Computer Science (including subseries)	52
Educational Technology & Society	46	Ubiquitous Learning	24	Towards Ubiquitous Learning, EC-TEL 2011	51
ACM International Conference Proceeding Series	29	Interactive Learning Environments	23	Educational Technology & Society	34
Interactive Learning Environments	23	Computers & Education	22	Handbook of Research on 3-D Virtual Environments & Hypermedia for Ubiquitous Learning	24
Computers & Education	22	Future of Ubiquitous Learning: Learning Designs for Emerging Pedagogies	16	Interactive Learning Environments	23
CEUR Workshop Proceedings	18	Ubiquitous Learning Environments & Technologies	15	Computers & Education	22
Communications In Computer & Information Science	18	Fifth IEEE International Conference On Wireless, Mobile & Ubiquitous Technologies in Education	13	CEUR Workshop Proceedings	18
Lecture Notes in Electrical Engineering	13	British Journal of Educational Technology	12	ACM International Conference Proceeding Series	17

generally follows a similar downward trend over time. This might indicate a more diverse range of cited papers across different years in WoS. Total citations per year (TCPY) can be viewed as an indicator of how 'current' or 'relevant' the citations are, i.e., how many citations a paper receives per year on average. For all databases, the highest TCPY is in 2002 for Scopus and the merged database, and in 2010 for WoS. It is notable that these figures generally decrease over time across all databases, with some fluctuations. For the most recent years (2021, 2022, and 2023), TCPA and TCPY are the lowest across all databases. This is expected as recent papers have less time to accumulate citations. For all databases, TCPA is higher than TCPY in the earlier years, but the gap narrows over time. By 2023, TCPA and TCPY are almost equal across all databases. This reflects the fact that older papers have more time to accumulate citations but may not continue to be cited as frequently in more recent years. As a result, the trend in both TCPA and TCPY suggests that while the academic interest in ubiquitous learning continues, the impact of newer papers (as measured by these citation metrics) is lower compared to earlier works. However, it is important to consider that citation count is just one measure of impact, and it can be influenced by many factors such as the paper's age, the journal's audience, and the overall growth of the field.

The Most Influential Publications

The source "Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)" is common across all three datasets and appears to be a significant source of research on ubiquitous learning, as evidenced by its high article count in Scopus (74), WoS (52), and the merged dataset (52) (**Table 2**).

The source "Ubiquitous Learning" is also common across all three datasets, with the highest number of articles in the merged dataset (63), followed by Scopus (48), and WoS (24). The "International Journal of Mobile Learning and Organization" is featured in both Scopus and the merged dataset, with an identical number of articles (54), indicating its importance in this field. Notably, the "Educational Technology & Society" and "Interactive Learning Environments" journals appear across all databases, albeit with varying article counts. There are unique sources in each dataset as well. For instance, "ACM International Conference Proceeding Series" and "Communications in Computer and Information Science" are exclusive to Scopus, while "British Journal of Educational Technology" and "Fifth IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education" are exclusive to WoS. This could reflect the differing focuses or

Table 3. Top-publications based on citations

Paper	DOI	TC	TCPY	Normalized TC
Scopus				
Hwang et al. (2008)		495	30.94	28.90
Park (2011)	10.19173/irrodl.v12i2.791	460	35.38	18.70
Hwang and Tsai (2011)	10.1111/j.1467-8535.2011.01183.x	431	33.15	17.52
Ogata and Yano (2004)	10.1109/WMTE.2004.1281330	403	20.15	3.77
Liu and Chu (2010)	10.1016/j.compedu.2010.02.023	393	28.07	17.52
Chu et al. (2010b)	10.1016/j.compedu.2010.07.004	347	24.79	15.47
Hwang (2014)	10.1186/s40561-014-0004-5	308	30.80	22.18
Yang (2006)		301	16.72	10.80
Hwang et al. (2009)	10.1016/j.compedu.2009.02.016	292	19.47	14.45
Frohberg et al. (2009)	10.1111/j.1365-2729.2009.00315.x	282	18.80	13.96
WoS				
Park (2011)	10.19173/irrodl.v12i2.791	335	25.77	15.22
Hwang and Tsai (2011)	10.1111/j.1467-8535.2011.01183.x	327	25.15	14.86
Hwang et al. (2008)		322	20.13	22.14
Liu and Chu (2010)	10.1016/j.compedu.2010.02.023	300	21.43	9.30
Chu et al. (2010b)	10.1016/j.compedu.2010.07.004	244	17.43	7.56
Hwang et al. (2009)	10.1016/j.compedu.2009.02.016	215	14.33	14.73
Frohberg et al. (2009)	10.1111/j.1365-2729.2009.00315.x	204	13.60	13.98
Ogata and Yano (2004)	10.1109/WMTE.2004.1281330	203	10.15	5.54
Yang (2006)		198	11.00	10.07
Chu et al. (2010a)	10.1016/j.compedu.2009.08.023	197	14.07	6.10
Merged				
Hwang et al. (2008)		495	30.94	33.28
Park (2011)	10.19173/irrodl.v12i2.791	335	25.77	22.61
Hwang and Tsai (2011)	10.1111/j.1467-8535.2011.01183.x	327	25.15	22.07
Hwang (2014)	10.1186/s40561-014-0004-5	308	30.80	25.46
Yang (2006)		301	16.72	12.98
Liu and Chu (2010)	10.1016/j.compedu.2010.02.023	300	21.43	17.06
Chu et al. (2010b)	10.1016/j.compedu.2010.07.004	244	17.43	13.87
Hwang et al. (2009)	10.1016/j.compedu.2009.02.016	215	14.33	18.24
Hwang and Wu (2014)	10.1504/IJMLO.2014.062346	204	20.40	16.87
Frohberg et al. (2009)	10.1111/j.1365-2729.2009.00315.x	204	13.60	17.31

coverage of each database. There are some sources, which are unique to either Scopus or WoS, but appear in the merged dataset, such as “Computers & Education” and “CEUR Workshop Proceedings”. This further demonstrates the value of considering multiple databases when reviewing research. Overall, these top sources illustrate the diversity of publication outlets for ubiquitous learning research, including both journals and conference proceedings. The variance between databases suggests that a thorough literature review in this area would benefit from considering multiple databases to ensure comprehensive coverage of the relevant literature.

The publication by Hwang et al. (2008) received the highest number of total citations in Scopus (495) and the merged database (495), as shown in **Table 3**. However, in WoS database, it has a slightly lesser total citation count (322). The publication by Park (2011) is the second most cited paper in Scopus and the merged database with 460 and 335 total citations respectively, while it tops the list in WoS with 335 total citations. Notably, the work of Hwang (2014) appears multiple times in all databases, indicating the significant impact of his research in the field. Some publications such as Hwang (2014) and Hwang and Wu (2014) appear only in Scopus and merged databases but not in WoS, suggesting different coverage between these databases. Comparing TCPY, it is apparent that the articles published in 2008 and 2014 in “Educational Technology and Society” (Hwang et al., 2008) and “Smart Learning Environments” (Hwang, 2014), respectively, shows the highest citation rate in Scopus and the merged database. Normalized total citations, which might account for factors such as the age of the paper and citation practices in the field, still present the work of Hwang (2014) as highly influential, especially in Scopus and the merged database. There are slight differences in the citation count for the same publications between Scopus and WoS. This could be due to different methodologies in citation tracking, different database sizes, or updates at different times. Overall, this analysis shows that certain works (notably those by Hwang, G.-J.) have had a significant impact in the field across multiple

Table 4. Top-authors based on some indexes

Element	h index	g index	m index	TC	NP	Publication year start
Scopus						
Hwang, G.-J.	35	71	1.94	5,130	73	2006
Ogata, H.	21	37	1.05	1,634	115	2004
Yano, Y.	16	33	0.80	1,094	48	2004
Huang, Y. M.	14	21	0.88	1,336	21	2008
Chu, H. C.	13	28	0.76	1,734	28	2007
Tsai, C. C.	12	15	0.75	2,375	15	2008
Uosaki, N.	12	19	0.86	423	53	2010
Kinshuk, K.	10	19	0.63	381	22	2008
Liu, G. Z.	10	17	0.71	443	17	2010
Mouri, K.	10	18	0.83	413	51	2012
WoS						
Hwang, G.-J.	29	56	1.61	3,237	56	2006
Huang, Y. M.	13	19	0.81	994	19	2008
Chu, H. C.	12	19	0.71	1,245	19	2007
Ogata, H.	12	25	0.60	685	49	2004
Tsai, C. C.	12	14	0.75	1,733	14	2008
Yano, Y.	10	20	0.50	470	20	2004
Liu, G. Z.	9	16		296	16	2010
Chen, N. S.	8	13	0.50	373	13	2008
Wu, T. T.	8	8	0.47	300	8	2007
Kinshuk, K.	7	14	0.44	226	20	2008
Merged						
Hwang, G.-J.	33	67	1.83	4,496	77	2006
Ogata, H.	20	33	1.00	1,346	114	2004
Yano, Y.	16	29	0.80	858	48	2004
Chu, H. C.	14	30	0.82	1,508	30	2007
Huang, Y. M.	14	23	0.88	1,147	23	2008
Tsai, C. C.	12	16	0.75	1,987	16	2008
Kinshuk, K.	11	18	0.69	343	29	2008
Uosaki, N.	11	18	0.79	404	52	2010
Liu, G. Z.	10	18		370	18	2010
Chen, N. S.	9	15	0.56	434	15	2008

databases. However, there are also differences between databases, suggesting that researchers might want to use multiple databases to get a comprehensive view of influential work in their field.

Top-Authors Based on Some Index

Hwang, G.-J. stands out as the top author across all databases based on all measures, suggesting that this author is highly productive (reflected in number of publications [NP]), highly influential (reflected in total citation [TC], h-index, and g-index), and consistently productive over time (reflected in m-index), as shown in **Table 4**. Comparatively, Scopus database appears to record higher values across all measures for Hwang, G.-J. (and most other authors), compared to WoS and the merged database. This could be due to Scopus's more comprehensive coverage or different citation tracking methods. There are some differences in the authors' rankings between the databases. For instance, Ogata, H. is ranked second in Scopus and merged databases but only fourth in WoS. Similarly, Chu, H. C. is ranked fifth in Scopus, third in WoS, and fourth in the merged database. The m-index, which attempts to account for the time factor in productivity, seems to correspond well with the other indices. Notably, Hwang, G.-J. leads on m-index in Scopus and merged databases, indicating a high level of sustained productivity over time. The start year of publication (publication year start) for the top authors in the databases ranges between 2004 and 2012. Authors with earlier start years have a potential advantage in terms of total citations, as their work has had more time to be cited. There are slight differences in the number of publications (NP) for the same authors between Scopus and WoS. This could be due to different coverage between these databases. Overall, while there are some differences between the databases, Hwang, G.-J. consistently stands out as the most influential and productive author across all databases. Other authors, such as Ogata, H., Yano, Y., and Chu, H. C., also appear as significant contributors to the field, although their rankings vary slightly between the databases. This analysis underscores the utility

Table 5. Affiliations' rank based on total publications

Affiliation	Articles
Scopus	
University of Tokushima	90
National Taiwan University of Science and Technology	64
National University of Tainan	54
Kyushu University	51
National Cheng Kung University	46
Athabasca University	36
National Central University	34
Osaka University	34
National Taiwan Normal University	27
Asia University	26
WoS	
National Taiwan University of Science and Technology	82
National Cheng Kung University	70
University of Illinois	63
University of Tokushima	57
Athabasca University	55
National University of Tainan	55
Kyushu University	48
Beijing Normal University	46
Universidad De Valladolid	44
Bohai University	40
Merged	
University of Tokushima	100
National Taiwan University of Science and Technology	87
National Cheng Kung University	70
University of Illinois	67
Kyushu University	67
National University of Tainan	65
Athabasca University	57
Beijing Normal University	50
Bohai University	40
National Central University	40

of using multiple databases and bibliometric indices to gain a comprehensive understanding of author impact and productivity in ubiquitous learning.

Which Countries and Institutions Have Contributed to Research

In Scopus database, the University of Tokushima has the highest number of articles published, at 90 (**Table 5**). This is followed by the National Taiwan University of Science and Technology with 64, and then the National University of Tainan with 54. All top-three institutions in Scopus are located in Asia. In WoS database, the National Taiwan University of Science and Technology ranks first with 82 articles. Next is the National Cheng Kung University with 70 articles, and then the University of Illinois with 63 articles. In contrast to Scopus, we see a more global representation here with the University of Illinois and Universidad de Valladolid in the list. In the merged data, the University of Tokushima leads again with 100 articles, followed by the National Taiwan University of Science and Technology with 87, and then the National Cheng Kung University with 70. Like WoS data, we see a broader geographical representation here. There are certain universities that maintain strong performance across all databases, such as the University of Tokushima, National Taiwan University of Science and Technology, and National University of Tainan. This suggests a consistent research output from these institutions. However, each database also highlights different universities. For example, the University of Illinois and Universidad de Valladolid are present in WoS data but not in Scopus. Similarly, Osaka University and Asia University appear in Scopus data but not in WoS or merged data. These differences may be due to the specific coverage of each database. The merged data provides a more comprehensive overview by combining the strengths of both Scopus and WoS databases. Yet, it is crucial to remember that the number of articles published is just one aspect of academic performance. Other factors, such as the quality and impact of research, along with citation counts, also play a significant role. One notable addition is Beijing Normal

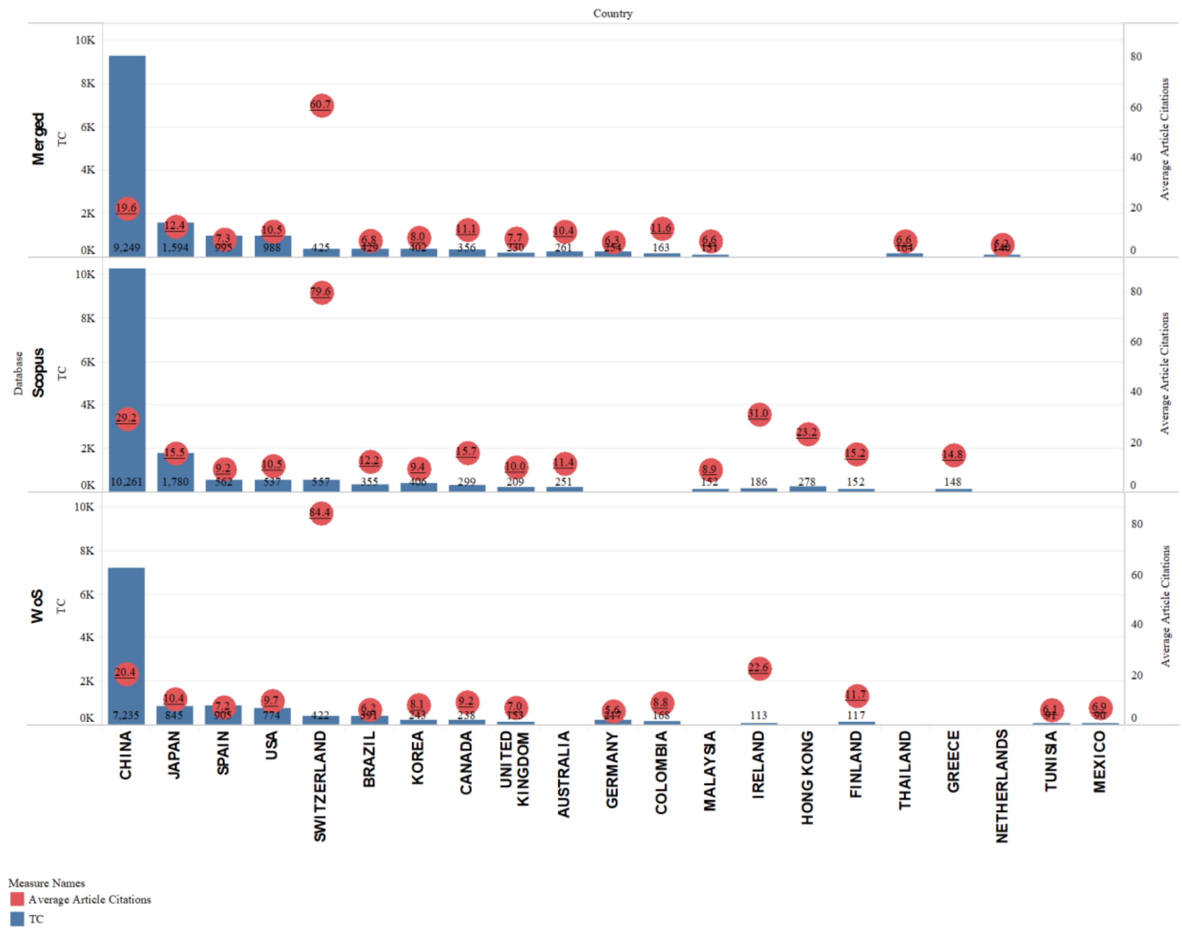

Figure 3. Top-countries based on total citations & average article citations (Source: Authors)

University, which performs well in WoS and merged data. This suggests that this university also has a strong research output, particularly in areas covered by WoS database.

In Scopus database, China has both the highest total citations (TC) at 10261 and a respectable average article citation count at 29.2, as shown in **Figure 3**. Japan follows with a total citation of 1,780 but a lower average article citation count of 15.5. Switzerland, despite having a lower total citation count (557), has the highest average article citations at 79.6. This suggests that while Swiss publications are fewer in number, their impact per article is significant. In WoS database, China also leads with the highest total citations (7,235), but with a lower average article citation count (20.4) compared to its performance in Scopus. Spain and Japan follow, with Spain showing a decrease in average article citations (7.2) compared to Scopus. Switzerland again shows strong performance in terms of average article citations (84.4), even higher than in Scopus. In the merged data, China remains the leader in total citations (9,249), with a lower average article citation count (19.6) than in either individual database. Japan and Spain follow, with both countries showing lower average article citations compared to Scopus but higher than WoS for Japan. Switzerland's average article citation (60.7) remains high, though lower than in either individual database.

Across all databases, China maintains a strong lead in total citations, highlighting its significant contribution to the global research output. Japan and Spain consistently appear in the top three, indicating a strong research output as well. However, the average article citation data reveals a slightly different story. Despite China's high total citations, its average article citation count is consistently outperformed by countries like Switzerland and Ireland. This suggests that while China produces a large number of research articles, the impact of each individual article (as measured by citations) may not be as high as in some other countries. Countries like Switzerland, despite their lower total citation count, have significantly high average article citation counts, indicating that their research has high impact per article. When comparing the databases, Scopus appears to give higher total citation counts and average article citations for most countries. The reason for this discrepancy could be due to the databases' different coverage and citation tracking systems. For

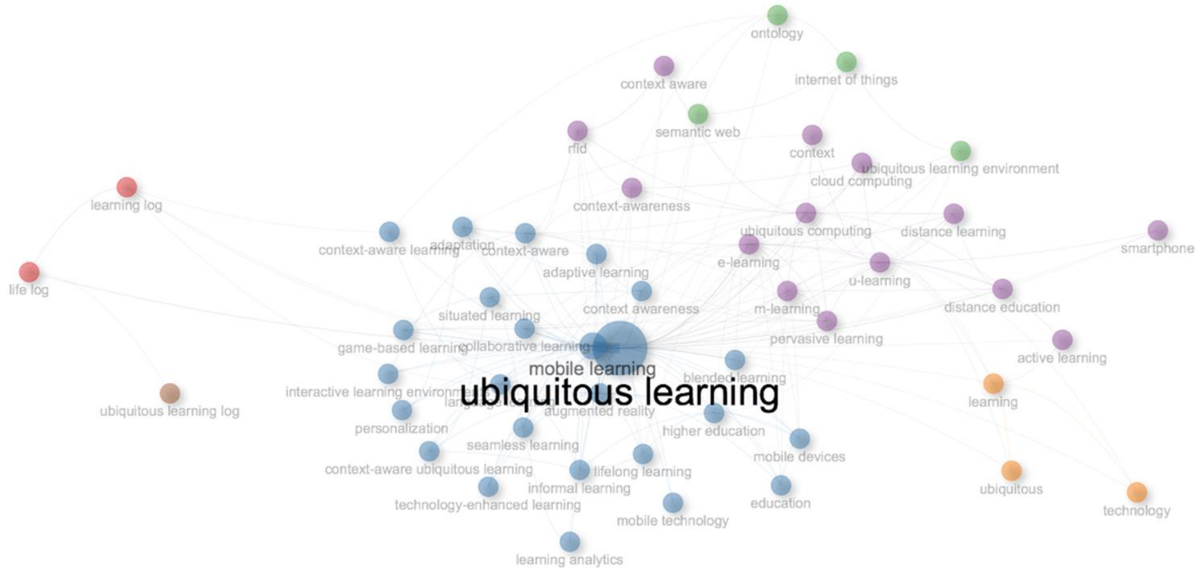

Figure 4. Co-keyword clusters for Scopus database (Source: Authors)

instance, Scopus, being a more extensive database, might include more journals leading to higher total and average citations. The merged data provides a balanced representation of the two databases, although the average article citations are generally lower compared to the individual databases. This is likely because the merged data includes more articles, which might lower the average citation count per article.

Research Front and Intellectual Based on Ubiquitous Learning

In Scopus, "ubiquitous learning" is the most prominent node based on the high betweenness centrality and relevance values, which indicates that it is central and connected to many other nodes in the network, as shown in **Figure 4**. It is also in the same cluster (cluster 2) with many of the terms, indicating a strong connection between ubiquitous learning and these terms. The terms "mobile learning" and "life log" also have significant betweenness centrality, suggesting their importance in bridging clusters or pathways within the network.

WoS database also shows "ubiquitous learning" as the most influential node, followed by "mobile learning" and "learning", as shown in **Figure 5**. Interestingly, in WoS, "learning" has a higher influence compared to Scopus. This might suggest that in WoS database, research on generic learning (not specifically tied to a technology or approach) is more connected with other research topics compared to Scopus.

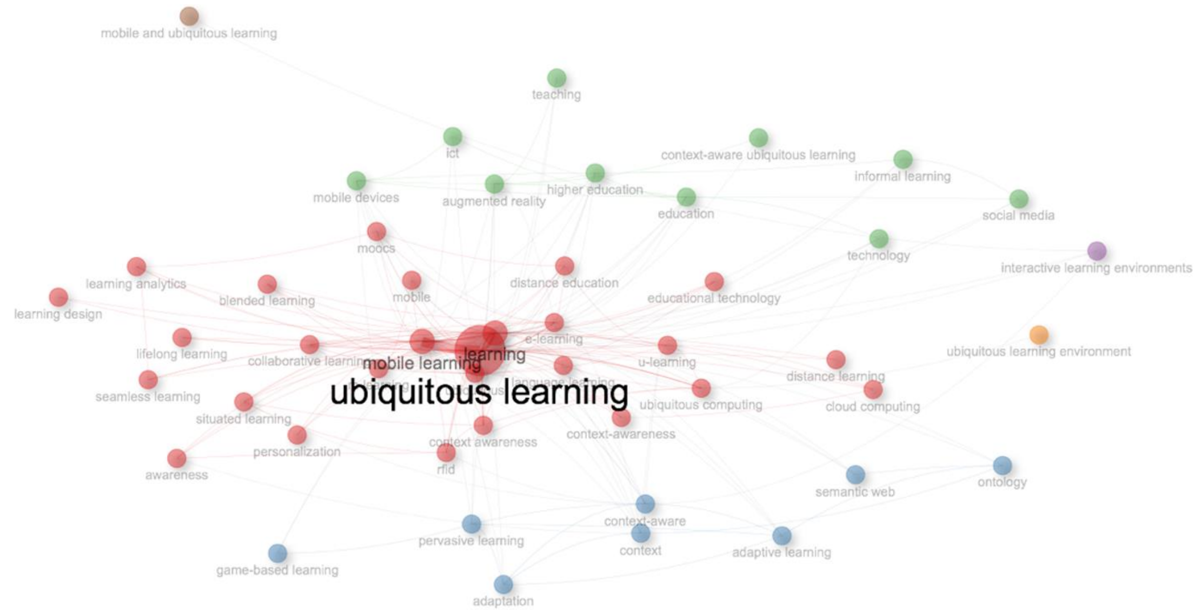

Figure 5. Co-keyword clusters for WoS database (Source: Authors)

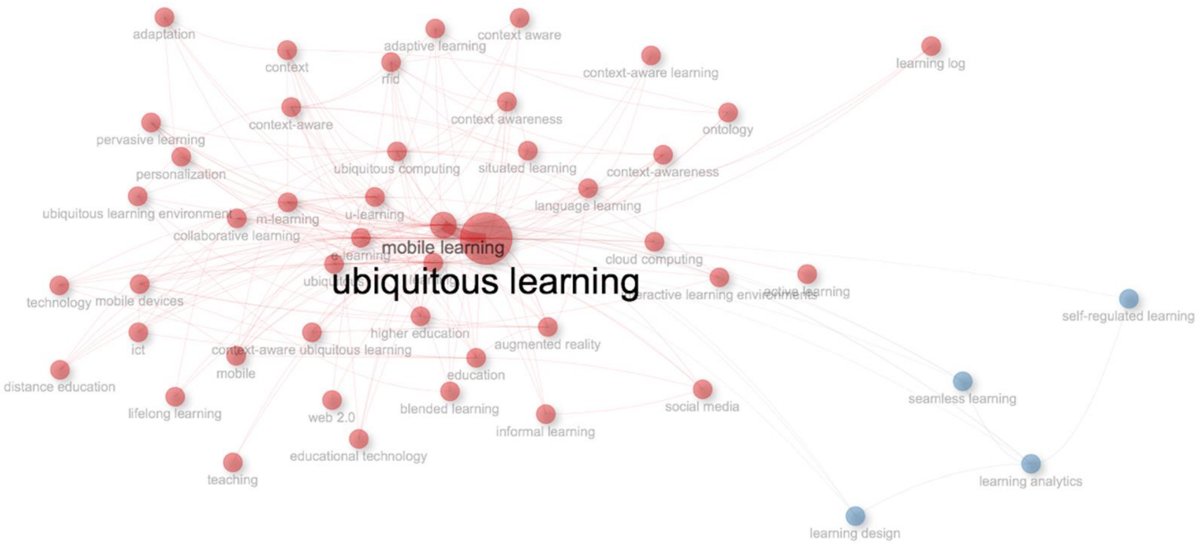

Figure 6. Co-keyword clusters for merged databases (Source: Authors)

The merged database, which combines both Scopus and WoS, still highlights "ubiquitous learning" as the most significant node, but the importance of "mobile learning" seems to increase compared to each of the individual databases, as shown in **Figure 6**. This implies that when considering both databases together, "mobile learning" becomes a more central topic.

All three databases highlight the importance of "ubiquitous learning," suggesting that it is a critical term in the literature regardless of the database used. Scopus database also brings forward the importance of "life log", while this term is not highlighted in WoS.

WoS database, on the other hand, shows "learning" as a more central term than Scopus does. When the databases are merged, "mobile learning" becomes more influential, suggesting it is a critical bridging topic between the two databases. These results highlight the importance of considering multiple databases when performing bibliometric analyses, as the specific database used can influence the observed centrality and connectivity of different terms.

Data provided from Scopus appears to be derived from a thematic map of topics related to learning and education, with a specific emphasis on technology-enhanced and ubiquitous learning, as shown in **Figure 7**.

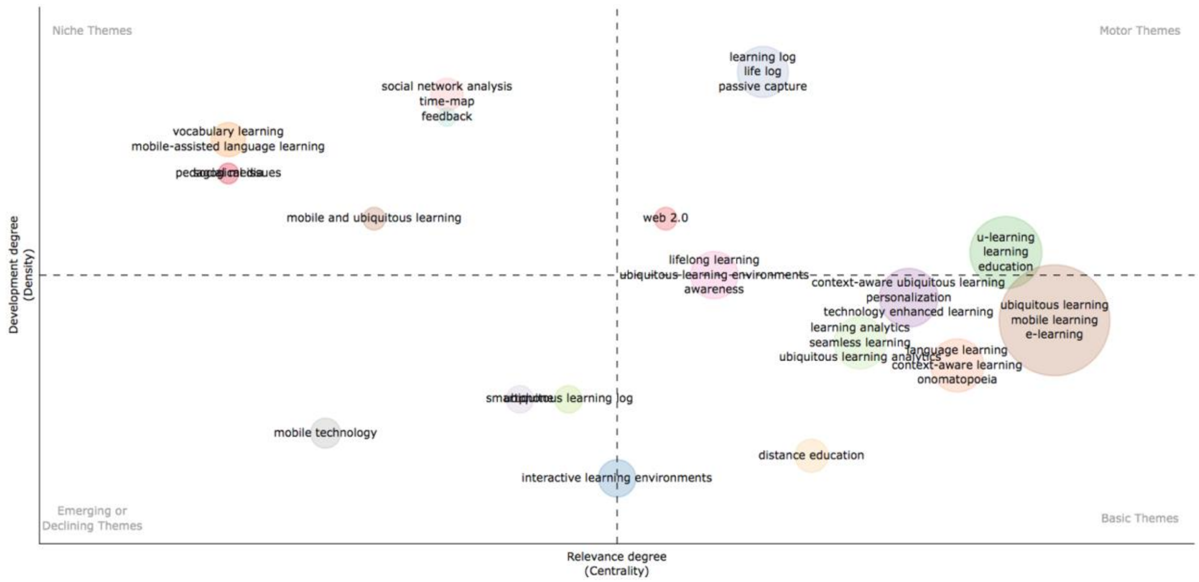

Figure 7. Themes based on keywords: Scopus database (Source: Authors)

The themes or clusters are sorted into various categories such as "web 2.0", "u-learning", "context-aware ubiquitous learning", "vocabulary learning", "ubiquitous learning", "lifelong learning", "mobile technology", "language learning", "learning log", "social media", "ubiquitous learning log", "interactive learning environments", "learning analytics", "social network analysis", "pedagogical issues", "distance education", "smartphone", "mobile and ubiquitous learning", and "feedback". The most prominent cluster, based on its relevance centrality, is "ubiquitous learning". Words in this cluster include "mobile learning", "e-learning", "ubiquitous computing", "augmented reality", "context awareness", "collaborative learning", "m-learning", "higher education", "context-aware", "context-awareness", and "ubiquitous learning environment". This suggests that the most influential topic in this map is related to ubiquitous learning, particularly mobile learning, e-learning, augmented reality, and collaborative learning, among others. Furthermore, a high degree of centrality indicates that these topics have strong interconnectedness with other topics in the network. Therefore, they can be considered central or pivotal points in the thematic map. For instance, mobile learning has a high betweenness centrality and relevance centrality. Terms like "u-learning", "context-aware ubiquitous learning", and "vocabulary learning" are also quite central, even though they have fewer occurrences. This highlights the significance of these topics in the thematic map and the overall discourse on technology-enhanced and ubiquitous learning. In summary, this map highlights the emerging and critical themes in the field of learning and education, with a clear emphasis on technology-enhanced and ubiquitous learning. It also provides a valuable tool for identifying the most influential topics and their relationships within this academic landscape.

The thematic map from WoS (**Figure 8**) appears to be a network visualization of co-occurrence frequencies and cluster analysis of topics related to educational technology. The clusters appear to be centered on common themes, as seen in the column "cluster label." For instance, you have clusters such as "informal learning," "ubiquitous computing," "ubiquitous learning," among others. Each cluster contains related terms and shows their respective occurrences, centrality measures, and significance in the network.

The informal learning cluster is focused on non-traditional, casual learning environments. Keywords in this cluster include 'technology', 'lifelong learning', 'social media', 'collaboration', and 'feedback', which suggests research themes in educational technology that emphasize the role of technology in promoting spontaneous and casual learning experiences. The use of social media and collaboration tools in facilitating lifelong learning are salient topics within this cluster. This ubiquitous computing cluster represents the idea of pervasive computing environments that seamlessly integrate with everyday life. It covers topics like 'context awareness', 'RFID', 'ontology', 'blended learning', 'language learning', and 'situated learning'. These are all components of or approaches to creating more integrated, contextually-aware learning environments. This ubiquitous learning cluster is heavily focused on mobile and ubiquitous learning contexts.

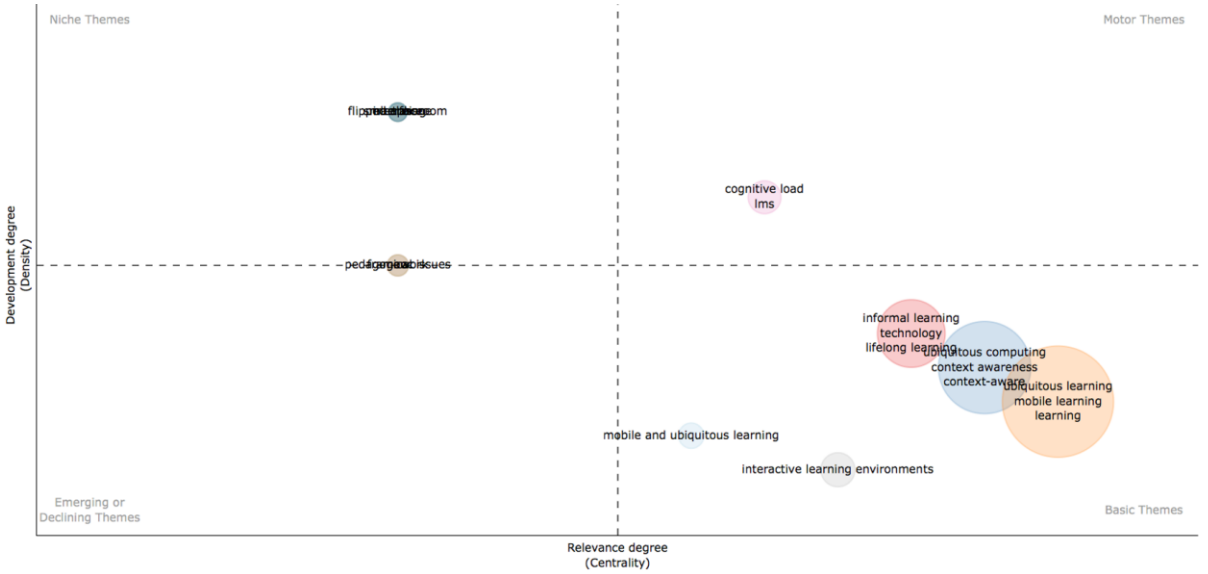

Figure 8. Themes based on keywords: WoS database (Source: Authors)

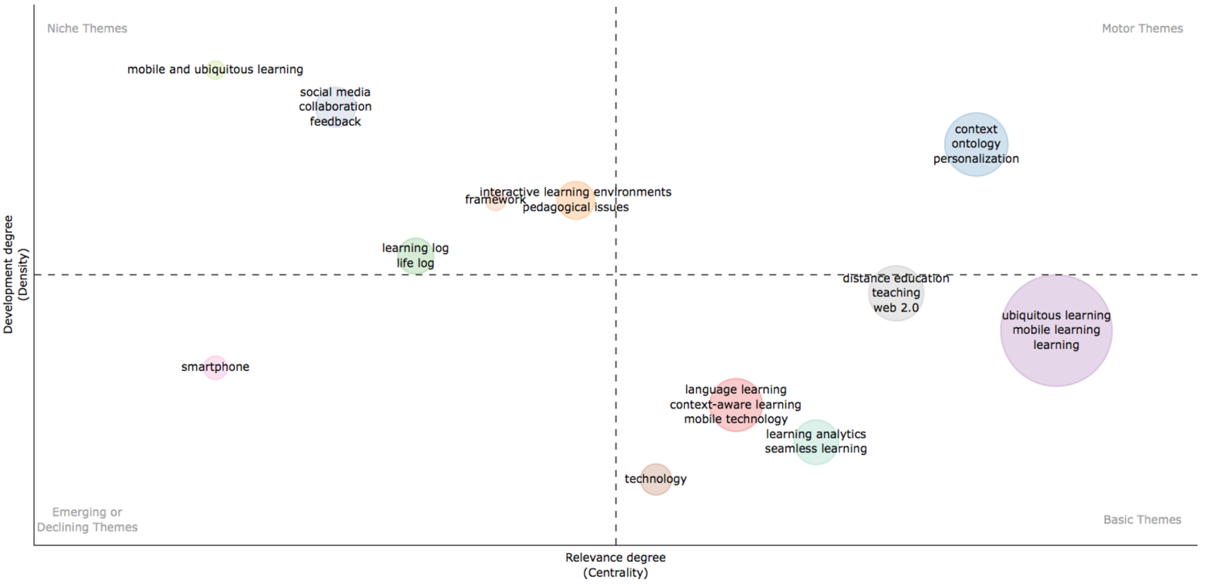

Figure 9. Themes based on keywords: Merged databases (Source: Authors)

Key terms include 'mobile learning', 'u-learning', 'e-learning', 'm-learning', 'augmented reality', 'collaborative learning', and 'education'. This highlights the prevalence and significance of mobile and ubiquitous learning in contemporary educational technology research. It also shows the diversity of technologies and methodologies being used, such as augmented reality and collaborative learning tools. Other smaller clusters include areas like pedagogical issues, interface, m-learning, smartphone, framework, cognitive load, interactive learning environments, mobile and ubiquitous learning, flipped classroom, and MOOC. These highlight other important topics in educational technology research. Centrality measures (betweenness, closeness, and relevance) indicate the significance of each term within the network. For example, 'ubiquitous learning' has the highest relevance centrality, indicating that it is a very significant node in the network, potentially linking many other nodes.

The data provided appears to be a thematic map of key terms in a body of text, possibly from an educational context given the prominence of learning-related phrases, as shown **Figure 9**. The thematic map clusters similar terms together and provides additional data, such as the frequency of occurrence, centrality, and relevance centrality, which might be interpreted as the importance of these terms in the context. The language learning cluster revolves around "language learning," with key terms like "mobile technology" and

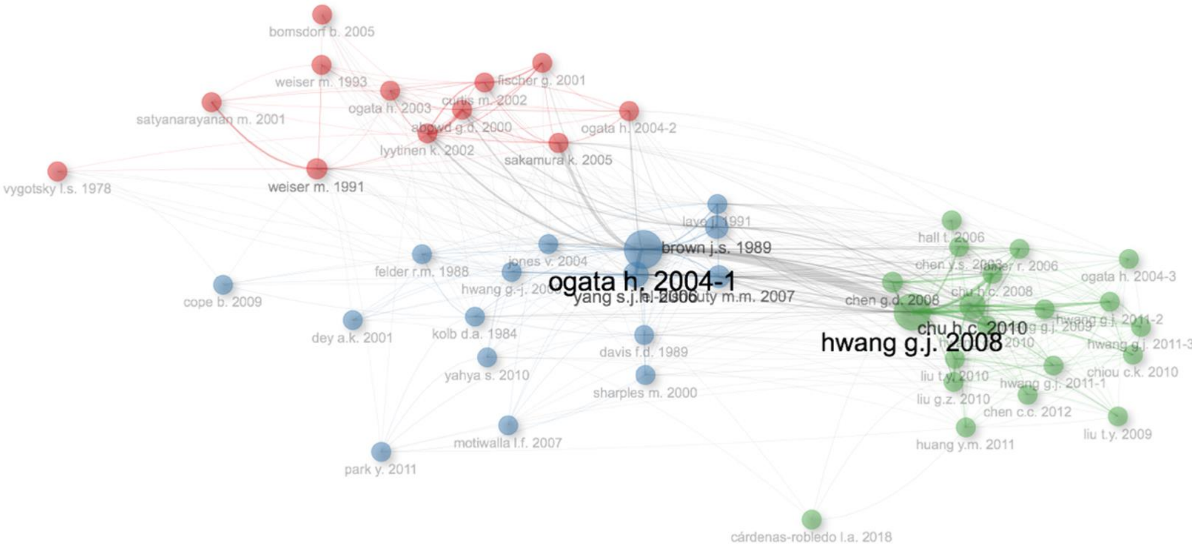

Figure 10. Co-network based on publication: Scopus database (Source: Authors)

"vocabulary learning" underlining the role of technology in language acquisition. Despite having a lower occurrence than "language learning", "context-aware learning" and "mobile technology" have a relatively high betweenness and closeness centrality, indicating their potential importance in the connectivity of the network. Context cluster focuses on adaptive, personalized learning in a semantic web. The term "context" stands out with a high betweenness centrality, suggesting it serves as a key bridge or connector between concepts in this cluster. Learning log cluster's theme is "learning log". It also includes "life log". But "life log" has a relatively low betweenness centrality, which could indicate its marginal role in this cluster. Ubiquitous learning cluster is the largest one with "Ubiquitous Learning" as the dominant theme. It covers a wide range of related concepts, from augmented reality, mobile learning, to higher education. This cluster has the highest occurrences, centrality, and relevance values, highlighting the importance of ubiquitous learning in the text. Notably, "mobile learning" stands out with the highest betweenness centrality, hinting at its role as a connector in the network. Interactive learning environments cluster five centers on "interactive learning environments", but it also includes "pedagogical issues", which suggests discussions on teaching approaches within interactive environments. Technology cluster is smaller and focuses solely on "technology". It is possible this cluster relates to the general role of technology in the discussed context. Smartphone cluster is centered on the usage of "smartphones" in the context, possibly in education or learning. Distance education cluster is focused on "distance education" and associated terms like "web 2.0", "distance learning", and "instructional design". This cluster suggests a discussion around remote or online learning methodologies. Learning analytics cluster revolves around "learning analytics" and includes "seamless learning", indicating analysis and tracking of learning processes. Framework cluster is focused on "framework", though it is not clear from the given data what specific framework is being discussed. Social media cluster includes "social media", "collaboration", and "feedback", suggesting a discussion on using social media for collaborative learning or gathering feedback. Mobile and ubiquitous learning cluster has "mobile and ubiquitous learning" at its core. In conclusion, the text seems to discuss various aspects of learning, with a significant focus on technology's role in education, including areas like mobile and ubiquitous learning, distance education, and the use of learning analytics.

All three data sets underline the role of ubiquitous and mobile learning in tech-enhanced education, but they also highlight different aspects of it. Scopus data points towards the interconnectedness of various themes within ubiquitous learning, WoS data shows the integration of technology in everyday and casual learning environments, and the merged data provides a broader view, covering themes like language learning, context-awareness, and social media's role in collaborative learning. These differences could stem from the different articles included in each data set and their respective focus areas. It is also worth noting that although certain themes are more prominent in one data set than the other, this does not necessarily indicate their overall importance in the field but may simply reflect the specific dataset's characteristics.

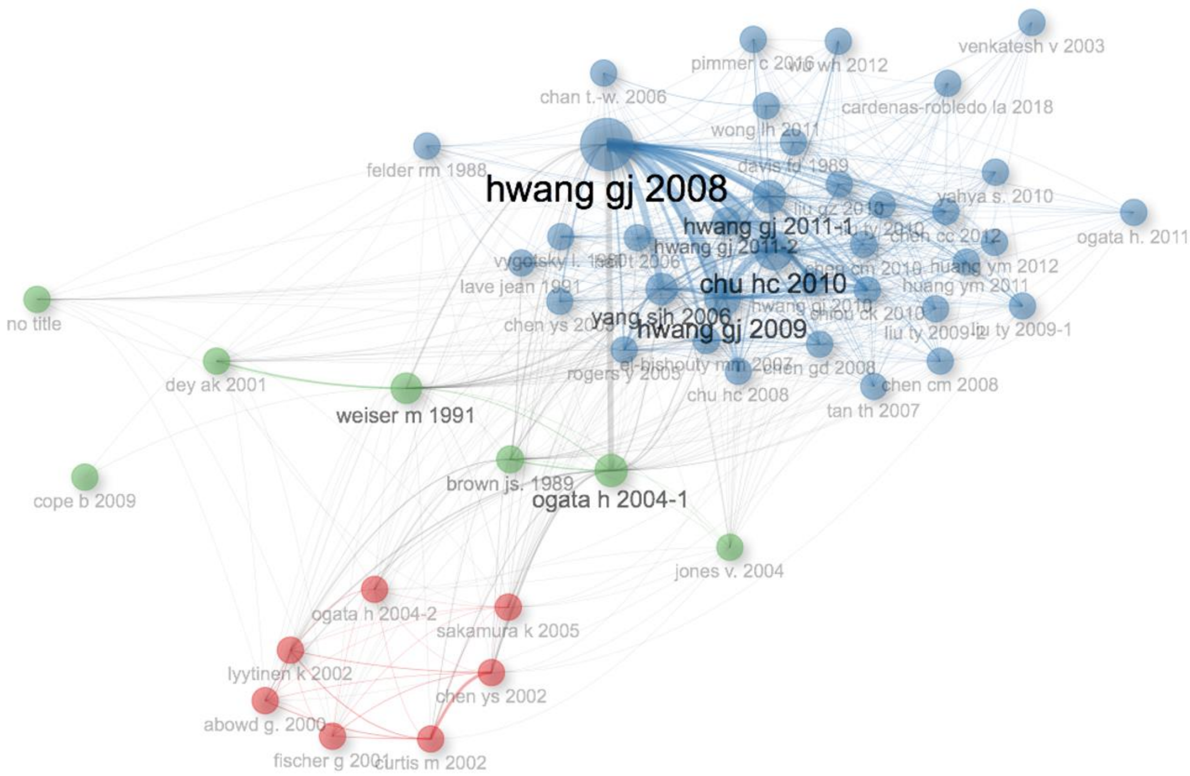

Figure 11. Co-network based on publication: WoS database (Source: Authors)

In Scopus network (**Figure 10**), we see three primary clusters of interconnected papers. The authors with the highest relevance, indicating their importance within the network, include 'Hwang, G.-J., 2008' from cluster 3, 'Ogata, H., 2004-1' from cluster 2, and 'Weiser, M., 1991' from cluster 1. 'Ogata, H., 2004-1' in cluster 2 demonstrates the highest betweenness, indicating this node's function as a bridge in the network, connecting different nodes or clusters.

In WoS network (**Figure 11**), we also see three major clusters. Here, 'Weiser, M., 1991' from cluster 3, 'Ogata, H., 2004-1' from cluster 3, and 'Hwang, G.-J., 2008' from cluster 2 have the highest relevance. As for the betweenness, 'Weiser, M., 1991', 'Ogata, H., 2004-1', and 'Sakamura, K., 2005' show the highest values, indicating their significant roles as bridges within this network.

In the merged network (**Figure 12**), we see 'Hwang, G.-J., 2008' from cluster 1, 'Chu, H. C., 2010' from cluster 1, and 'Hwang, G.-J., 2009' from cluster 1 having the highest relevance. The authors with the highest betweenness are 'Weiser, M., 1991', 'Ogata, H., 2004', and 'Hwang, G.-J., 2009', once again, highlighting their role as bridges in the network. In comparing the three networks, it is clear that 'Hwang, G.-J., 2008' and 'Weiser, M., 1991' have consistently high relevance across all databases, indicating their important roles. Additionally, 'Ogata, H., 2004-1' appears as a significant bridge in both Scopus and WoS databases. Overall, this suggests a high level of convergence in the co-network of publications across these databases, with these particular authors and works forming central nodes within the networks.

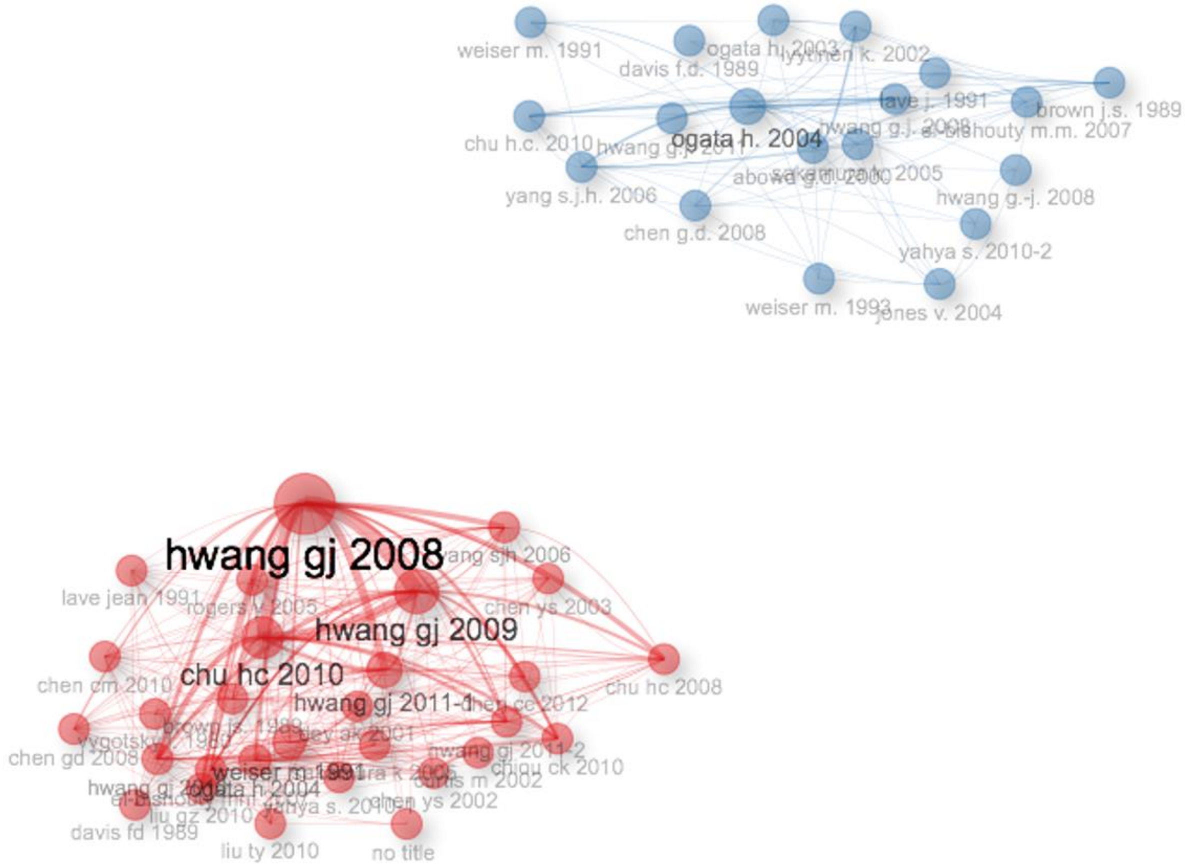

Figure 12. Co-network based on publication: Merged databases (Source: Authors)

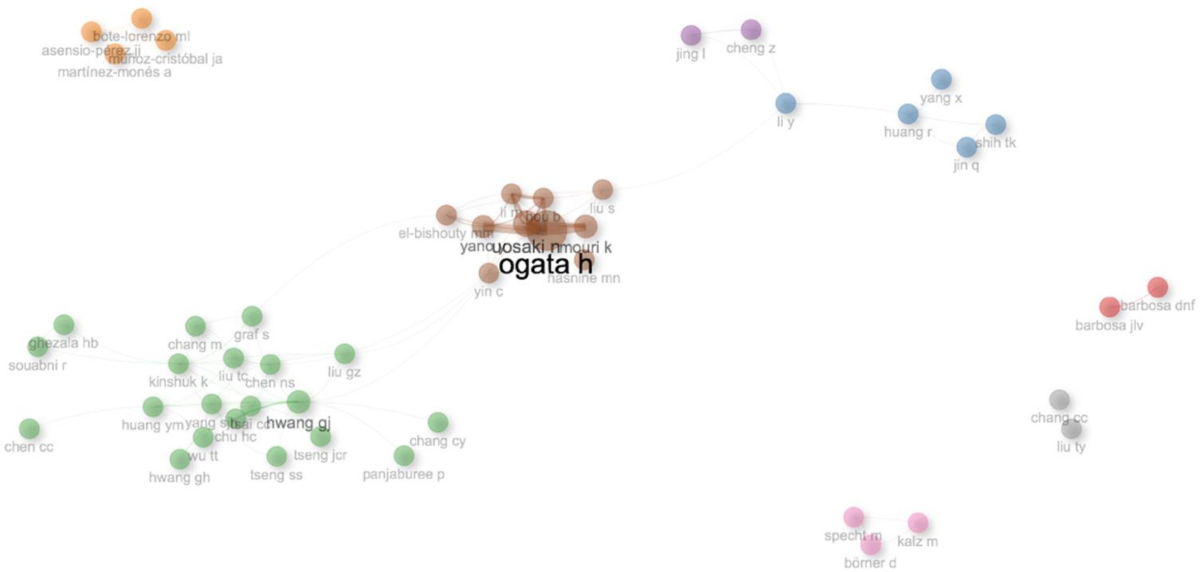

Figure 13. Co-network based on authors: Scopus database (Source: Authors)

Based on the centrality measures provided, it can be noted that different authors play distinct roles in the collaboration network (Figure 13, Figure 14, and Figure 15). These roles are characterized by the cluster, betweenness, closeness, and relevance of each author.

In Scopus database, authors such as Hwang, G.-J., Kinshuk, K., and Ogata, H. stand out due to their higher betweenness centrality values, which suggests that they serve as important bridges in their respective clusters. These authors are crucial for knowledge transmission and collaboration within their networks.

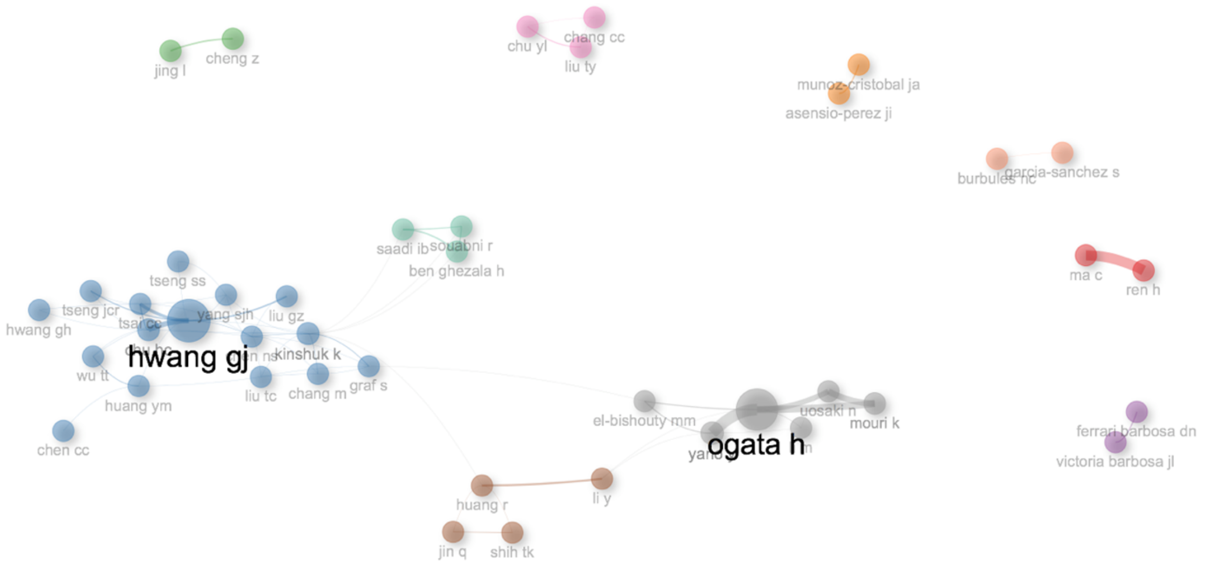

Figure 14. Co-network based on authors: WoS database (Source: Authors)

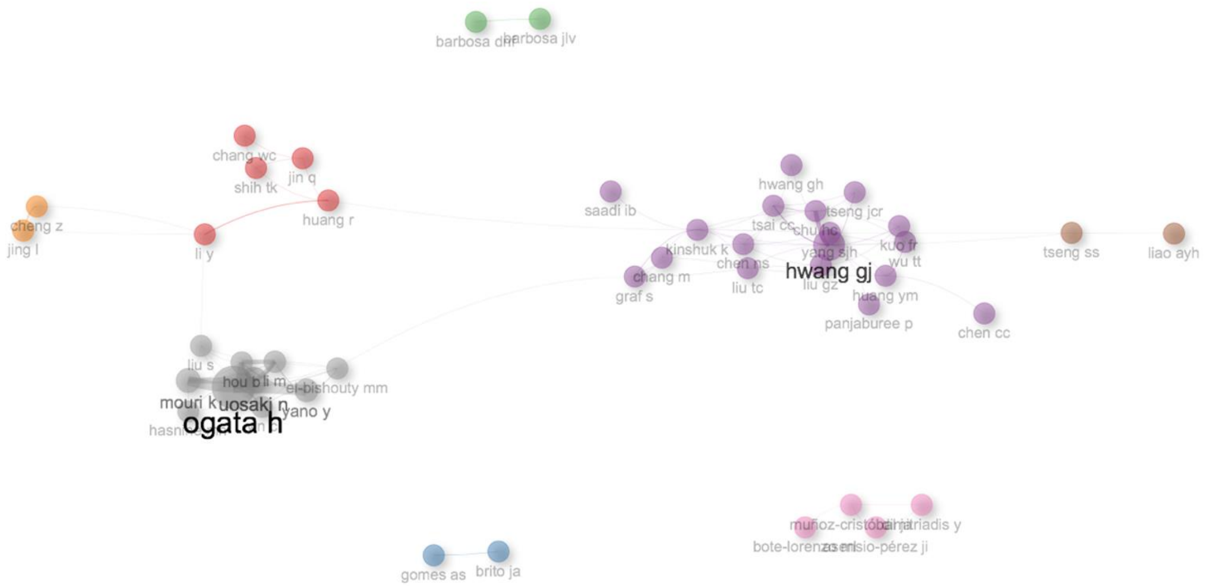

Figure 15. Co-network based on authors: Merged database (Source: Authors)

In contrast, Wos database shows a similar pattern with authors like Hwang, G.-J., Kinshuk, K., and Huang, R. They have high betweenness values, indicating their key role in connecting different nodes in their clusters.

For the merged database, Hwang, G.-J., Kinshuk, K., and Ogata, H. again appear as central figures in their respective clusters, showcasing their prominent roles in collaboration and knowledge dissemination. Closeness centrality represents the distance from a node to all other nodes in the network. In general, nodes with high closeness can quickly interact with others in the network. It is noticeable that authors with high closeness centrality are distributed across different clusters in all databases. From these measures, it can be inferred that while there are central figures like Hwang, G.-J. and Kinshuk, K. in each database, the exact network structure varies across the different databases. This could be due to the different coverage, scope, and update frequency of these databases. Additionally, the structure of the co-authorship network can also be influenced by various factors, such as the authors' research interests, collaboration habits, geographical locations, among others.

DISCUSSION

This study focuses on the research trends, major contributors, geographical representation, and key themes within ubiquitous learning. The analysis indicates a growing interest and research output in this field, particularly around 2016. Utilizing different databases (Scopus, WoS, and a merged dataset) for the analysis yielded enriching results, revealing differences in citation counts, types of documents, and unique sources. Major contributors, high-output institutions, and countries with significant contributions were identified. The network analysis highlighted "ubiquitous learning" as the most prominent node, with "mobile learning" and "life log" also emerging as significant nodes. The co-keyword clusters and co-network based on publication underscored the centrality of certain themes, authors, and publications.

However, this study has several limitations. The exclusive use of Scopus and WoS databases may not capture all relevant literature in the field, and the exclusion of non-English publications could omit significant contributions. The bibliometric analysis provides a snapshot of the field based on the existing literature and citation patterns, but it may not capture the complete spectrum of research activities or emerging trends that are not yet widely published or cited.

The use of different databases (Scopus, WoS, and a merged dataset) for the analysis provided enriching results. Each database provides unique insights and indicates differences in citation counts, types of documents, and unique sources. In many bibliometric studies (Caputo & Kargina, 2022; Echchakoui, 2020; Farooq, 2022), the importance of using and combining different databases has been emphasized. Authors like Hwang, G.-J., Ogata, H., Yano, Y., and Chu, H. C. have been highlighted as significant contributors. Considering the Scpous and WoS databases, Ogata, H. and Yano, Y. made their first broadcast in 2004, Chu, H. C. in 2007 and Hwang, G.-J. in 2008.

Additionally, institutions like the University of Tokushima and National Taiwan University of Science and Technology have high research outputs. In the study (Hwang & Tsai, 2011) covering the years 2001-2001, the USA was influential in the number of publications between 2001-2005, while Taiwan stood out between 2006-2010. In our study, however, China came to the fore. While China has the highest total citations, other countries like Switzerland and Ireland also contribute significantly through high-impact articles.

The analysis of centrality measures in Scopus, WoS, and merged databases reveals a number of interesting patterns and trends about the field of ubiquitous learning research. In all three databases, "ubiquitous learning" emerges as the most prominent node, indicating its central role in the research network. The high betweenness centrality and relevance values for "ubiquitous learning" suggest its pivotal role in connecting many other nodes in the network. The prominence of this node in all databases underscores the centrality and relevance of ubiquitous learning in the broader research landscape.

Other important nodes such as "mobile learning" and "life log" also emerge as significant in the network based on their betweenness centrality. The prominence of "mobile learning" is not surprising given the strong connection between mobile technology and the concept of ubiquitous learning. In some studies (Hwang & Tsai, 2011; Pimmer et al., 2016), mobile learning and ubiquitous learning are discussed together. The appearance of "life log" as a significant node suggests an emphasis on personalized, lifelong learning within the field. The fact that these nodes are important in bridging clusters or pathways within the network further emphasizes their relevance in the ubiquitous learning research network. This may be due to the prioritization of real-world content in learning processes (Alioon & Delialioğlu, 2019; Chu et al., 2010; Roach et al., 2018; Sotiriadou et al., 2019).

The analysis of co-keyword clusters provides a rich view of the thematic landscape of ubiquitous learning research. In Scopus dataset, "ubiquitous learning" stands out as the most influential topic based on its relevance centrality. This cluster is populated with terms such as "mobile learning", "e-learning", "ubiquitous computing", "augmented reality", and "collaborative learning", suggesting the critical role these sub-themes play in the field. When the relevant keywords are considered, the related concepts emerge. For example, augmented reality applied outdoors is directly effective with ubiquitous learning (Allcoat et al., 2021; Cárdenas-Robledo & Peña-Ayala, 2018; Hwang, 2014). Mobile learning is already becoming an indispensable element for ubiquitous learning (Hwang & Wu, 2014; Pimmer et al., 2016; Virtanen et al., 2018).

The co-network based on publication further emphasizes the centrality of certain authors in the field of ubiquitous learning. For instance, the study titled "Criteria, strategies and research issues of context-aware ubiquitous learning" by Hwang et al. (2008) has been a collaborative study by many studies. The study titled "Context-aware support for computer-supported ubiquitous learning", which was also written by Ogata and Yano (2004), became a prominent work in the co-network. These authors, along with others that show high betweenness centrality, are significant for their role as connectors in the network, serving as bridges that link different clusters of knowledge.

This study also highlights several areas for future research. First, the prominence of "ubiquitous learning" and related terms in the network analysis suggests a need for more in-depth exploration of these themes and their interconnections. Second, the significant role of certain authors and institutions in the network indicates potential collaboration opportunities and knowledge exchange. Lastly, the changing geographical representation in the literature, with China emerging as a significant contributor, suggests a need for more global and cross-cultural research in the field.

In summary, this bibliometric analysis provides valuable insights into the field of ubiquitous learning. It reveals the key themes, authors, and publications that are shaping the field, while also demonstrating the interconnectedness of these various elements. These findings underline the complexity of the field and its ongoing evolution in response to technological advancements. It highlights the need for future research to continue exploring the diverse dimensions of ubiquitous learning and to consider multiple sources.

CONCLUSIONS

The bibliometric analysis of scientific output in the field of ubiquitous learning, using Scopus and WoS databases and a merged dataset, provides important insights into the evolution, collaboration, and current trends in this domain. Three main conclusions can be drawn from this analysis:

1. Growing interest and diverse data sources: There is a clear expansion in the field of ubiquitous learning over the years, demonstrated by an increasing use of diverse data sources and a continuously active research arena. The analysis reveals a peak in interest around 2016, followed by a decline, potentially attributed to incomplete recent data. The prevalence of 'article' type documents and the significance of conference papers in Scopus and the merged dataset highlight the importance of multiple platforms for research dissemination.
2. Influential contributors and geographical representation: Hwang, G.-J., Ogata, H., and Yano, Y. are among the most influential and productive authors, with Asian institutions like the University of Tokushima and National Taiwan University of Science and Technology showing high research output. However, a broader geographical representation is observed in WoS and merged databases, with significant contributions from institutions such as the University of Illinois and Universidad de Valladolid. China leads in total citations, but Switzerland and Ireland show high average article citations, indicating the high impact of their individual articles.
3. Key themes and collaboration structure: Terms like "mobile learning" and "life log" exhibit significant betweenness centrality, indicating their critical roles in bridging different research clusters. The network analysis reveals the interconnectedness of various terms related to technology-enhanced and ubiquitous learning, and highlights the collaborative nature of the field, with authors like Hwang, G.-J. and Ogata, H. serving as central figures in the co-authorship network.

In summary, this study provides a comprehensive overview of the state of ubiquitous learning research, highlighting the key contributors, geographical representation, and thematic landscape. The analysis underscores the importance of using multiple databases for a holistic understanding and reveals the collaborative structure and significant figures in the field. Despite the limitations related to database coverage and language restrictions, these insights are valuable for researchers and practitioners seeking to understand the evolution and current state of ubiquitous learning research.

Author contributions: All authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. All authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics declaration: Authors declared that the study did not require ethics committee approval. Data is based on published studies.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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