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🔓 **Review Article**

Bibliometric Analysis of Mobile Learning Research Trends Over the Last Decade

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Abstract

The use of mobile devices in learning is increasing, allowing students to access learning resources. In the ever-growing digital era, mobile learning not only offers innovative learning alternatives but also shapes the future of education. This study provides a comprehensive bibliometric analysis of 8352 articles on mobile learning in higher education from 2002 to 2023. With the help of VOSViewer, the researcher can explore complex relationships between scientific information, gain deep insights into specific subject areas, and make decisions supported by powerful bibliometric analysis. Key findings reveal a peak in 2019 with 673 publications, and the most cited work is "Current Status, Opportunities And Challenges Of Augmented Reality In Education" by Wu et al. (2013) with 1285 citations. Prolific authors include Hwang, Huang, Ogata, and Looi. Productive sources are ACM International Conference Proceedings Series and journals like International Journal Of Mobile Learning And Organization. Institutions like National Taiwan University and countries like ChinaUnited States, and Taiwan lead in productivity. Top keywords include "mobile learning," "e-learning," and "students," offering insights for future research planning.

Keywords: Bibliometric analysis, mobile learning, research trend, VOSviewer

1. INTRODUCTION

The use of mobile devices in learning is increasing, allowing students to access learning resources via their cellphones (Martin & Ertzberger, 2013). Mobile Learning (m-learning) is referred to as learning carried out by students that is mediated by mobile devices, so that it can be done anytime, anywhere, both formally and informally (Kukulska et al., 2008).

In 2020 we are faced with the COVID-19 pandemic which affects all aspects of life, including education. Learning takes place online so that the application of mobile learning continues to increase. This research presents a bibliometric analysis regarding the use and application of mobile learning from various countries, especially over the last ten years.

Mobile learning is defined as a wireless, digital, and technological device, generally produced for the public, used by a student as they participate in education (Traxler, 2007). Mobile learning is learning where the learner does not stay in one place or learning activities that occur when learning uses mobile technology devices. Learning practices use mobile technology directly or simply complement learning

with information technology and communication which allows the learning process to occur anytime and anywhere (Volsoo, 2015).

One of the main characteristics of mobile learning is its flexibility. Compared to traditional classroom learning, mobile learning gives students the freedom to set their own study schedule. They can choose learning materials according to their interests and appropriate level of difficulty. This flexibility also allows students who have busy schedules or are committed full-time to continuing their education without having to sacrifice work or other activities.

In addition to flexibility, mobile learning also offers a variety of features that enhance the learning experience, including interactive, multimedia, and personalization. Mobile learning applications often present learning material in engaging formats, such as videos, animations, simulations, and educational games. This interactivity not only makes learning more fun but also helps students understand difficult concepts through hands-on experience and experimentation.

Apart from that, mobile learning also allows personalization of learning. Through artificial intelligence technology and data analysis, mobile learning applications can assess individual student abilities and weaknesses. With this information, the app can create learning plans tailored to each student's needs. This personalization helps students to learn in the most effective and efficient way for them, speeding up the learning process and improving learning outcomes.

Mobile learning also has a positive impact on educational inclusiveness. This allows access to education for people with disabilities who may face barriers to learning in traditional settings. Mobile learning apps can be designed with accessibility needs in mind, such as large text, voice, or touch controls, so that students of all abilities can learn comfortably.

In the ever-growing digital era, mobile learning not only offers innovative learning alternatives but also shapes the future of education. By continuing to develop mobile learning technology and applications, education can become more affordable, inclusive and effective for everyone.

Bibliometric research is becoming increasingly important in today's digital information era because it enables decision making that is supported by strong empirical data. Researchers and policy makers use bibliometric research results to guide their steps in developing relevant research and accelerating scientific progress.

Bibliometric research in the field of mobile learning involves the analysis of bibliographic data related to research, articles, conferences, and other scientific literature related to the use of mobile technology in learning. This approach provides an in-depth look at trends, researcher productivity, and research impact in the field of mobile learning.

Bibliometric research helps identify knowledge gaps in the mobile learning literature. By recognizing research areas that are still underexplored, researchers can design in-depth studies to fill these gaps and improve our understanding of mobile learning.

Through a bibliometric approach, stakeholders in the field of mobile learning, including researchers, educators and policy makers, can make evidence-based decisions to support the sustainable and effective development of mobile learning. Bibliometric analysis is a very important tool in planning and managing research and understanding the latest developments in the field of mobile learning.

1.1 Purpose of the Study

Based on existing literature, it has been reported that there is a significant increase on the use of mobile learning. As a result, this study will build on earlier

findings. This research includes journal publications and conference papers, particularly from the last ten years in order to provide a complete view. The bibliometric method was employed by the author to determine the annual quantity of publications and citations, the most often cited documents, the most productive authors and sources, the most active countries and institutions, and the most pertinent keywords.

RQ1: How has the research output and citation trends evolved for academic papers on mobile learning within higher education?

RQ2: Which documents receive the highest number of citations in the context of mobile learning research within higher education?

RQ3: Who are the leading authors and primary sources driving the publications on mobile learning in higher education?

RQ4: Which institutions and countries demonstrate the highest levels of productivity in the field of publishing papers related to mobile learning in higher education?

RQ5: What are the most pertinent keywords, and how do they interrelate in the landscape of mobile learning research within higher education?

2. METHODS

2.1 Data Search Strategy and Acquisition

Data collection began for this research from the Scopus database on September 14 2023. Scopus was chosen as the source of data mining in this research because it has broad subject coverage (Fahimnia et al.; Ghani et al., 2022; Phulwani et al., 2020) and provides convenience in exporting data for input into bibliometric software. Descriptive analysis and bibliometric analysis were combined to achieve the objectives of this research. Bibliometric analysis is an objective and quantitative method used to determine the intellectual formation of a field of scientific study (Garfield, 1979).

The first search was carried out using the keyword "mobile learning" in the title, abstract or list of keywords. This search produced 9627 documents published from 1984 to 2023 which were then filtered to 8352 documents leaving journal articles and conference papers for further study. The collected data is downloaded from the Scopus database into CSV format.

There are several terms related to bibliometric analysis (Jan van Eck & Waltman, 2018). The term 'item' refers to an object of interest, such as a publication, author, country, or keyword. When two items are connected or related to each other, this connection is identified as a 'link'. This link can be measured, for example when two authors are connected to each other and have many publications they have written together, then this link becomes stronger. The cumulative strength of an item's relationship to other items is identified as 'total link strength'. A collection of objects can generate a 'network' by creating links. VOSviewer can generate maps and graphs based on this network data.

VOSviewer is free JAVA-based software and was developed by van Eck and Waltman from The Center for Science and Technology Studies (CWTS) Leiden University in the Netherlands in 2009, especially for literature data (Eck & Waltman, 2009). In this research, analysis was carried out on the co-authorship of authors, countries, and organizations, as well as keyword co-occurrence to create a network map showing: (1) co-authorship between researchers, countries, and institutions, and (2) word occurrence key simultaneously. VOS Viewer has become a popular tool among researchers, libraries, and educational institutions for understanding and visualizing the structure of scientific literature and scientific collaboration. With the

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help of VOS Viewer, users can explore complex relationships between scientific information, gain deep insights into specific subject areas, and make decisions supported by powerful bibliometric analysis.
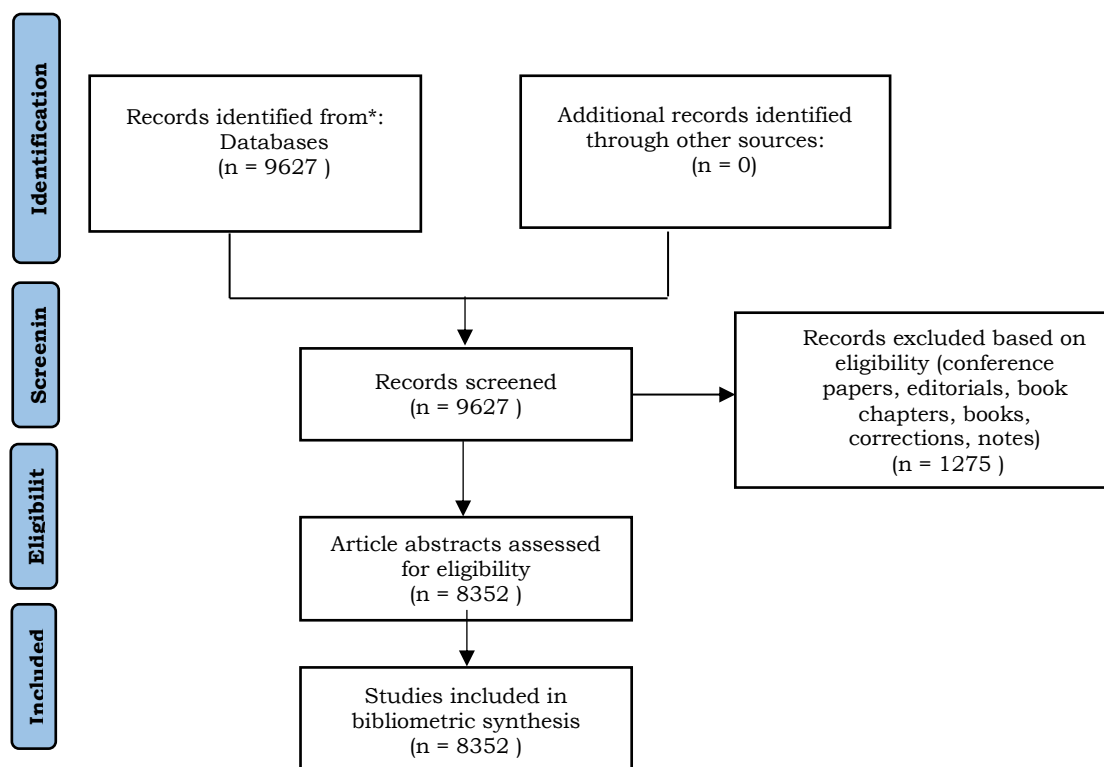

Figure 1. PRISMA Flow Diagram of the Present Study

3. RESULTS

3.1 Publication Output

An important metric for evaluating trends in a subject is the quantity of publications, and the quantity of publications in a field within a nation indicates, to some degree, the strength of that nation's research in that field. (Li et al., 2021). This study offers a thorough analysis of how the literature on mobile learning has changed and developed over time in the context of higher education until 2023. This bibliometric analysis looks at research keywords, organizations, countries, authors, sources, output growth, and top references.

Using citation analysis, the impact of research publications can be evaluated. The significance of a research work is measured by the number of times other works cite it. Figure 1 shows the trend in the distribution of publications and citations from year to year. The database contains 8352 publications that have been published. These articles have been cited 111,599 times, averaging 13.36 citations per article and 4852.13 citations annually. The database had 8 articles and 682 citations in 2002. From 103 publications and 1244 citations in 2006 to 673 publications and 1244 citations in 2019, the trend of publications and citations increased steadily. With 9202 citations, 2013 had the highest number of citations.
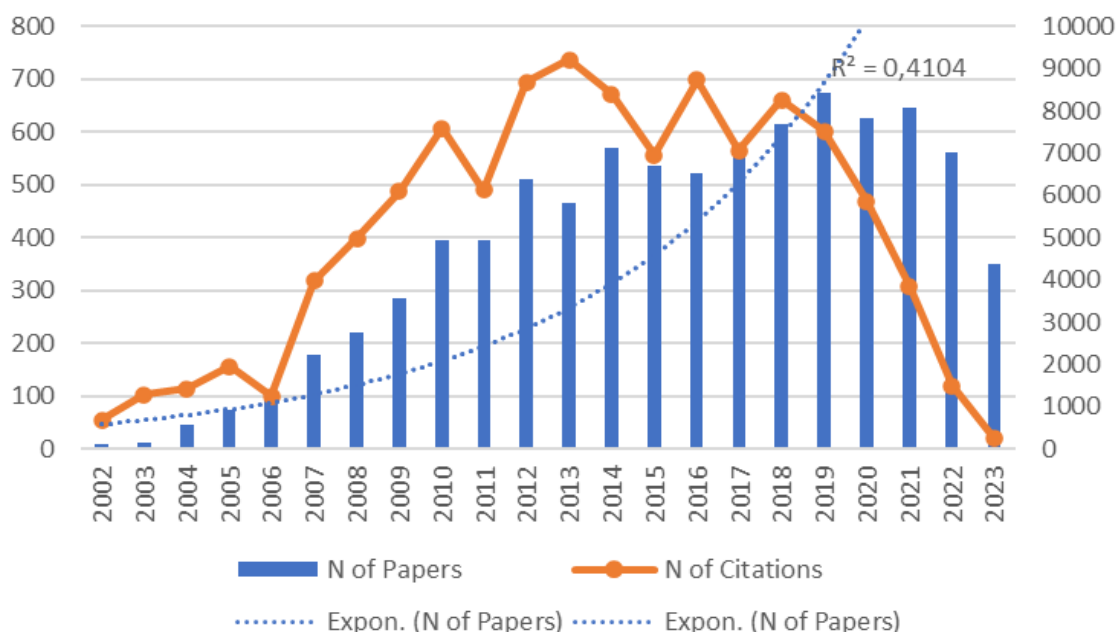
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Figure 2. Distribution of articles dan citations by year (2002-2023)

During the pandemic around 2020 to 2022, publications on this theme were still high, namely 560 publications in 2022 and 1498 citations. In 2022 the number of published articles will be 509, and articles cited will be 8669 times. Since 2002, interest in this subject has continued to increase until 2019. This increase can be seen both in the number of publications and citations. The number of articles and citations both show an increase. This review was conducted in September 2023, and at that time there were 351 papers in this topic with 260 citations.

The total number of publications annually displays an exponential growth curve, with a doubling of the body of literature every ten to fifteen years. Furthermore, it was discovered that the determination value (R2) was 0.4104.

3.2 Most Cited Documents

Citation analysis is a valuable method for assessing the impact of research publications, as it quantifies the influence of a work based on how often it is cited by other research. Table 1 presents the top 10 papers that have garnered the most citations in the scientific literature. In this context, we have analyzed articles that have made a substantial impact in the field. At the time of our study, these top 10 papers collectively accounted for 7111 citations out of a total of 111599 citations, representing a significant percentage. Notably, the paper titled 'Current status, opportunities, and challenges of augmented reality in education' authored by Wu et al. holds the top spot in terms of citations, with an impressive 1285 references, making it the most frequently cited publication. Following closely, 'The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis' by Sung et al. ranks second with 860 citations. The third position is held by 'Investigating the determinants and age and gender differences in the acceptance of mobile learning' authored by Wang et al., with 762 citations. An interesting observation from Table 1 is that seven of the most cited papers originate from 'Computers and Education,' two from the 'British

Journal of Educational Technology,' and the remaining papers are sourced from 'Internet and Higher Education'.

Table 1. Top 10 Most Cited References

Authors	Title	Year	Source	Cites
Wu et al., 2013	Current status, opportunities and challenges of augmented reality in education	2013	Computers and Education	1285
Sung et al., 2016	The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis	2016	Computers and Education	860
Wang et al., 2009	Investigating the determinants and age and gender differences in the acceptance of mobile learning	2009	British Journal of Educational Technology	762
Gikas et al., 2013	Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media	2013	Internet and Higher Education	756
Motiwalla L.F.	Mobile learning: A framework and evaluation	2007	Computers and Education	645
Cheon et al., 2012	An investigation of mobile learning readiness in higher education based on the theory of planned behavior	2012	Computers and Education	627
Wu et al., 2012	Review of trends from mobile learning studies: A meta-analysis	2012	Computers and Education	601
Hwang et al., 2011	A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students	2011	Computers and Education	580
Park et al., 2012	University students' behavioral intention to use mobile learning: Evaluating the technology acceptance model	2012	British Journal of Educational Technology	500
Evans C.	The effectiveness of m-learning in the form of podcast revision lectures in higher education	2008	Computers and Education	495

3.3 Most Influential Authors and Sources

The top 10 most productive authors based on the total number of articles (N), country of origin and H-index value are presented in Table 2. These top ten authors have produced at least 24 publications. As can be seen, Gyojen Hwang is the most prominent author with 95 papers, followed by Huang, Y.M with 45 papers and Ogata, H as the third most prolific author on this subject.

The ten authors come from Taiwan, Japan, China, Netherlands, New Zealand, Sweden, Spain and Austria.

Table 2. Top 10 Prominent Authors

Author	Institution	Country	N	H-Index
Hwang, G.J	National Taiwan University of Science and Technology	Taiwan	95	74
Huang, Y.M	National University of Tainan	Taiwan	45	2
Ogata, H	Kyoto University	Japan	44	32

Author	Institution	Country	N	H-Index
Looi, C.K	The Education University of Hong Kong	China	42	30
Specht, M	DelftUniversity of TechnologyThis link is disabled.	Netherlands	33	33
Parsons, D	The Mind Lab	New Zealand	30	16
Milrad, M	Linnaeus University	Sweden	28	22
Garcia-Penalvo, F.J	University of Salamanca	Spain	27	49
Yano, Y	Tokushima University	Japan	25	21
Sarrab, M	Organization of the Petroleum Exporting Countries	Austria	24	16

Table 3 lists the top 10 journals by number of most popular publications. The total number of documents published was 1466 or 17,555 of the total documents. The most publications, 234, were published in the ACM International Conference Proceedings Series. The International Journal of Interactive Mobile Technologies and the International Journal of Mobile Learning and Organization, with 205 and 199 papers, respectively, came next.

Table 3. Top 10 Most Influential Sources

Journal	N	Q	SJR 2022	Publisher
ACM International Conference Proceeding Series	234	-	0,21	Association for Computing Machinery (ACM)
International Journal Of Mobile Learning And Organisation	205	Q2	0.65	Inderscience Publishers
International Journal Of Interactive Mobile Technologies	199	Q2	0.65	Inderscience Publishers
Communications In Computer And Information Science	148	Q4	0.19	Springer Science and Business Media Deutschland GmbH
Advances In Intelligent Systems And Computing	129	-	-	Springer Science and Business Media Deutschland GmbH
Computers And Education	121	Q1	3.68	Elsevier Ltd
Ceur Workshop Proceedings	114	-	0.2	-
International Journal Of Mobile And Blended Learning	113	Q2	0.44	IGI Global Publishing
Journal Of Physics Conference Series	97	Q1	1.22	Informa Healthcare
Education And Information Technologies	97	Q1	1.25	Kluwer Academic Publishers

3.4 Most Productive Institutions and Countries

Institutional analysis is used to determine the impact of each institution through the number of publications and collaboration between institutions (Li et al., 2021). Table 4 presents the 10 best universities that participated the most, amounting to 8.86% of all papers collected. The top three institutions were National Taiwan University of Science and Technology, National Central University and Athabasca University with 106, 84 and 81 publications respectively. Then followed by National Taiwan Normal University (80), Nanyang Technological University (67), Universiti Teknologi Malaysia (67), Universiti Teknologi MARA (64), National Institute

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of Education (64), National Cheng Kung University (64) and National University of Tainan Taiwan (63).

Table 4. Top 10 Most Prolific Institutions

Institution	Country	Types	N
National Taiwan University of Science and Technology	Taiwan	Public	106
National Central University	Taiwan	Public	84
Athabasca University	Canada	Private	81
National Taiwan Normal University	Taiwan	Private	80
Nanyang Technological University	Singapore	Public	67
Universiti Teknologi Malaysia	Malaysia	Public	67
Universiti Teknologi MARA	Malaysia	Private	64
National Institute of Education	Singapore	Private	64
National Cheng Kung University	Taiwan	Public	64
National University of Tainan Taiwan	Taiwan	Public	63

A country's research prowess in an area is reflected in the number of papers it has published in that field, which is a useful indicator for evaluating developments in that field. (Li et al., 2021). Table 5 presents the top 10 countries that publish the most papers. China tops the list with 949 articles. The number of papers is 11.36% of the total papers. Then followed by the United States with 727 articles (8.7%), then Taiwan with 697 articles (8.34%).

Table 5. Top 10 Most Productive Countries

Country	N of papers	%
China	949	11.36
United States	727	8,.70
Taiwan	697	8.34
United Kingdom	560	6.70
Malaysia	555	6.65
Indonesia	398	4.76
Australia	368	4.41
Spain	366	4.38
Germany	319	3.82
Canada	228	2.72

3.5 Co-authorship for Author and Country

In this section, an analysis of collaboration between authors is presented. When the minimum number of papers by an author was set at a minimum of 5, a total of 24 authors met the threshold out of a total of 7574 authors. With this setup, there are 6 different clusters. When the threshold is increased to 6, there are 13 authors who meet the threshold in 4 clusters (Figure 2). Looking at Figure 3, the largest cluster (red) has 4 authors. The second group, which consists of three authors, is the green cluster. There are three authors in the blue cluster, which is the third largest group, and three authors are in the yellow cluster, which is the final cluster.
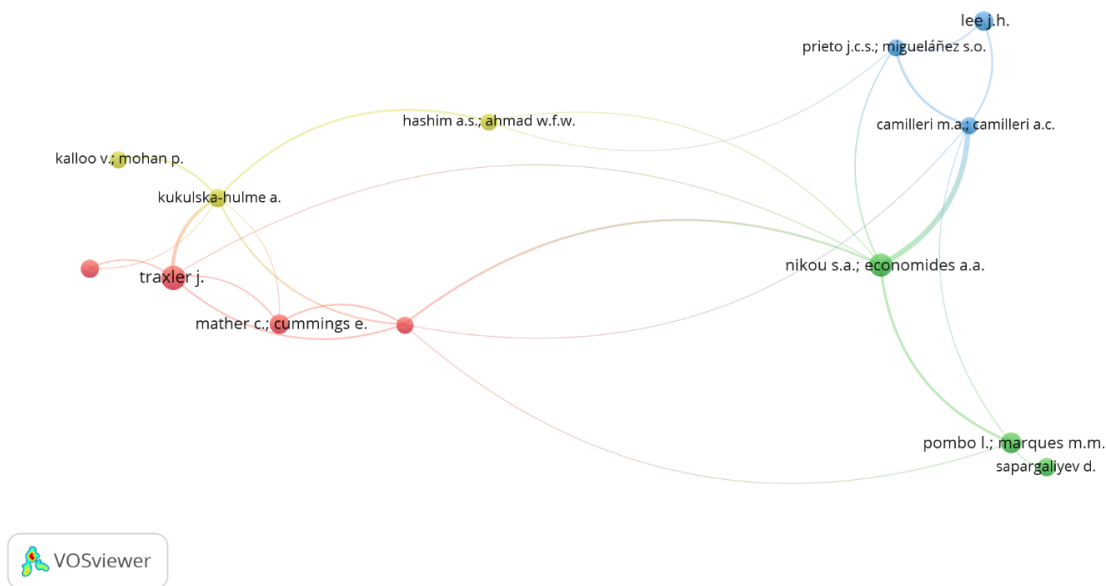
Figure 3. Map of Co-Created Connected Clusters
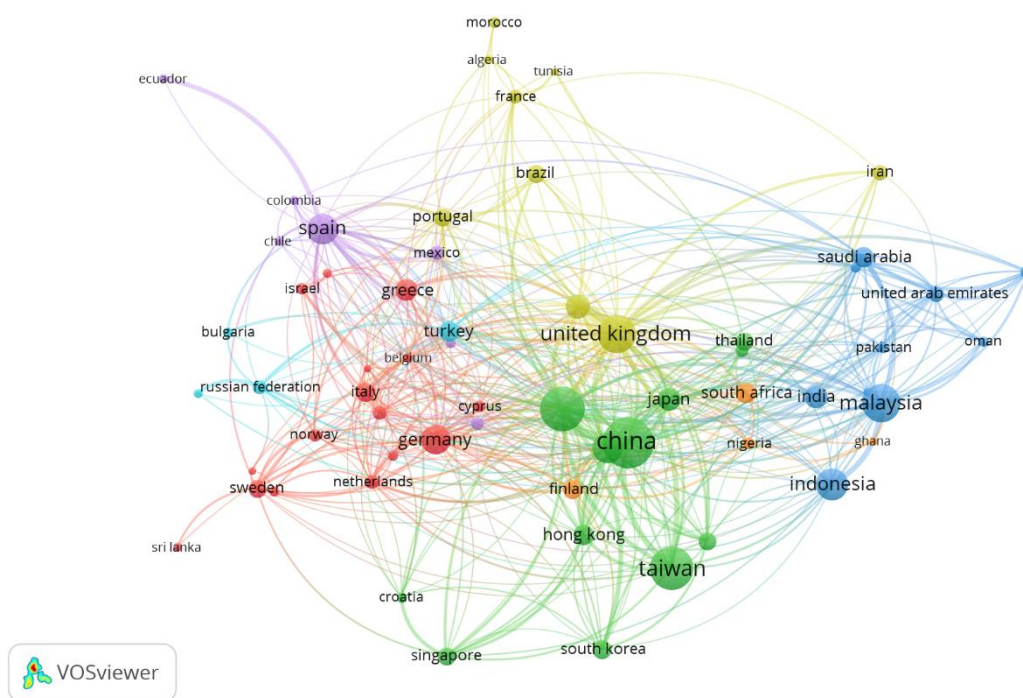
Figure 4. Network Visualization of Co-Authorship Countries

The author also analyzes the co-authorship relationship between countries (see Table 6). Figure 4 depicts a map of co-authored countries. The node size on the map represents a nation's total number of publications, while the intensity of the relationship between clusters is shown by their distance from one another. If we establish a country's minimum document count at 5, then 100 countries fall under the 203 threshold. Nine clusters consisting of 98 related countries out of 100 total.

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Table 6. Most Frequently Used Keywords

Author Keywords	OCC
Mobile Learning	5911
E-learning	3332
Students	1927
Learning Systems	1503
Education	1294
Teaching	1173
Mobile Devices	1157
Engineering Education	944
Computer Aided Instruction	943
M-Learning	684

3.6 Co-occurrence of Author Keywords

Research trends and popular topics are found by keyword clustering analysis. The frequency with which pertinent terms appear in publications in connection with the author's keywords is determined. Table 6 displays the top 10 keywords that occur together. The analysis results show that the keywords that appear most frequently are as follows: Mobile Learning, E-learning, Students, Learning System, and Education.

Figure 5. Visualization of the Shared Keyword Network: The Most Used Author Keywords

Research hotspots are depicted in Table 6 together with the term occurrence map produced by VOSviewer (Figure 5). Research on relevant topics is revealed using keyword analysis. On related topics, minimum appearance thresholds are established. With a minimum occurrence criteria of 25, 146 keywords out of 12755 were selected for study. Related keywords that appear in the same hue make up each cluster. The largest note contains the most pertinent keywords. The findings indicate that there are ten clusters and that mobile learning (5911) is the most often used keyword. Other than that, the most popular keywords are Students (1927), Learning System (1503), E-Learning (3332), and Education (1294).

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4. CONCLUSION

From data taken over the last ten years, it can be said that the peak of research on this theme occurred in 2019 with 673 publications. Meanwhile, the most citations occurred in 2013 with 9202 citations. The work of Wu H.-K, Lee S.W.-Y., Chang H.-Y., Liang J.-C. entitled Current status, opportunities and challenges of augmented reality in education is the most cited article with 1285 citations. The most prolific authors in this field are Hwang, G.J, Huang, Y.M, Ogata, H and Looi, C.K. ACM International Conference Proceedings Series, International Journal Of Mobile Learning And Organization, and International Journal Of Interactive Mobile Technologies are the most productive sources. Meanwhile, the most active institutions are National Taiwan University of Science and Technology, National Central University, Athabasca University and National Taiwan Normal University. China, United States and Taiwan are the most productive countries. The keywords that are trending are "mobile learning", "e-learning" and "students". This study can be helpful for other researchers to expose the gap in current knowledge, improve the quality of research and provide maps as guidance for future research planning and implementation.

Conflict of Interest

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