Global Trends on Mobile Learning in Higher Education: A Bibliometric Analysis (2002–2022)

Irwanto Irwanto*, Anip Dwi Saputro, Widiyanti Widiyanti, and Sigit Dwi Laksana

***Abstract*—This study explores the research landscape of mobile learning in the context of higher education (MLHE) by conducting a comprehensive bibliometric analysis over the years. A total of 2477 papers published in peer-reviewed journals and conferences up to May 2022 were retrieved from the Scopus database. The results revealed an increase in MLHE research over time with a peak in 2021. The first paper was published in 2002, indicating the beginning of the field. The works of J. Gikas and M. M. Grant, L. F. Motiwalla, and J. Cheon *et al.* stand out as the most cited articles among the analyzed documents. T. Cochrane, F. J. Garcı́a-Peñalvo, and H. Farley are the most prolific authors. *ACM International Conference Proceeding Series, International Journal of Interactive Mobile Technologies,* and *International Journal of Mobile Learning and Organisation* are the most productive sources. University of Salamanca, Science University of Malaysia (Universiti Sains Malaysia), and the University of Southern Queensland are the most active institutions. China, the US, and the UK are the most relevant countries. Keywords such as "*mobile learning*", "*m-learning*", "*higher education*", "*e-learning*", and "*mobile devices*" remain the trending keywords in this area. This review offers a comprehensive overview of scientific production and the future direction of the field.**

***Index Terms*—Mobile learning, higher education, bibliometric analysis, research trends**

I. Introduction

In the digital era, the emergence of mobile technology encourages the emergence of a new paradigm of teaching and learning with the aid of technology. The use of mobile devices for educational purposes, known as mobile learning (m-learning), has attracted the attention of practitioners and researchers worldwide and has become an increasingly popular learning approach in recent years [1]. M-learning is seen as a new concept in the context of learning that takes place with the help of portable electronic devices and can occur anywhere and anytime both inside and outside the classroom [2]. This may be due to the fact that students can easily carry their mobile devices from one location to another to access information and knowledge; thus, m-learning provides more options for students to learn and access learning content quickly and on time without certain space restrictions [3]. Interestingly, the interest in using m-learning in higher education has increased rapidly so far [4]. In a study conducted in Kuwait, Sulaiman and Dashti [5] reported that out of 1012 undergraduate students, 1008 respondents own a smartphone and 70% of them use a smartphone for more than four hours every day. As more higher education students have mobile devices, they may be better prepared and more competent to adopt m-learning than K-12 students [6]. This shows that higher education is the right place for m-learning integration as mobile devices have become ubiquitous [7]. Thus, nowadays, higher education is heavily influenced by this trend.

Over the past decade, m-learning has attracted the growing interest of scholars, students, educators, and academic institutions around the world [1, 4, 5]. However, despite the rapid development of mobile learning studies in higher education among scholars, the understanding of the annual number of publications, most-cited papers, most influential authors and sources, most active institutions and countries, co-authorship for authors and countries, and co-authors occurrence of author keywords in mobile learning research is still limited. Limited understanding in this field may hinder the development of future mobile learning studies. Given the importance of m-learning [3] and increasing the number of publications in the field, there is an opportunity to investigate the status and trends of research on mobile learning in the context of higher education in the literature. As such, this bibliometric review fills this gap to guide future research and serves as a reference point for mobile learning scholars, curriculum developers, and educators in the higher education sector.

We assume that comprehensive bibliometric analysis in m-learning is very important. This may be due to the fact that bibliometric analysis is highly useful for mapping the focus of cumulative scientific research and providing a comprehensive picture of scientific production and development over time in a particular field [8]. In general, the bibliometric analysis consists of two main techniques [8], namely performance analysis, which aims to evaluate scientific production both quantitatively (e.g. number of publications) and qualitatively (e.g. average citations per article), and scientific mapping, which provides a spatial representation of bibliometric maps (e.g. co-word and co-authorship analysis). To this end, this study was carried out to evaluate the scientific literature addressing mobile learning in higher education and identify the most important topics and issues that will help design future studies. This research includes identifying scientific production, the most prolific research works, authors, reference sources, organizations, countries, and keywords used within this research domain. Thus, the analysis helps researchers to understand the current status and research landscape of this area more comprehensively.

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II. Literature Review

M-learning is postulated in various ways. For instance, El-Hussein and Cronje [9] define mobile learning as "any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners, and mobility of learning" (p. 20). In general, mobile learning has several features, such as increasing the availability and accessibility of information networks, engaging students in learning activities in diverse physical locations, supporting project-based group work, promoting communication and collaborative learning, and enabling fast content delivery [10]. Thus, we, in this study, conceptualize m-learning as a formal and informal learning method that utilizes wireless technology devices including tablets, iPads, and smartphones with the aim of transferring new concepts and information to meet educational goals. In the literature, formal learning focuses on student activities to engage with materials designed by the teacher during a teaching program, whereas informal learning highlights students' daily learning activities that are often intentional but unstructured, such as reading and visiting libraries [11]. From a student-centered perspective, m-learning allows learning to be more personal and collaborative [12] and allows students to learn at their own pace.

In the existing literature, m-learning is seen as one of the most influential technologies for many students at all levels of education, especially for university students, and a harbinger of the future of effective learning [13]. Because it is considered an effective new form of learning to improve student performance, the use of m-learning has been explored in different disciplines, such as science [14, 15], technology [3], language and art [2, 16], social science [17], engineering [18], and mathematics [19]. In previous studies, m-learning was also reported to be effective in increasing student learning efficiency [20], enhancing social interaction [21], promoting mobility [15], providing timely access to information and resources [22], and providing instant feedback to students on their performance [23]. Another advantage of m-learning is that learning activities are more flexible, accessible, and personalized [9]. Regarding student learning outcomes, previous studies also have revealed the positive impact of m-learning on academic achievement [17, 19, 23], learning interest [18, 19], technology self-efficacy [14], and learning attitudes [18].

Previous literature reported that the use of mobile learning has increased significantly over time [1, 24, 25]. For example, Elaish *et al.* [24] reviewed 3087 papers from the WoS database during 1982–2015. They found that (i) the trend of publications and citations generally increased from 2004 to 2014, (ii) Taiwan and the US produced the most number of cited papers, (iii) Computer & Education was the most productive journal, (iv) G. J. Hwang is the most prolific and most-cited author, and (v) mobile learning is the most frequently cited keyword in this area. While several bibliometric studies on mobile learning, in general, exist [1, 24, 25], no studies have analyzed this area, specifically in higher education, from the Scopus database. Accordingly, the current study will expand on existing research. In order to obtain a more comprehensive picture, our study also involves journal articles and conference papers throughout the year. This is motivated by a survey released by Statista [26] which reports the growth of smartphone users worldwide over time. In light of the above information, there is an urgent need to perform a bibliometric analysis of MLHE across time involving primary sources from leading databases, such as Scopus. Scopus was selected due to its comprehensive coverage of peer-reviewed research documents in education [27]. In addition, Scopus is one of the most common collections of publications used in bibliometric studies [28]. For this reason, we conducted the bibliometric methods of citation analysis, co-authorship analysis, and co-word analysis. The objective of this paper is to determine the current state of scientific production regarding m-learning applications in higher education. The main research questions (RQs) proposed in the current study are as follows:

RQ1: How is the growth of research output and citation of papers on m-learning in higher education?

RQ2: What are the highly-cited documents in studies of m-learning in higher education?

RQ3: Who are the most active authors and publishing sources on m-learning in higher education?

RQ4: Which are the most productive institutions and countries publishing papers on m-learning in higher education?

RQ5: What are the most relevant keywords, and which co-occurrence patterns exist in studies on m-learning in higher education?

III. Methodology

A. Study Design

In this study, we performed a bibliometric mapping analysis. In order to conduct scientific mapping research, a main five-step procedure including research design, a compilation of bibliometric data, analysis, visualization, and interpretation was employed [29]. We carried out bibliometric analyses based on a series of criteria, such as annual publications, references, authors, journals, institutions, countries, and keywords in the field. It should be noted that no ethical approval was obtained because the study did not involve human or animal interactions.

B. Data Collection

Electronic search and data retrieval was carried out on May 29, 2022. We first started by searching for articles in one of the most important bibliographic databases, namely Scopus (https://www.scopus.com). Scopus was selected for this bibliometric analysis because this online database holds a greater quantity of research papers on multidiscipline subjects. It covered over 84 million documents, more than 825 book series, and over 25.8 thousand peer-reviewed journals [30].

The keyword search was set to include titles, abstracts, and keywords. The search string combinations, operators, and filtering employed in this study were: TITLE-ABS-KEY ((“mobile Learning” OR “m-learning” OR “mlearning” OR “mobil* learn*”) AND (“higher education” OR “tertiary education” OR “universit*” OR “undergraduate*” OR “college*”)). The search string included a combination of

different terms concatenated with "OR" and "AND" operators. These connectors were employed to enhance the rigor of the search. We also involved the wildcard symbol (*) to represent any group of characters, for example, universit* matches university or universities.

The inclusion criteria were: 1) peer-reviewed research articles should contain one of the keywords either title, abstract, or keywords, 2) they were written in English, and 3) the search period was unlimited. While the exclusion criteria were: 1) papers published in languages other than English and 2) in the form of editorials, book chapters, books, corrections, short surveys, and notes as they are not primary sources. No particular time span was used. For this purpose, the bibliometric mapping analysis included documents published throughout the year to fully understand this field.

The Scopus database returned 3179 publications with full bibliographic information, including articles (1424), proceedings papers (1053), and other document types (702). In this study, we only sourced journal articles (44.79%) and conference papers (33.12%). Using Scopus filters, other types of publications (22.08%) and non-English papers were excluded from the document list. After filtering to exclude some irrelevant documents based on inclusion and exclusion criteria, we were left with 2477 articles for the bibliometric analysis. It should be noted that there are no articles on mobile learning published before 2002 in the Scopus database. The oldest publication was founded in 2002, which is only 2 articles.

C. Data Analysis

The data were downloaded from the Scopus database in comma-separated values (CSV) and research information systems (RIS) formats including the citation information, bibliographical information, and abstract and keywords. For data analysis and visualization, we performed Microsoft Excel and VOSviewer [31]. As a powerful science mapping analysis tool, VOSviewer was utilized to create a collaborative network for different variables and keywords. Excel was run to analyze the descriptive data, such as the most productive countries and authors, and journal distribution. It should be noted that a single count was used for scientific production statistics of authors, institutions, and countries. For example, if a paper has two authors, then each author is fully credited with a single count.

In this study, we analyzed the documents across timeframe, highly cited articles, the most prolific authors and sources, the most productive institutions and countries, co-authorship for authors and countries, and co-occurrence of author keywords. Citation analysis was performed to analyze the number of articles and citations, and journals, organizations, and countries that had a high impact on the field. Co-authorship analysis demonstrates how scholars interact with each other in the field. This approach can also be performed on other parameters, such as countries in the domain of MLHE. Co-occurrence analysis was executed to analyze the most prominent keywords and understand how they are connected to other terms related to MLHE. In this context, the size of the node refers to the frequency with which a keyword appears along with other terms, and related nodes are connected by lines, which are called links. A link is a connection between two nodes and the width of the link indicates the level of connection strength between the two nodes [31]. In the visualization network map, strong correlation nodes are classified into a cluster. Each cluster was then assigned a different color code, where the nodes in the same cluster were highly homogeneous. Thus, this bibliometric mapping analysis has allowed researchers to detect the status of research and hottest topics conducted during the period 2002-2022.

IV. Results

A. Publication and Citation Trends

Fig. 1 depicts the distribution trend of publications and citations in MLHE studies on a year-by-year basis. The 2477 published articles in the database have been cited 29,825 times, with an average of 12.04 citations per article and 1491.25 citations per year. In the year 2002, the database covered 2 publications, and the citations reached 37. In 2012, the number of articles grew to 158, and the articles were cited 3368 times. In 2013 and 2020 there was a slight decrease in interest in the subject in that year compared to the previous year, while the decline was evident in both the number of publications and citations. As of May 2022 (when this review was conducted), the number of publications in this area was 94 and the articles were cited 25 times. The number of publications reached a peak in 2021 with 261 published documents (592 citations).

Overall, the number of publications per year shows an exponential growth curve that satisfies Price's law of growth [32], where every ten to fifteen years existing literature doubles. In addition, the determination value (R^2) was found to be 0.756 reflecting that the exponential trend line is reliable. Therefore, it can be concluded that the number of publications related to MLHE has increased significantly. This positive trend is likely to continue in the coming year.

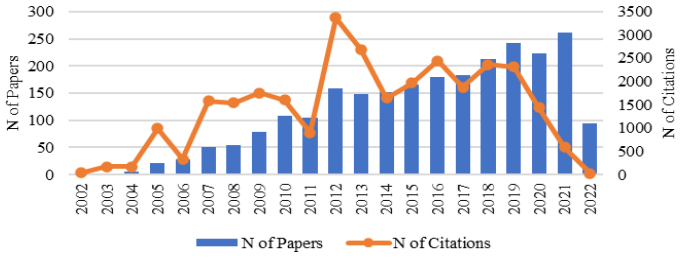

Fig. 1. Distribution of articles and citations by year (2002-2022).

B. Highly Cited Documents

Table I presents the top 10 total cited documents in MLHE scholarly literature over the years. This information helps to identify which of all the target articles are the most impactful in this field. The total number of citations (C) of the top 10 papers was 4332, which corresponds to 14.52% of the total citations of the collection at the time of this study (29,825 citations). Specifically, there are 47 articles (1.90%) that have at least 100 citations and 628 articles (25.35%) have not received citations to date. Regarding Table I, the *Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media* is most frequently cited by having 640 citations, which ranks first among all published documents. In this study, Gikas and Grant [11] investigated students' perceptions of learning to use cell phones, smartphones, and social media. As a result, they reported that mobile computing devices and the use of social media offer opportunities for students to interact with instructors and peers as well as collaborate and engage in content creation and communication using social media. The top two most cited papers are *Mobile learning: A framework and evaluation* written by Motiwalla [12] with 589 citations. In this study, he designed and pilot-tested m-learning applications on 63 undergraduate and graduate students and then explored their views on the role and value of m-learning applications in higher education. Cheon *et al.* [7] produced one of the top three most-cited papers with 516 citations. In *An Investigation of mobile learning readiness In higher education based on the theory of planned behavior*, Cheon *et al.* [7] analyzed how students' beliefs influenced their intention to adopt mobile devices and, as a result of this concern, they noted that attitudes, subjective norms, and behavioral control significantly influenced their intentions to adopt m-learning in their coursework. Four out of ten papers in the top 10 were conducted and published with the first author from the US. The rest are from the UK, Japan, South Korea, Australia, South Africa, and Turkey (1 each). This indicates that most highly cited papers were written by scholars from western countries/regions.

TABLE I: TOP 10 MOST CITED REFERENCES

Author(s) & Year	Document Title	Publication Source	C
Gikas, J. and Grant, M. M, (2013)	Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media	Internet and Higher Education	640
Motiwalla, L. F, (2007)	Mobile learning: A framework and evaluation	Computers and Education	589
Cheon, J. Lee, S. Crooks, S. M. and Song, J, (2012)	An investigation of mobile learning readiness in higher education based on the theory of planned behavior	Computers and Education	516
Evans, C, (2008)	The effectiveness of m-learning in the form of podcast revision lectures in higher education	Computers and Education	452
Thornton, P. and Houser, C, (2005)	Using mobile phones in English education in Japan	Journal of Computer Assisted Learning	444
Park, S. Y. Nam, M.-W. and Cha, S.-B, (2012)	University students' behavioral intention to use mobile learning: Evaluating the technology acceptance model	British Journal of Educational Technology	407
Kearney, M. Schuck, S. Burden, K. and Aubusson, P, (2012)	Viewing mobile learning from a pedagogical perspective	Research in Learning Technology	357
Martin, F. and Ertzberger, J, (2013)	Here and now mobile learning: An experimental study on the use of mobile technology	Computers and Education	324
El-Hussein, M. O. M. and Cronje, J. C, (2010)	Defining mobile learning in the higher education landscape	Educational Technology and Society	310
Cavus, N. and Ibrahim, D, (2009)	M-Learning: An experiment in using SMS to support learning new English language words	British Journal of Educational Technology	293

C. Most Influential Authors and Sources

The top 10 most productive authors based on the number of total articles (A), number of citations for all articles (C), and average citation per article (C/A) are shown in Table II. The results show that eight authors produced at least 10 documents. As we can see in this list, T. Cochrane is the most significant author with 18 papers. The author's work focused on m-learning [33], mobile virtual reality [34], and e-learning [35], with the first publication in 2005. F. J. García-Peñalvo followed T. Cochrane with 16 articles. His first study was published in 2013, and most of his work focused on m-learning [36], learning beliefs [4], and the technology acceptance model [37]. Following F. J. García-Peñalvo, H. Farley published 14 articles. Her work was about e-learning and m-learning [38] and mobile instant messaging [39]. In terms of the author's influence, Dr. Mostafa Al-Emran from British University in Dubai, UAE, has the largest number of citations in this area (630), followed by Dr. Nadire Cavus, Professor at Near East University, Turkey (598) and Dr. Francisco García-Peñalvo, Professor at the University of Salamanca, Spain (537). In general, three of the top ten authors are from Australia, indicating their active role in the field. We can conclude that these three authors are the most prolific and fundamental in MLHE research.

TABLE II: TOP 10 MOST PROMINENT AUTHORS

Author	Affiliation	Country	A	C	C/A
Cochrane, T.	University of Melbourne	Australia	18	354	19.67
García-Peñalvo, F. J.	University of Salamanca	Spain	16	537	33.56
Farley, H.	University of Southern Queensland	Australia	14	103	7.36
Ganchev, I.	Plovdiv University Paisii Hiledarski	Bulgaria	12	53	4.42
Al-Emran, M.	British University in Dubai	UAE	11	630	57.27

Murphy, A.	University of Southern Queensland	Australia	10	88	8.80
O'Droma, M.	University of Limerick	Ireland	10	47	4.70
Wang, M.	San Diego State University	US	10	448	44.80
Almaiah, M. A.	King Faisal University	Saudi Arabia	9	215	23.89
Cavus, N.	Near East University	Turkey	9	598	66.44

A total of 2477 papers were published in 1004 different sources. Furthermore, the results inform that nearly a third of the published documents on m-learning (27.94%) are found in open-access journals. Table III lists the 10 most popular journals for publishing papers on MLHE. The top 10 journals published 423 articles, sharing 17.08% of the total amount. The *ACM International Conference Proceeding Series* published 89 articles and 292 total citations in the past 20 years, by far the most. It was followed by the *International Journal of Interactive Mobile Technologies* (74) and the *International Journal of Mobile Learning and Organisation* (53). Of these journals, *Computers and Education*, a journal focusing on the pedagogical uses of digital technology, had the most citations (4003 citations). This journal was followed by the *International Review of Research in Open and Distance Learning* (1744 citations) and the *British Journal of Educational Technology* (1585 citations). Six out of the ten highest-influence sources are listed in the first quartile, indicating that these journals are highly influential in the field of MLHE. One of the four sources from the US, *Education and Information Technologies*, is in the first quartile. Out of the rest of the six sources, two belong to the UK and Germany, one is from Switzerland, and one is from Canada. These journals come from nine different publishers. The majority of these journals are related to education and technology, which indicates the theme of MLHE.

TABLE III: TOP 10 MOST INFLUENTIAL SOURCES

Source	Country	A	C
ACM International Conference Proceeding Series	US	89	292
International Journal of Interactive Mobile Technologies	Germany	74	596
International Journal of Mobile Learning and Organisation	Switzerland	53	457
Education and Information Technologies	US	34	561
Computers and Education	UK	32	4003
International Journal of Emerging Technologies in Learning	Germany	32	252
International Journal of Mobile and Blended Learning	US	28	185
International Review of Research in Open and Distance Learning	Canada	28	1744
CEUR Workshop Proceedings	US	27	94
British Journal of Educational Technology	UK	26	1585

D. Most Productive Institutions and Countries

In total, there are 4118 research institutions in the sample documents of this study. The main productive institutions are summarized in Table IV. The top 10 universities participated in 8.28% of the publication collection and accounted for 9.09% of the total citations. The top three institutions are the University of Salamanca (Spain; 29 publications), Universiti Sains Malaysia (Malaysia; 23), and the University of Southern Queensland (Australia; 21), as the leading institutions. The remaining institutions have 17 to 20 papers that have been published. The top three institutions for total citations are Near East University (689), the University of Salamanca (588), and the National Taiwan University of Science and Technology (341). The remaining seven institutions in the top 10 were cited between 58 and 323 times. Articles from Near East University (36.26), the University of Salamanca (20.28), and the National Taiwan University of Science and Technology (17.95) generated the highest C/A. Five of the top active institutions are based in Asia, three in the Middle East, one in Australia, and one in Western Europe. Interestingly, three of the ten most productive institutions are located in Malaysia. This implies that Malaysia plays a predominant role in MLHE research.

TABLE IV: TOP 10 MOST RELEVANT INSTITUTIONS

Institution	Country	A	C	C/A
University of Salamanca	Spain	29	588	20.28
Universiti Sains Malaysia	Malaysia	23	279	12.13
University of Southern Queensland	Australia	21	133	6.33
King Abdulaziz University	Saudi Arabia	20	143	7.15
The University of Hong Kong	Hong Kong	20	323	16.15
Near East University	Turkey	19	689	36.26
National Taiwan University of Science and Technology	Taiwan	19	341	17.95
Universiti Teknologi MARA	Malaysia	19	66	3.47
Universiti Pendidikan Sultan Idris	Malaysia	18	58	3.22
Zayed University	UAE	17	90	5.29

With regard to leading countries, the number of papers by nation is analyzed. A total of 2477 documents were published by authors from 139 different countries/territories. Table V shows the top 10 relevant countries' publications, total citations, and average article citations. According to this table, China contributed the most to MLHE research with 229 publications. It was followed by the US and the UK with 219 and 190 documents. Countries in the African region made the least contribution (72; 2.91%). This suggests that research related to MLHE is dominated by Eurasian countries. It is interesting to highlight that, the total number of publications in the top 3 countries is 638 (25.76%). We then analyzed the number of citations, which is an important indicator of research quality. It should be noted that the US (5979) generated far more total citations than the UK (3577), followed by Taiwan (2557), Australia (2514), and China (1816). The remaining countries have a number of citations from 362 to 1586. Furthermore, the US ranks first in C/A (27.30), followed by Taiwan (19.23) and the UK (18.83). It implies that China, the US, and the UK are the top three countries exploring the use of mobile learning in the context of higher education extensively. This reflects that developed countries play an important role in MLHE research.

TABLE V: TOP 10 MOST PRODUCTIVE COUNTRIES

Country	A	%	C	C/A
China	229	9.25	1816	7.93
US	219	8.84	5979	27.30
UK	190	7.67	3577	18.83
Australia	181	7.31	2514	13.89
Malaysia	176	7.11	1389	7.89
Spain	144	5.81	1586	11.01
Taiwan	133	5.37	2557	19.23
Saudi Arabia	86	3.47	1065	12.38
South Africa	72	2.91	694	9.64
Indonesia	68	2.75	362	5.32

E. Co-authorship for Authors and Countries

In this section, we present an analysis of the collaboration between authors on MLHE. When the threshold was set at a minimum of 5 documents per author, out of 5493 authors, 79 authors met this requirement and 7 authors were connected. The results of the analysis also exhibit 45 different clusters, in which only 3 clusters are connected (see Fig. 2). In other words, these 7 authors are arranged in 3 clusters. This indicates that only 7 authors, with 5 or more papers, collaborated in producing articles related to MLHE. Looking at Fig. 2, the largest cluster (red) has 3 authors, including Cochrane (18 papers, 4 links, 10 TLS), Narayan (9 papers, 4 links, 10 TLS), and Birt (5 papers, 2 links, 2 TLS). The second group is the green cluster composed of 2 authors: Burden (5 papers, 1 link, 4 TLS) and Kearney (5 papers, 4 links, 7 TLS). The third-largest group is the blue one, which also contained 2 authors: Farley (14 papers, 4 links, 13 TLS) and Murphy (10 papers, 1 link, 10 TLS). TLS refers to the total strength of an author's co-authorship links with other authors [31].

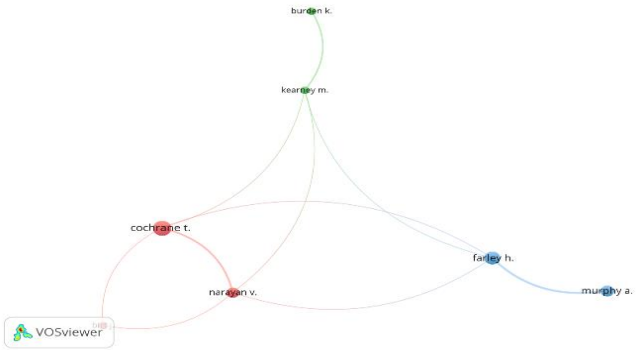

Fig. 2. Co-authorship connected clusters map.

We also analyzed co-authorship relationships between countries. Fig. 3 depicts the country co-authorship map. As shown on the map, the size of the node is the number of publications of the country and the distance between the cluster implies the strength between them [31]. When we set the minimum number of documents of a country to five, 73 met the threshold. Among contributing countries, only 71 are connected and are organized in 11 clusters. The largest cluster has 12 countries (red). Germany is a leader in it with 66 documents, 14 TLS, and 13 collaborations with different countries. The second cluster (green) has 10 countries and is led by Australia with 180 documents, 39 TLS, and 20 relations of collaboration. The third cluster (blue) consists of 9 countries and is built around Spain with 144 documents, 35 TLS, and 24 collaborations with other countries. Not surprisingly, developing countries generally have weak cooperation with other countries in the network.

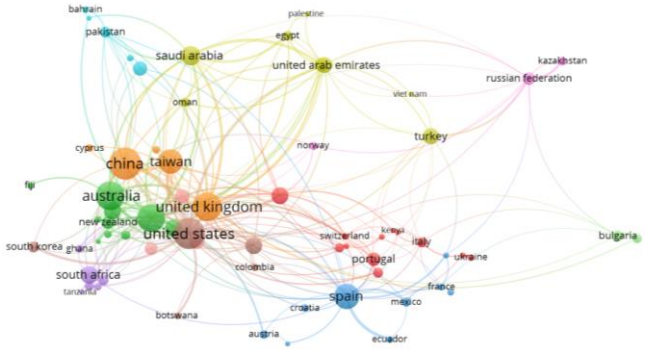

Fig. 3. The visualization network of the country co-authorship.

F. Co-Occurrence of Author Keywords

The number of occurrences (Occ) of relevant words in the publications with regard to author keywords is identified. The top 10 co-occurring keywords are presented in Table VI. As can be seen on this list, there are only one author keywords that appear at least a hundred times. The results of the analysis show that the most frequent keywords are as follows: *mobile learning*, *m-learning*, *higher education*, *e-learning*, and *mobile devices*.

TABLE VI: MOST FREQUENTLY USED KEYWORDS

#	Author Keywords	Occ	TLS
1	Mobile learning	1238	1044
2	M-learning	423	372
3	Higher education	303	291
4	E-learning	211	198
5	Mobile devices	102	95
6	Blended learning	73	68
7	Mobile technology	65	62
8	Education	62	56
9	Mlearning	60	54
10	Technology acceptance model	49	48

In order to visualize the research hotspots, the co-occurrence map of keywords created by VOSviewer is then visualized in Fig. 4.

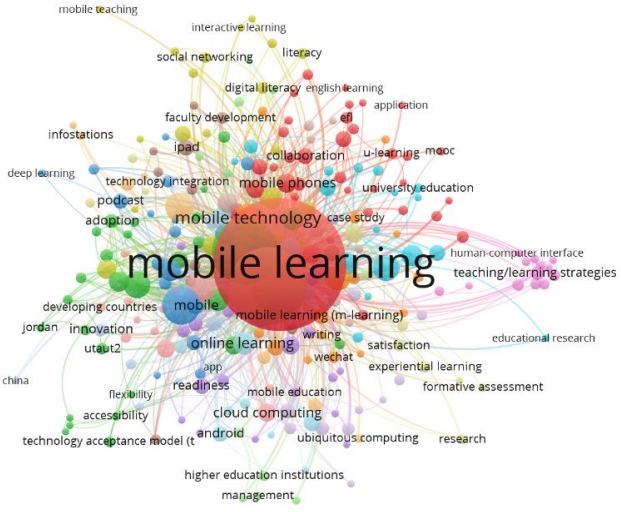

Fig. 4. Co-keyword network visualization: the most used author keywords.

Keyword analysis provides information about research on related topics. The minimum occurrence threshold was set at

5 which resulted in 281 author keywords out of 4769 for analysis. Each cluster consists of related keywords that appear in the same color. It is noteworthy that the size of the node indicates the number of occurrences [31]. In other words, the most relevant keywords are displayed by the largest node. Our results revealed that there are 17 clusters and the most used keyword is *mobile learning* (1238 occurrences, 1044 TLS). In addition, it was revealed that *m-learning* (423, 372), *higher education* (303, 291), *e-learning* (211, 198), and *mobile devices* (102, 95) were the top 5 most used keywords in articles. On the map, the main keyword per cluster is *mobile learning* (red cluster), *higher education* (green), *mobile devices* (dark blue), *social media* (yellow), *distance education* (dark purple), *augmented reality* (Tosca green), etc. For instance, *mobile learning* is connected to *information technology*, *mobile phones*, *apps*, *learning performance*, and *electronic learning*. Similarly, a keyword *smart learning environment* is closely connected to *educational technology*, *teacher education*, *tablet*, and *technology acceptance model*.

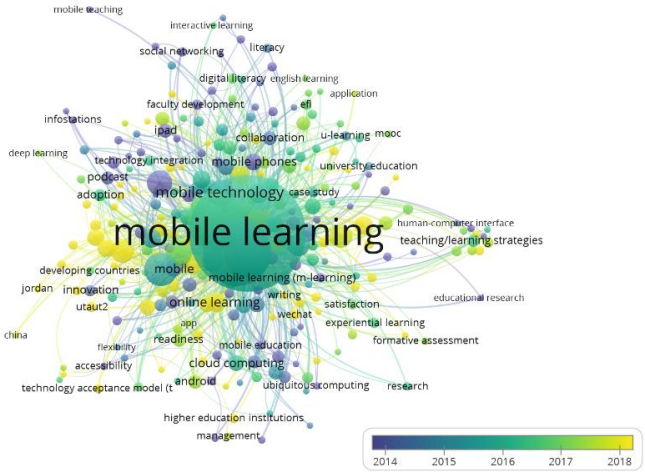

Fig. 5. Co-keyword network visualization: distribution of the number of articles using the keywords by year.

The distribution of the number of articles using the keywords by years is shown in Fig. 5. As shown in Fig. 5, different colors indicate the publication date of the related document where these keywords appear together. The hottest topics in MLHE research are observed in this figure, such as *flipped classroom*, *self-directed learning*, *educational innovation*, and *COVID-19 pandemic*. This finding shows that these keywords have stood out in recent years. It can be concluded that in recent years, scholars have turned to research on the mentioned topics.

V. Discussion and Conclusions

The current study provides a comprehensive perspective on the evolution and development of m-learning literature in the context of higher education for all times up to 2022 (the last 20 years). By using bibliometric analysis, we analyze output growth, top references, authors, sources, organizations, countries, and keywords in MLHE research.

In terms of the evolution of scientific publications, studies in mobile learning in the context of higher education appear to have started in 2002. This situation reflects the beginning of the growth of publications in the field. Interestingly, the number of publications has continued to exhibit a significant growth trend ever since. The study is convergent with previous studies in this area [40–43]. This growth implies that MLHE is increasingly attracting the attention of scholars. It Is reasonable that from 2002 to 2021, the number of publications tends to increase year by year. In 2021, 261 papers were published, which makes it the highest publication so far. It is also noteworthy that the data were collected in May 2022. Therefore, regarding the fast-growing interest in education technology, scientific output in this area is expected to continue to grow this year and in the coming years compared to 2021. In terms of the average citations per paper, we can see that the citation rate fluctuates throughout the year, with a peak value observed in 2003 of 84.00 citations per publication. The number of citations refers to the impact of scientific publications. Specifically, there are 47 articles that have more than 100 citations; 4.60% of the publications had more than 50 citations, and 74.65% of the documents were cited at least once, indicating that the majority of MLHE publications attracted the attention of researchers. This finding may be related to advances in digital technology in recent decades. Another plausible reason is the increasing availability of mobile technologies (e.g. mobile phones, tablets, smartphones), and in turn, increasing m-learning applications in higher education [44]. This is confirmed by Statista [26], which notes that the number of smartphone users worldwide will increase from 4.5 million subscriptions in 2017 to more than 6.5 million users in 2022, and is projected to reach 7.7 million users in 2027. Overall, it is evident that the use of m-learning in the higher education context is gaining more attention from educators and researchers; thus, it is expected that more studies in this area will continue to be published.

Based on the results of citation analyses, the 2477 published articles have registered a total of 29,825 citations. As listed in Table I, the most influential references were written between 2005 [16] and 2013 [11, 45]. This is confirmed by Lai [46], who asserts that the majority of highly cited articles were published during this period. In this study, the most cited document on MLHE was that by Gikas and Grant [11], with 640 total citations and with the highest number of citations per year (71.11). The second most cited article was that by Motiwalla [12], with 589 citations and 39.27 citations per year. The work by Cheon *et al.* [7] is the third most cited, with 516 citations in total and 51.60 citations per year. Our findings are consistent with the previous studies (e.g. [43, 46]). It is worth mentioning that frequently cited papers are seen as beneficial and of high quality for further research and receive greater recognition by other researchers in the field [47, 48]. In particular, a possible reason why the work of Gikas and Grant [11] received lots of citations may be that it was a pioneering document that used the term mobile learning in its title. This could also be due to the focus of the current study on mobile learning research in higher education [11, 45]. As revealed by Wu *et al.* [43], articles published earlier tend to have a longer time to be disseminated and cited in other related articles. Interestingly,

the majority of papers were published in the most influential and high-impact factor journals, for instance, *Internet and Higher Education* and *Computers and Education*. It is not surprising that they received a higher number of citations so far, due to the fact that the impact factor is proportional to the frequency of citations [49].

At the author level, a total of 5493 authors contributed to the published documents, a mean of 2.22 authors per document. With regard to the number of publications, Thomas Cochrane (University of Melbourne, Australia), which significantly outperforms other authors, was the highest-ranked contributor with 18 total publications and 354 citations, which is not surprising as the author consistently published in 2005, 2008-2013, 2016, and 2018-2019. His writings (e.g. [33, 35]) are considered a useful reference in mobilizing learning and e-learning. Francisco J. Garc á-Pe ñalvo (University of Salamanca, Spain) and Helen Farley (University of Southern Queensland, Australia) were the second and third most productive authors with 16 and 14 total publications (and 537 and 103 citations) respectively. Regarding the citation counts, the results further indicate that Mostafa Al-Emran (British University in Dubai, UAE), Nadire Çavuş (Near East University, Turkey), and Francisco J. Garc á-Pe ñalvo remain the most cited authors. It can be said that these researchers are the most prominent authors among the top ten authors. In this regard, the massive adoption of technology in the education sector could be the main reason behind this situation [45, 50].

According to the analysis conducted in the context of sources, the top 10 most productive sources have published 423 papers, accounting for 17.08% of the collection with a total of 1240 citations or equivalent to 32.75% of the total number of citations. In this list, the *ACM International Conference Proceeding Series (ACM-ICPS),* the *International Journal of Interactive Mobile Technologies,* and the *International Journal of Mobile Learning and Organisation* published the most articles in the last two decades. Similar findings were also made in a previous bibliometric study [25], which reported that *ACM-ICPS* was among the top 3 most productive publication venues in terms of the number of publications related to m-learning. Furthermore, the most cited source journal is *Computers and Education*, which publishes original papers on the uses of digital technology to improve education. The *International Review of Research in Open and Distance Learning*, a journal published in Canada, ranked second in total citations (1744), followed by the *British Journal of Educational Technology* (1585 citations) and the *International Journal of Interactive Mobile Technologies* (596 citations). In a similar context, this finding is supported by Osman and Napeah [25], who revealed that *Computers & Education*, which started its publication life in 1976, is the most contributing journal in this field. We noticed that among the top 10 publishing sources in m-learning, there were six Q1 and two Q3 journals and two non-quartile conference proceedings. This indicates that the quality of scientific publications in this area tends to be high. In a study, documents published in high-ranking international journals have the potential to influence the visibility and impact of the paper in the field [51]. Hence, these most influential sources confirm their contribution to the dissemination of the subject.

When examining the most influential institutions, it is noticed that the University of Salamanca ranks first with 29 publications, followed by Universiti Sains Malaysia, and the University of Southern Queensland. Out of the top 10, 5 originate from Asian countries, which implies the dominance of Asia in this area. This finding is comparable to previous bibliometric studies, where universities from Asia published the highest number of documents (e.g. [41, 42]). Besides, it is interesting to note that Near East University [2], from Turkey, has the highest number of citations (689) during 2002–2022, although it has only 19 publications, demonstrating the high quality and influence of its publications. The University of Salamanca has the second-highest total citations (588) and the National Taiwan University of Science and Technology has arranged third place with 341 citations. This topic has attracted the interest of researchers from both developed and developing countries. This may be due to the high interest of these institutions to publish their scientific works related to MLHE in the Scopus database.

We then perform the same analysis, but for countries/territories. According to data from the Scopus database, authors from 139 countries around the world contributed to this field. The countries producing the most publications on MLHE were China (229 publications), followed by the US (219 publications) and the UK (190 publications), leading the research process in the field. By far, China is the most prominent country in terms of the number of publications on this topic. This may be due to the fact that the Chinese government has been highly committed to the development of m-learning since the 1990s, such as infrastructure construction, resource production, academic education, and non-academic training [52]. Interestingly, Asian scholars have produced 24.47% of papers, higher than the percentage of papers published by researchers from African (2.91%), Middle Eastern (3.47%), Northern American (8.84%), Oceanian (7.31%), and Western European (13.48%) countries. In other words, countries in the Asian and European regions dominated publications related to m-learning, while countries in the African region made the least publications. Thus, significant efforts should be made among African countries to enhance their collaborative work in this field. The leading roles of these top three countries are also documented in m-learning research (e.g. [25, 40, 42]). In terms of total citations by country, the US was still the country with the largest number of citations with 5979 citations (equivalent to 20.05%), followed by the UK with 3577 citations (11.99%) and Taiwan with 2557 citations (8.57%). It can be inferred that the US, UK, and Taiwan are considered influential countries in scientific publications compared to other countries. This may be due to the fact that these three countries are technologically advanced and have greater mobile and internet penetration rates than others [41].

When creating the co-authorship network by the author, it can be seen that the visualization network shows the collaboration of 79 authors. The five authors with the highest total link strength were H. Farley (13), T. Cochrane (10), A. Murphy (10), V. Narayan (10), and M. Kearney (7), all of whom worked in Australian institutions. It can be inferred

that research collaborations in this area are not much. Collaborations in MLHE-related research mainly stem from groups of authors working in two or four organizations. In other words, the cooperation between authors working on MLHE was low. In another bibliometric study conducted up to 2019, Goksu [1] also noted that the collaboration among the clusters formed by m-learning researchers was still weak. This suggests that only a few authors are well-connected and have contributed to the literature by working together. As Goksu [1] reveals, new working groups have emerged in recent decades and new researchers are engaging in cooperative author groups that form a centerpiece in the MLHE field.

The results of the co-authorship analysis among countries indicated that the US was quite far ahead of other countries with total link strength (TLS) of 95 and 217 publications with 5979 citations. It was followed by the UK (TLS, 70; documents, 219; citations, 3577) and China (TLS, 69; documents, 229; citations, 1816). It indicates that Europe and the US played the leading role in publication quantity and total citations. The US has been the center of global cooperation in this area because of its higher international cooperation activity compared to other countries. In the literature, scientific collaboration is seen as an important component to improve the quality and impact of research [53]. Moreover, the advancement in technology is another possible reason for the main contribution of developed countries to m-learning in higher education. In a recent study, the US, UK, and China were listed among the top ten most effective countries in MLHE research productivity [1].

Finally, we examined the author keywords that appeared most frequently in selected articles. As far as we know, keywords play a significant role in the discoverability of documents. It should be noted that discoverability mainly depends on how well the title, abstract, and keywords are organized in the article [54]. In order to significantly improve its findability on search databases and its potential impact, keywords should be meaningful and unmistakable [54, 55]. According to the keyword co-occurrence analysis, *mobile learning* and *m-learning* were the most commonly used keywords in MLHE articles, followed by *higher education*, *e-learning*, and *mobile devices*. It can be concluded that the most effective research is *mobile learning*, *m-learning*, *higher education*, *e-learning*, and *mobile devices* research. These keywords are being investigated in advancing mobile learning in higher education. The findings obtained in this study echo the existing literature (e.g. [1, 24, 25]). Moreover, the present study suggested that author keywords such as *flipped classroom*, *self-directed learning*, *educational innovation*, and *COVID-19 pandemic* were relatively the most recent in the retrieved literature. These keywords generally represent the main trends followed by scholars and these issues seem to be central to MLHE research. In other words, mobile learning is still a trending topic to be explored by researchers worldwide and would continue to be studied within the scope of these keywords.

VI. Limitations and Recommendations

The current study has succeeded in providing an up-to-date picture of research trends on mobile learning in higher education. However, some limitations should be taken into account. First, the target documents analyzed in the current study refer only to the bibliographic data documented in Scopus as the primary source; thus, the findings presented are from only one perspective of the existing literature. Although Scopus was selected due to its comprehensive coverage of peer-reviewed research documents in education [27], the online databases analyzed excluded available scientific sources such as WoS, ERIC, Microsoft Academic, Dimensions, EBSCO, and Google Scholar which might provide more valuable information. We suggest future researchers expand their study using other well-known databases in order to arrive at conclusions that are more comprehensive and better reflect the evolution of publications in this area. Secondly, we only focused on documents published in research articles and conference proceedings so that future studies can consider other sources, e.g. books, book chapters, or notes. Lastly, the database employed in this review only extracted and analyzed documents written in English; as such, it ignores other non-English publications that might yield more valuable results. Lastly, this bibliometric study only focused on 5 variables as listed in the RQs; thus, further research needs to combine it with content analysis, such as research design/methods, main focus points, and research results in the analyzed articles to enrich the findings. Notwithstanding the above limitations, we believe that this study can be used as a reference for future researchers and practitioners to better understand the conceptual structure of m-learning in the context of higher education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

I. Irwanto conducted the research and wrote the paper. W. Widiyanti analyzed the data, and A. D. Saputro and S. D. Laksana reviewed and finalized the paper. All the authors had approved the final version.

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