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Bibliometric analysis of mobile learning user experience industrial revolution 5.0

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ABSTRACT

User experience or usability is under research, particularly in mobile learning in the era of industrial revolution (IR) 5.0. This article discusses incorporating sophisticated mobile technologies such as augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) into the user experience in educational settings. Therefore, this paper investigates the relatively new revolutionary potential of mobile learning user experience in the context of the IR 5.0, where the digital and technology spheres meet for better user experiences, particularly for students in learning. The research explores novel meta-mobile technology approaches by examining concrete cases from 2012, analyzing their impact, and improving the user experience. Likewise, this article elucidates the need for mobile learning user experience research based on bibliometric analysis.

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1. INTRODUCTION

Meta-mobile technology has arisen as a disruptive force in education in the era of industrial revolution (IR 5.0), characterized by the convergence of cutting-edge technologies and unparalleled interconnectedness [1], [2]. The integration of mobile devices with augmented reality (AR), virtual reality (VR), mixed reality (MR), and other upcoming technologies is also meta-mobile technology [3], [4]. In the framework of IR 5.0, this paper investigates how meta-mobile technology is revolutionizing learning [5]–[9]. Meta-mobile technology provides immersive and engaging learning experiences that could capture students' attention and encourage active involvement [10], [11]. Students can explore virtual settings, control digital items, and engage in hands-on experiences using AR and VR technologies [12], which leads to improved motivation [11], [13], [14] and more profound knowledge [15]. Meta-mobile technology also allows for adaptive and personalized learning [16] that caters to individual learning styles and preferences [17], [18]. Meta-mobile technology supports self-paced learning and critical thinking and empowers students to take ownership of their education by adapting instructional content to their requirements [19]. This approach also reduces physical classroom borders [20], [21], allowing for distant and global learning experiences [22], [23]. Students can work with classmates from different geographical regions, engage in cross-cultural exchanges, and discover diverse perspectives, preparing them for IR 5.0's globalized world.

Industrial revolution 5.0 embraces a human-centered approach, particularly in education, where students benefit from immersive technologies [24], [25]. For instance, AR allows students to dissect virtual organisms or recreate chemical reactions, enhancing engagement and understanding in science [4], [18], [26]. In history education, students can virtually visit historical sites and interact with virtual figures, deepening their connection and comprehension of historical events [23], [27]. AR programs help visualize complex scientific processes and conduct virtual experiments, making them ideal for skill-based training, like in medical education, where students practice surgical techniques in simulated environments [28], [29]. These technologies create safe, immersive learning experiences by combining virtual and real elements. Despite these advantages, access to meta-mobile technology remains challenging, especially in underserved areas [24], [30]. Educators face the task of bridging the digital divide and ensuring equal access for all learners. Furthermore, teachers require training and support to effectively integrate these technologies into their teaching [31]–[33]. Professional development should focus on enhancing teachers' technical skills and instructional strategies to create meaningful learning experiences [34].

This research explores the potential of meta-mobile technology, highlighting intelligent customization enabled by the integration of artificial intelligence (AI) and meta-mobile technology. Algorithms personalize content and feedback based on individual learner needs and contexts [4], [18]. These advancements offer more adaptive and personalized learning experiences [19], [35]. Technologies like XR enable collaborative learning in virtual spaces, enhancing teamwork, communication, and cross-cultural understanding [36], [37]. The potential of meta-mobile technology in education is vast, with advancements in wearable devices, haptic feedback, and neurotechnology creating more immersive experiences [38], [39]. Integrating data analytics, machine learning, and AI further personalizes learning paths and enables predictive educational models [40], [41]. The rise of IR 5.0 technologies, including AR, VR, MX, and AI, has sparked new interest in mobile learning user experiences [5]–[8], [42]–[44]. However, emerging meta-technology remains novel and under-researched, especially regarding usability and user experience in mobile applications [3]. Despite this, there is significant potential for future impact [45], [46].

This study is driven by the rapid development of mobile learning and the integration of technologies like AR, VR, and AI in education. It conducts a bibliometric analysis to explore trends, research patterns, and advancements in user experience within mobile learning, particularly in the context of IR 5.0. The goal is to understand the impact of these technologies on education and learning experiences. The study aims to optimize AR, VR, and AI in educational settings in the UX domain. It seeks to understand how these technologies can improve educational outcomes and create immersive, interactive, and personalized learning environments. The research investigates current patterns, potential applications, and future directions for mobile learning technologies related to user experience.

The study suggests a holistic approach to improving mobile learning experiences within the framework of IR 5.0 technologies. The proposal recommends the incorporation of cutting-edge technologies such as AR [47], VR [20], and AI [5] to develop highly interactive and immersive learning environments. The approach prioritizes user-centric design by ensuring that mobile learning platforms are intuitive and easily accessible [48]. Examining the existing literature using bibliometric analysis [49] provides insights into the development and progression of mobile learning technologies. In addition, the strategy involves creating flexible systems for customized learning experiences and promoting interdisciplinary research to tackle the intricacies of technology integration in education.

2. METHOD

Bibliometrics collects, manages, and analyzes bibliographic data from scientific publications [50]. It encompasses advanced techniques like document co-citation analysis and descriptive statistics, including publishing journals, publication years, and principal author categorization [51]. A successful literature review requires iterative keyword selection, literature search, and analysis [52]. The following sections cover search term adoption, initial result screening, and search refinement [53]. High-quality journals were prioritized to understand the theoretical evolution of the research topic. Data was sourced from the Scopus database for comprehensive coverage [54]. Only articles from rigorously peer-reviewed academic journals were included, excluding books and conference proceedings [55].

A screening procedure was used in the study to select the search terms for article retrieval. The study began by querying the Scopus database with TITLE-ABS-KEY (("mobile learning" OR mlearning OR m-learning) AND ("Human-Computer Interaction" OR "User Experience" OR UX OR "Usability Evaluation" OR "Usability Testing" OR "Usability Engineering" OR "Heuristic Evaluation" OR "Design Thinking" OR "Software Testing" OR ergonomic)) AND (LIMIT-TO (LANGUAGE, "English")), yielding at first 680 articles from the year 1997 till 2023. This selection of years is due to the article on user experience and meta-mobile technology. The reasons for this selection of years are limited due to its still infancy. However, the query string was then altered so that the search for English language articles. This procedure produced 669 results, further refined to include only English research papers and article reviews. The final refinement of the search string thus included 669 articles for bibliometric analysis. As of July 2023, all papers from the Scopus database relevant to mobile learning and meta technology had been added to the research. This search is essential to understand the emerging themes of mobile meta-technology in education, particularly of the current trends on IR 5.0. Data sets containing the research publication year, publication title, author name, journal, citation, and keyword in PlainText format were obtained from the Scopus database [49] and examined in VOSviewer version 1.6.15. This program was used for map analysis and creation using the VOS clustering and mapping methodologies. The goal of VOSViewer, which is an alternative to the multidimensional scaling (MDS) approach [56], is to place items in low-dimensional areas in such a way that the distance between any two items accurately reflects their relatedness and similarity [57]. Unlike MDS, which is focused on the computation of similarity measures such as Jaccard indexes and cosine, VOS employs a more appropriate technique for normalizing co-occurrence frequencies, such as the association strength (ASij), which is determined as:

$$ASij\ {}^{1}\!/_{4}\ Cij$$
$$Wiwj$$

This formula is "proportional to the ratio between the observed number of co-occurrences of I and j on the one hand and the expected number of co-occurrences of I and j on the other hand under the assumption that co-occurrences of I and j are statistically independent" [56]. As a result, VOSviewer uses this index to place things on a map after lowering the weighted sum of the squared distances between all item pairs. LinLog/modularity normalization was implemented [57]. In addition, by applying visualization techniques to the data set using VOSviewer, patterns based on mathematical correlations were discovered, and studies such as keyword co-occurrence, citation analysis, and co-citation analysis were carried out.

3. RESULTS AND DISCUSSION

The findings were sought in alignment with the objectives [49]. This study investigates the development of UX in mobile learning within the context of the IR 5.0. The primary objective is to incorporate cutting-edge technologies such as AR, VR, and AI into the field of education. These technologies are crucial for developing immersive and personalized learning experiences that improve engagement and interaction [58]. The adoption of mobile learning platforms with sophisticated UX design caters to various learning preferences and provides accessible educational solutions [59], going beyond the confines of traditional classroom environments [60]. The bibliometric analysis provides a comprehensive examination of significant trends and patterns in research on mobile learning. Therefore, it offers valuable insights into this study area's academic emphasis and publication activities. Gaining insight into these patterns is essential for optimizing the educational capabilities of IR 5.0 technologies.

3.1. Trends in online learning studies by document number and year

Table 1 illustrates trends and research patterns [61] in online learning studies by publication year, detailing the number of e-learning publications from 2012 to 2023. Research on meta-mobile technology in education shows significant fluctuation, from 28 publications in 2012 to 11 in 2023. As of July 2023, there were 11 articles (1.644% of publications); in 2022, 38 publications (5.680%); in 2021, 49 publications (7.324%); in 2020, 58 publications (8.670%); in 2019, 54 publications (8.072%); in 2018, 41 publications (6.129%); in 2017, 60 publications (8.969%); in 2016, 48 publications (7.175%); in 2015, 55 publications (8.221%); in 2014, 51 publications (7.623%); in 2013, 24 publications (3.587%); and in 2012, 28 publications (4.185%). The highest publications were in 2017, 2020, and 2015.

Table 1. Trends in online learning studies by document count and publication year

Year	Number of documents	Percentages (%)
2023	11	1.644
2022	38	5.680
2021	49	7.324
2020	58	8.670
2019	54	8.072
2018	41	6.129
2017	60	8.969
2016	48	7.175
2015	55	8.221
2014	51	7.623
2013	24	3.587
2012	28	4.185

3.2. The countries publishing according to the number of articles

Table 2 shows the countries publishing articles on mobile learning user experience, ranked by article count. Malaysia leads with 73 articles (10.912% of publications), followed by the United Kingdom with 60 articles (8.969%), the United States with 45 articles (6.726%), Spain with 43 articles (6.428%), and China with 40 articles (5.979%). Other notable contributors are Finland with 29 articles (4.335%), Germany with 28 articles (4.185%), Australia with 26 articles (3.886%), Taiwan with 24 articles (3.587%), and Indonesia with 23 articles (3.438%).

3.3. The authors, who, and how much has been published in the field

Table 3 lists authors by the number of publications on mobile learning user experience. Nieminen leads with eight articles (1.196% of publications), followed by Dirin with seven (1.046%). Eliasson, Fetaji, Fetaji, and Kumar each have six articles (0.897%). Ahmad, Ariffin, Barbosa, and Fonseca each contributed five articles (0.747%).

3.4. The documents that were published the most by the institutions

Table 4 lists institutions by the number of mobile learning user experience publications. Leading institutions are Universiti Teknologi MARA, Malaysia, with 14 publications (2.093%), and Universiti Teknologi PETRONAS, Malaysia, and Tampere University, Finland, each with 11 publications (1.644%). Aalto University, Denmark, has ten publications (1.495%). Universiti Utara Malaysia, The Open University, UK, and Stockholms Universitet, Sweden has nine publications (1.345%). Universidad de Castilla-La Mancha, Spain. Universidade de São Paulo, Brazil, and Universiti Pendidikan Sultan Idris, Malaysia contributed eight publications (1.196%).

Table 2. The countries have published, according to the number of articles

	Country/territory	Numbers	Percentages (%)
1	Malaysia	73	10.912
2	United Kingdom	60	8.969
3	United States	45	6.726
4	Spain	43	6.428
5	China	40	5.979
6	Finland	29	4.335
7	Germany	28	4.185
8	Australia	26	3.886
9	Taiwan	24	3.587
10	Indonesia	23	3.438

Table 3. Authors of the countries, according to the number of articles

	Author name	No of articles	Percentages (%)
1	Nieminen, M.	8	1.196
2	Dirin, A.	7	1.046
3	Eliasson, J.	6	0.897
4	Fetaji, B.	6	0.897
5	Fetaji, M.	6	0.897
6	Kumar, B.A.	6	0.897
7	Ahmad, W.F.W.	5	0.747
8	Ariffin, SA.	5	0.747
9	Barbosa, E.F.	5	0.747
10	Fonseca, D.	5	0.747

Table 4. The documents published by the institutions

Affiliation	Numbers	Percentages (%)
Universiti Teknologi MARA	14	2.093
Universiti Teknologi PETRONAS	11	1.644
Tampere University	11	1.644
Aalto University	10	1.495
Universiti Utara Malaysia	9	1.345
The Open University	9	1.345
Stockholms universitet	9	1.345
Universidad de Castilla-La Mancha	8	1.196
Universidade de São Paulo	8	1.196
Universiti Pendidikan Sultan Idris	8	1.196

3.5. The publishers that produced the most documents per year by source

Table 5 details annual document production by source title and publisher [61]. Lecture Notes in Computer Science, including subseries in Artificial Intelligence and Bioinformatics, lead with 108 publications (16.143%). ACM International Conference Proceeding Series follows with 42 publications (6.278%), and Communications in Computer and Information Science has 19 publications (2.840%). The International Journal of Interactive Mobile Technologies contributed 11 publications (1.644%). Computers and Education, Education and Information Technologies, and Journal of Physics Conference Series have nine publications (1.345%). Advances in Intelligent Systems and Computing has eight publications (1.196%). Finally, CEUR Workshop Proceedings and the International Journal of Advanced Computer Science and Applications have seven publications (1.046%).

3.6. The documents that were published the most by the institutions

Table 6 details publications by subject area. Computer science leads with 547 publications (81.764%), followed by social sciences with 182 publications (27.205%) and mathematics with 144 publications (21.525%). Engineering has 131 publications (19.581%), and decision sciences has 26 publications (3.886%). Business management and accounting have 24 publications (3.587%), while physics and astronomy have 21 publications (3.139%). Arts and humanities account for 20 publications (2.99%), psychology has 16 publications (2.392%), and medicine has 14 publications (2.093%) as shown in Table 6.

3.7. The document type published by the authors

Table 7 details publications by document type. Conference papers lead with 427 publications (63.827%), followed by articles with 178 publications (26.607%) and conference reviews with 31 publications (4.634%). Book chapters account for 19 publications (2.840%), reviews for 10 publications (1.495%), and books for two publications (0.299%). Finally, editorials and notes have one publication (0.149%) as shown in Table 7.

Table 5. The documents published by the publisher

Source title	Numbers
Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	108
ACM International Conference Proceeding Series	42
Communications in Computer and Information Science	19
International Journal of Interactive Mobile Technologies	11
Computers and Education	9
Education and Information Technologies	9
Journal of Physics Conference Series	9
Advances in Intelligent Systems and Computing	8
CEUR Workshop Proceedings	7
International Journal of Advanced Computer Science and Applications	7

Table 6. The documents by subject area

Subject area	No	Percentages (%)
Computer science	547	81.764
Social sciences	182	27.205
Mathematics	144	21.525
Engineering	131	19.581
Decision sciences	26	3.886
Business, management, and accounting	24	3.587
Physics and astronomy	21	3.139
Arts and humanities	20	2.990
Psychology	16	2.392
Medicine	14	2.093

Table 7. The documents type published by the authors

Document type	No	Percentages (%)
Conference paper	427	63.827
Article	178	26.607
Conference review	31	4.634
Book chapter	19	2.840
Review	10	1.495
Book	2	0.299
Editorial	1	0.149
Note	1	0.149

3.8. The documents that were published the most by the institutions

For most cited authors, from Table 8, sources from Herzing search in Scopus [62], B. A. Kumar has 29 citations; M. Kuhnel has citations. Likewise, A. Dirin has 22 citations, N. Parsazadeh has 19, and K. C. Brata has 13. Consequently, M. Pikhart has 11 citations, N. Wahab has nine citations, M. Fetaji has 8, and A. B. Hussain has 7. Finally, O. Harfoushi has six citations, A. Dirin has 6, and A. Hussain has 6.

3.9. The documents that were published the most by the institutions

Table 9 lists the top publishers with the highest citations [63]. Education and Information Technologies has 29 citations, followed by Interactive Technology and Smart Education with 24, and the International Journal of Interactive Mobile Technologies with 22. Studies in Educational Evaluation has 19 citations, and the International Journal of Electrical and Computer Engineering has 13. Procedia Computer Science has 11 citations, and the 2010 2nd International Conference on Computer Engineering and Applications has 9 citations. ICCEA 2010 and ACM International Conference Proceeding Series each have 8 citations. ARPN Journal of Engineering and Applied Sciences has 7 citations. Lastly, the International Journal of Interactive Mobile Technologies, CSEDU 2017 Proceedings, and Jurnal Teknologi have 6 citations.

Table 8. The most cited authors

Cites	Authors	Year
29	B. A. Kumar	2020
24	M. Kuhnel	2018
22	A. Dirin	2015
19	N. Parsazadeh	2018
13	K. C. Brata	2020
11	M. Pikhart	2021
9	N. Wahab	2010
8	M. Fetaji	2011
7	A. B. Hussain	2015
6	O. Harfoushi	2017
6	A. Dirin	2017
6	A. Hussain	2015

Table 9. The publishers with the highest citations

Cites	Authors	Title	Source
29	B. A. Kumar	A framework for heuristic evaluation of mobile learning applications	Education and Information Technologies
24	M. Kuhnel	Mobile learning analytics in higher education: usability testing and evaluation of an app prototype	Interactive Technology and Smart Education
22	A. Dirin	mLUX: Usability and user experience development framework for M-learning	International Journal of Interactive Mobile Technologies
19	N. Parsazadeh	The construction and validation of a usability evaluation survey for mobile learning environments	Studies in Educational Evaluation
13	K. C. Brata	User experience improvement of Japanese language mobile learning application through the mental model and A/B testing	International Journal of Electrical and Computer Engineering
11	M. Pikhart	Human-computer interaction in foreign language learning applications: Applied linguistics viewpoint of mobile learning	Procedia Computer Science
9	N. Wahab	Engaging children in science subject: A heuristic evaluation of mobile learning prototype	2010 2nd International Conference on Computer Engineering and Applications, ICCEA 2010

3.10. The keywords co-occurrence

According to Figure 1, nine clusters with 235 keywords are identified. The largest cluster is red with 41 keywords, including mobile learning, collaborative learning, design, learning process, ubiquitous computing, AI, and learning content [20], [49], [50], [62]–[65]. The green cluster follows 37 keywords, featuring e-learning, user experience, mobile applications, VR, and user-centered design. The blue cluster has 34 keywords: teaching, education, usability testing, evaluation, and user interface designs. The fourth-largest, yellow cluster, includes 32 keywords like curricula, technology-enhanced learning, interactive learning, and game-based learning. Other clusters contain keywords like engineering education, AR, and human-computer interaction in the purple cluster (22 keywords); mobile devices, higher education, and student engagement in the turquoise cluster (20 keywords); human-computer interaction, educational technology, and cognitive systems in the orange cluster (19 keywords); and mobile computing, knowledge management, and wireless technologies in the peach-greyish cluster (16 keywords). The pink cluster has 14 keywords, including usability engineering, user interfaces, smartphones, and wireless networks. These clusters highlight the growing importance of mobile user experience in IR 5.0, emphasizing meta-technology integration to enhance student learning via mobile tools [66]–[70].

The research analyzed "mobile learning" OR m-learning OR mlearning from 76,784 publications between 1997 and 2023, representing 0.008713% of all e-learning research in Scopus, with 669 out of 76,784 focusing on mobile learning. A quantitative metadata analysis was conducted to examine outputs by year, universities, countries, authors, journals, and research areas as of July 11, 2023 [71]. Malaysia, the United Kingdom, the United States, Spain, and China led in publication volume. However, Fiji, Germany, Finland, Iran, and Indonesia were the most cited, showing a disparity between publication quantity and citation influence as shown in Table 10. Fiji National University, Aalto University, Universiti Teknologi Mara (UiTM), Graz University of Technology, and Tampere University of Technology were cited most as presented in Table 11. Although some universities like Aalto University publish extensively, they are not the most cited. Based on total link strength (TLS), UiTM, Universiti Teknologi PETRONAS, Tampere University, Aalto University, and Universiti Utara Malaysia are the most influential. Co-occurrence analysis highlighted the growing importance of students' experiences with emerging technologies and meta-mobile technology in the IR 5.0 era, which is still nascent. Influential sources include Lecture Notes in Computer Science, ACM International Conference Proceeding Series, Communications in Computer and Information Science, International Journal of Interactive Mobile Technologies, and Computers and Education. Despite these trends, research on usability and evaluation in mobile learning remains limited. Keywords like "mobile usability" (8 occurrences, TLS: 56), "mobile user experience" (5 occurrences, TLS: 38), "usability studies" (5 occurrences, TLS: 54), and "design thinking" (10 occurrences, TLS: 32) had few hits. Countries leading in collaboration by TLS include the United Kingdom, the United States, China, Malaysia, and Spain [71].

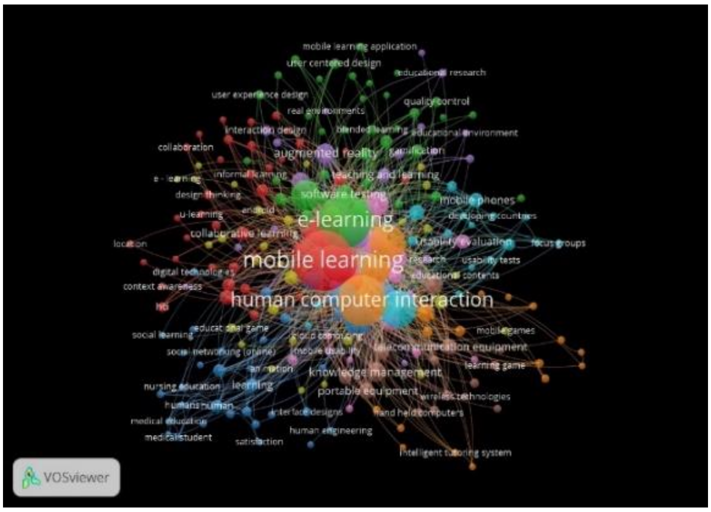

Figure 1. The Network visualization map of keywords' co-occurrence

Table 10. The countries by clusters' TLS

Country	Cluster	TLS	Documents	Citations
United Kingdom	2	16	60	1289
United States	5	19	45	944
China	4	11	40	597
Malaysia	8	20	73	592
Spain	1	3	43	460

Table 11. The university by documentation and citations

University	Links	Documents	Citations
Department of Computer Science and Information Systems, Fiji National University	0	3	86
Department of Computer Science, Aalto University	0	5	49
Faculty of Computer and Mathematical Sciences, Universiti Teknologi Mara (UiTM)	0	3	18
Graz University of Technology	0	4	8
Tampere University of Technology	0	3	9

4. CONCLUSION

This study revealed that research on usability or mobile user experience in mobile learning has been relatively low and under research compared to other research topics in recent years. The study is limited to the Scopus database; hence, it can be further elaborated in the future. The study's conclusion highlights the crucial significance of user experience in incorporating IR 5.0 technologies such as AR, VR, and AI into mobile learning. It emphasizes the transformative impact of these technologies on educational methods, providing inter-immersive and personalized learning experiences. The implications suggest a requirement for targeted research on improving user interfaces and interactions in educational technology. This research presents new opportunities for enhancing user experience, improving accessibility, and maximizing the educational benefits of advanced technologies in educational settings.

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