Mapping of Mobile Learning Research Directions and Trends in Scopus-Indexed Journals: A Bibliometric Analysis

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Abstract—In comparison to traditional classroom lessons, mobile learning is hailed as a simple, convenient, engaging, innovative, and modern means of learning. Students exhibit more self-discipline and organization during the mobile learning process. Mobile learning is becoming increasingly prevalent in the classroom. It is crucial to develop a shared understanding of the research conducted to comprehend how mobile learning is used. The goal of the study is to give a summary of the literature on mobile learning based on a bibliometric evaluation of several journal articles published in the Scopus database and to determine fresh ideas and knowledge gaps as a resource for more research. The technique is bibliometric analysis with the use of the programs VOSviewer, SEforRA, and Publish or Perish. The findings of this analysis show that from 2000 to 2018, the growth of mobile learning research on the Scopus database trended upward and peaked. The expanding trend of research on mobile learning has led to the discovery of numerous themes or keywords that might be used as the basis for further study. In conclusion, the bibliometric analysis provides knowledge and information about the development of mobile learning research for the possibility of a new study.

Keywords—mapping, trend, mobile learning, Scopus, bibliometric

1 Introduction

Rapid advancements in wireless, information, and communication technologies have made mobile devices more accessible, inexpensive, and practical [1]. Thus, a sizable portion of the global population has come to embrace the usage of mobile devices and the improvement in internet accessibility and speed. Researchers and educators have focused on developing educational applications to simplify the procedure for teaching and learning as more students own mobile devices [2]. As a result, the term "mobile learning" has been used in the literature. Because mobile learning may transcend geographic and temporal boundaries, its usage in educational research has gained prominence [3]. In this regard, academics have concentrated on how mobile technology might offer learning opportunities that include innovative teaching techniques, both within and outside of the classroom [4, 5]. [6] emphasizes the potential of mobile technology to offer engaging and cutting-edge educational approaches.

Learning Due to the importance of cell phones in today's digital world for student learning achievement, mobile learning is employed extremely strategically in education, specifically in the classroom. Students spend a lot of time on smartphones, according to [7], who found that 3-year-olds spend the most time on smartphones, on average, 6 hours per day, while 5-year-olds spend the most time on touch-screen devices. Students should be able to direct their older siblings to use technology in positively from an early age (0.6 hours every day).

The integration of technology into the teaching and learning process to enhance students' creative thinking skills is a challenge that educators must meet along with the growing importance of creative thinking skills for university graduates. Students can very quickly organize themselves in a mobile learning environment with the correct teacher intervention. [6] According to the study's findings [8], the fact that teachers and students can use collaborative mobile learning technology to effectively mold students' professional competence is the practical importance of the research findings. The collaborative mobile environment is founded on the ideas of user participation, communication, and learning as well as teacher coordination of student actions. The study demonstrated that flexible transitions from mixed learning models to distance learning and back again are possible using collaborative mobile learning. [9] describes mobile learning as an alternative to traditional classroom instruction that is simple, practical, engaging, inventive, and current.

Due to practical lectures, programs that incorporate real-world business settings, and other elements, students who participate in mobile learning exhibit higher levels of self-discipline and organization. They are also considerably more engaged and productive. According to [10], mobile devices can be effectively incorporated into early childhood teaching practices and used to assist interactive learning with the use of suitable development software. We advise creating enhanced teaching digital resources that combine the use of computers, particularly tablets, to give students of all performance levels a good opportunity.

2 Literature review

The literature contains many definitions of mobile learning. These various definitions are primarily because mobile learning has a wide range of applications, from commerce to health, from the armed forces to schools. For illustration, [11] emphasizes the concept of "mobility" in its definition and describes "mobile learning" as "the delivery of education and training via PDAs, palmtops, handheld devices, smartphones, and mobile phones." Mobile learning is education enabled by portable technology like media players, tablets, and mobile phones. [12], [13]. both informal and academic environments [14]. As more mobile devices with cutting-edge wireless communication capabilities have been developed, "on-the-go" learning—using mobile devices in educational settings—has become more common. This enables students to access educational materials from different times and places [15], [16], [17], and to share educational materials with others [18].

Regarding the purpose of mobile learning, [19] claimed that wireless mobile technology enables people to access knowledge and educational resources anywhere. This feature is mentioned in other definitions as well. For instance, [20] views mobile learning as an expanded form of e-learning, while [21] refers to it as a subset of e-learning and describes it as a method for delivering timely learning. Additionally, [22] distinguishes e-learning from mobile learning in its pedagogical framework by defining mobile learning as the utilization of wireless and mobile devices for learning. Mobile devices, according to Schuck and Maher (2018), enable students and teachers to take on new roles and transcend the confines of conventional learning spaces. This is how mobile learning design fosters opportunities for seamless learning [23]. As a result, it has been compared as a link between communal and individual learning environments where time and location restrictions are lifted [24]. Learning that is individualized, contextual, and unrestricted by environmental or temporal constraints are only a few of the unique characteristics that mobile learning offers to students [25].

Mobile learning is becoming increasingly prevalent in the classroom. It is crucial to develop a shared understanding of the research conducted to comprehend how mobile learning is used. This systematic review uses a thorough analysis and synthesis of studies from 2000 onwards to uncover trends in mobile learning in science. Numerous research techniques were employed, offering a rich research perspective. More research is needed to increase educators' capacity to adopt mobile technology as the use of mobile learning continues to rise across all industries and levels of education. [25].

Researchers have studied the application of mobile learning in education, but there hasn't been a coordinated effort to compile and aggregate these findings. [26] emphasized the need for a thorough synthesis of the studies on mobile learning in science education to better understand how mobile technology and science education interact. Through such initiatives, researchers would be able to expand on this body of information and obtain a greater grasp of the fields in which research has been conducted. Additionally, this endeavor will help educators discover more about the nature of mobile learning employed in the classroom. With this knowledge, they will be able to evaluate their instruction in light of studies on the use of mobile technology in education and take steps to apply their newly acquired knowledge to their practices. The purpose of this study is to map the direction and trends of mobile learning research in journals that are indexed by Scopus to undertake bibliometric analysis investigations.

There is a lot of bibliometric research on the topic of mobile learning, but bibliometric research on mobile learning in Scopus-indexed journals has not comprehensively discussed it. There are several bibliometric research results on mobile learning but not many foci on Scopus-indexed journals such as research by Schobel [27] with the title Two decades of game concepts in digital learning environments – A bibliometric study and research agenda, research by Sobral [28] with the title Mobile Learning in Higher Education: A Bibliometric Review, research by Goksu [29] with the title Bibliometric mapping of mobile learning, research by Elaish [30] with the title A bibliometric analysis of m-learning from topic inception to 2015, and research by Churiyah

[31]with the title Mobile learning uses in vocational high school: A bibliometric analysis. All of these studies are bibliometric research on mobile learning but the discussion does not focus on Scopus-indexed journals. Therefore, bibliometric research on mobile learning is more focused on articles published in journals indexed by Scopus.

The study focuses on publications that Scopus has indexed. To undertake bibliometric analysis, the following five bibliographic databases can be used: Web of Science (WoS), Scopus, Google Scholar, Microsoft Academic, and Dimensions [23, 24]. The two that are most frequently used for bibliometric analysis are WoS and Scopus. Because it has a greater variety of documents than other databases, we chose to use the Scopus database as a search engine for this study [25,26].

This study aims to offer a thorough overview of mobile learning research themes in Scopus-indexed journals by using bibliometric analytical approaches. However, the following Research Questions (RQ) were specifically established as part of this study:

1. RQ1. What are the topic's relevance and contribution?
2. RQ2. What is the most popular phrase used in relation to this research issue, and how has it changed or developed over the past few years?
3. RQ3. Which researcher has the most peer-reviewed articles on this subject published? especially in journals with a Scopus index?
4. RQ4. Which prestigious journals contributed to this field of study?

3 Methods

Research method employs article searches with the Publish or Perish application version 8 and bibliometric analysis techniques with Vosviewer. Bibliometric analysis, a tool frequently used to examine trends and performance on the subject, offers a reliable and objective approach to calculating the contribution of an article to the advancement of knowledge. definite [36]. To identify research gaps and innovation as the basis for additional study, bibliometric analysis is utilized to better understand how educational philosophy has evolved in the academic community. Although many other domains have conducted bibliometric analysis research, no one has done so in the area of mobile learning. Studying bibliometric analysis in mobile learning might be fascinating.

Novelty and research trends can be discovered in studies using bibliometric analysis, according to numerous studies [28,29,30,31,32,33, 34]. The Scopus database is where the article documents are located. This is based on the reliability of Scopus as a global publication platform for researchers. To search for titles, abstracts, and keywords from 1995 to 2021, the term "mobile learning" is used as a filter. The general research techniques are: (a) using the Publish or Perish application version 8 to define "mobile learning" topics; (b) optimizing Scopus Elsevier; (c) downloading RIS and CSV; (d) analyzing RIS data using VOSViewer software [38], [35,36]; (e) analyzing CSV data using Microsoft Excel; and (f) interpretation (g). Get profiles and news about mobile learning research trends. The methodology utilized in this research, according to [40], is divided into the following five stages: In Figure 1.

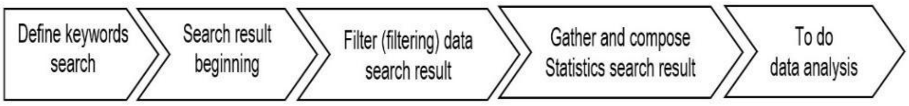


Fig. 1. Five steps of bibliometric analysis method

3.1 Determining search

Keyword The keyword that is used as a reference in this research is "mobile learning". In addition to keywords, the year of publication of the article is also taken into consideration in mining articles. There are two article mining with two different tools. The first tool (Publish or Perish 8) with a search mode for the year published 1995-2021 [46] and the tool (SEforRA) with a search mode limiting the year published between 1999-2022. [47]. (The selected journal article database platform is Scopus. Articles from the Scopus database are used as the basis for obtaining good-quality articles. Scopus is a multidisciplinary database of articles that compiles content from credible journals published by Elsevier, Springer, Wiley, Taylor & Francis, Emerald, Nature, etc. on a global scale.

3.2 Preliminary search

Results Data for 200 journal articles published between 1995 and 2021 and 500 journal articles published between 1999 and 2012 are provided in the search results using the tools Publish or Perish 8 and SEforRA, respectively. 2022. The CSV and RIS formats for the article data.

3.3 Data filtering

The collected article data is still in RIS and CSV file formats, therefore CSV files must be changed into xls file formats to be handled easily in Microsoft Excel, while Mendeley's reference management software requires The RIS file to read it. Then the journal data in xlsx format files are processed and filtered according to analysis needs.

3.4 Collecting and compiling search results statistical data

After the article data is filtered and processed data is produced, including the evolution of the last 26 years of articles (1995-2021), Top 10 articles with the most citations, Top 10 publishers, and journals, as well as other data needed in the analysis.

3.5 Performing data analysis (Bibliometrics)

Bibliometric analysis was carried out with the use of VOSviewer. With its beautiful and interactive data visualization, analysis, and research tools, VOSviewer can work effectively with massive amounts of data [48]. Then, using co-citation networks to create publication maps, author maps, journal maps, or display keyword maps, VOSviewer can do both [49].

4 Results

4.1 The evolution of mobile learning publications

This study's data on the evolution of mobile learning articles came from the Scopus-Elsevier database. Using the database from the Publish or Perish (PoP) tools, with the following information: The keywords used are "mobile learning," "data search year is not limited," and "data source is scoped." The data search year is automatically provided as a range of publishing years between 1995 and 2021. There are a total of 200 papers that may be taken. The article with the title A Mobile Robot's Sensor-Based Navigation Using Fuzzy Logic and Reinforcement Learning written by H. Rak Beom and published in 1995 with the title Vol. 25 No. 3 IEEE Transactions on Systems, Man, and Cybernetics pages 464-477 and total of 208 citations is the oldest article based on this data. According to [50], the fuzzy rule base is developed via reinforcement learning, which only needs a little amount of evaluation data as opposed to a large amount of input-output training data. A fuzzy rule base can be easily created for more complicated contexts since fuzzy rules for each behavior are acquired through reinforcement learning techniques. Ultrasonic sensors that are mounted on the mobile robot are utilized to ascertain the state of the machine at the moment. Several simulations were used to confirm the efficiency of the suggested strategy.

Table 1. Article metadata

Citation Metrics	
Publication years	1995-2021
Citation years	27 (1995-2021)
Papers	200
Citations	43193
Cites/year	1599.74
Cites/paper	215.97
Authors/paper	1.00
h-index	136
g-index	200

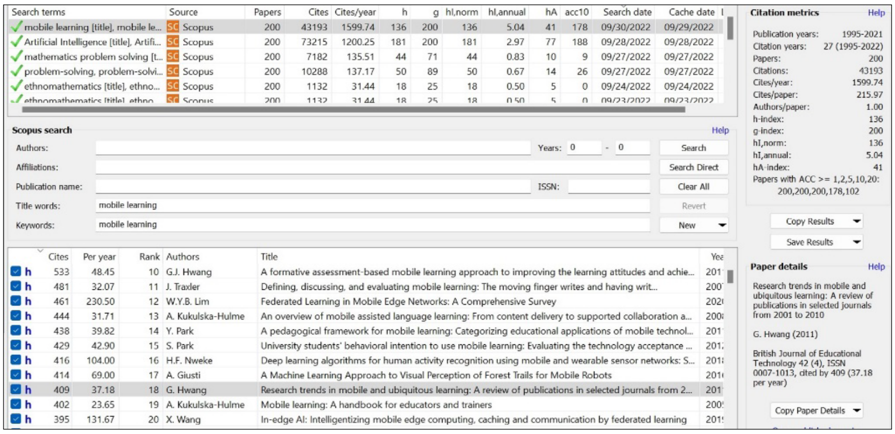


Fig. 2. Article search results with Harzing's Publish or Perish

The number of mobile learning article publications from 1995 to 2021 on average increased from 1995 and peaked in 2018 (Figure 3); with the highest number of articles published in 2018 at 22, and in 2012 and 2016 at 17 articles and the least number of articles published in 1995, 1996, 1999, 2000 and 2001, each with 1 article. Based on Figure 3, in the range of 1995 to 2021 the number of published mobile learning articles experienced a significant increase and reached its peak in 2018. This increase occurred after 2000 and above the internet began to be widely used and increased ease of access. [51]. The significant increase in the number of articles published is linear with global internet traffic and monthly data usage. Improved infrastructure and media have triggered an increase in publications, moreover driven by the open access movement [52] around the world which has led to a massive increase in the release of scholarly articles.

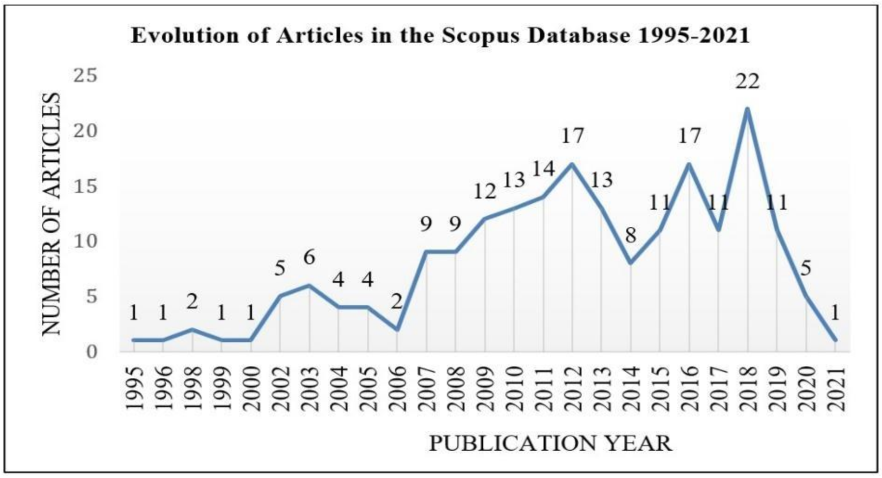


Fig. 3. Graph of the evolution of mobile learning articles in the Scopus database 1995-2021

Of the 200 published papers from 1995-2021, the types of publications consist of 81% articles, 1% books, 1% book chapters, 11.50% conference papers, 0.5% editorial and 5% review. The complete type of data publication is seen in Table 2.

Table 2. Publication

Type Publication	Paper	Percentage
Article	162	81%
Book	2	1%
Book Chapter	2	1%
Conference Paper	23	11.50%
Editorial	1	0.50%
Review	10	5%
TOTAL	200	100%

Table 3 shows that 500 articles were located using the search results generated by the SEforRA tools. Of those, 43 articles were distributed as follows: in Q1=15, Q2=0, Q3=10, Q4=0, NQ=0, and NI=18 in 2011, while 1 article was published in Q1=15 in 2006, the year with the fewest articles published. The number of articles included in the Quartile Q1 Scimago journal rank is 134 (26.80%) out of 500 articles published from 1999 to 2022. This shows that the articles written with the theme of mobile learning are articles of high quality. This is high when compared to articles published in Quartile Q3 as many as 77 articles or 15.40% and in Q4 as many as 8 articles or 1.6%. When viewed in more detail, 2017 was the peak of the highest number of articles included in Q1 with a total of 21 published articles.

Table 3. Ranking in Scimago journal

Year	Scimago Journal Rank						Sub Total	Year	Scimago Journal Rank						Sub Total
	Q1	Q2	Q3	Q4	NQ	NI			Q1	Q2	Q3	Q4	NQ	NI	
2003	0	4	0	0	0	0	4	2013	3	8	7	0	0	7	25
2004	2	0	0	0	0	0	2	2014	7	3	6	0	0	5	21
2005	2	0	0	0	0	1	3	2015	2	12	7	1	1	9	32
2006	0	1	0	0	0	0	1	2016	7	13	0	1	0	4	25
2007	1	1	0	0	12	4	18	2017	21	9	0	0	0	3	33
2008	2	0	8	0	0	2	12	2018	0	29	1	0	0	7	37
2009	4	0	12	0	11	7	34	2019	13	9	1	0	0	9	32
2010	3	15	13	0	0	4	35	2020	15	8	1	4	0	8	36
2011	15	0	10	0	0	18	43	2021	13	9	0	0	0	15	37
2012	10	0	11	2	0	8	31	2022	14	18	0	0	0	7	39
Total									134	139	77	8	24	118	500
Percentage									26,8	27,8	15,4	1,6	4,8	23,6	

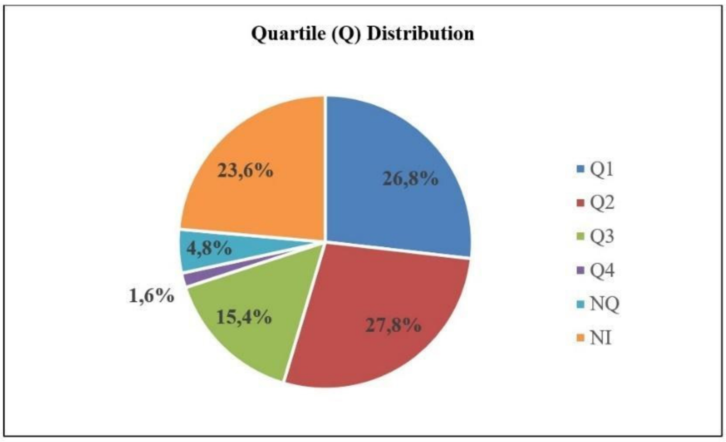


Fig. 4. of Quartile distribution diagram (Q) in Schimago with SEforRA tools (1999-2022)

4.2 Ranking top ten (Top 10)

Referring to the results obtained from the bibliographic analysis, there are several findings as follows. (1) YT Sung is the most cited author, with 717 citations. (2) Published in the journal Computers and Education in 2016 with the Title A meta-analysis and research synthesis evaluating the impact of mobile device integration on students' learning performance. (3) The authors of this article carried out a meta-analysis and research synthesis study on the combined effects of mobile devices on teaching and learning. 110 experimental and quasi-experimental journal articles published between 1993 and 2013 were coded and analyzed as part of the study. The average effect size of mobile device use in education is 0.523, which is regarded as a low effect size. The effect sizes of the moderator variables were looked at based on the content analysis of individual studies, and the advantages and disadvantages of mobile learning at various levels of the moderator variables were summarized. [53] Mobile technology has evolved into learning tools that hold tremendous promise for both indoor and outdoor learning, including laptops, PDAs, and mobile phones.

Table 4. Top 10: author, article, journal, and citation

No	Author	Title Paper	Citation	Year	Journal Publication
1	YT Sung	The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis	717	2016	Computers and Education
2	S. Thrun	Learning metric-topological maps for indoor mobile robot navigation	707	1998	Artificial Intelligence
3	Y. Wang	Investigating the determinants and age and gender differences in the acceptance of mobile learning	687	2009	British Journal of Educational Technology

No	Author	Title Paper	Citation	Year	Journal Publication
4	J. Gikas	Mobile computing devices in higher education: Student perspectives on learning with cell-phones, smartphones & social media	676	2013	Internet and Higher Education
5	C. Zhang	Deep Learning in Mobile and Wireless Net-working: A Survey	664	2019	IEEE Communica-tions Surveys and Tutorials
6	M. Sharples	The design of personal mobile technologies for lifelong learning	617	2000	Computers and Education
7	L.F. Moti-walla	Mobile learning: A framework and evaluation	605	2007	Computers and Education
8	J. Cheon	An investigation of mobile learning readiness in higher education based on the theory of planned behavior	550	2012	Computers and Education
9	W.H. Wu	Review of trends from mobile learning studies: A meta -analysis	548	2012	Computers and Education
10	G.J. Hwang	A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students	533	2011	Computers and Education

4.3 Journals that publish mobile learning research articles

Findings about various journals containing mobile learning research between 1995 and 2021 can be seen in the Table 5.

Table 5. Journals that publish mobile learning research articles

No	Source	Article Total	%	Cites	%	Cites Per Year	%
1	Computers and Education	32	15.84	8592	19.9	976.42	12.4
2	Journal of Computer Assisted Learning	18	8.911	3812	8.85	289.47	3.68
3	Educational Technology and Society	10	4.95	1843	4.28	189	2.4
4	British Journal of Educational Technol-ogy	8	3.96	2482	5.76	241.16	3.07
5	Computers in Human Behavior	6	2.97	1215	2.82	1999.99	25.4
6	Turkish Online Journal of Educational Technology	4	1.98	514	1.19	41.3	0.53
7	ReCALL	4	1.98	1068	2.48	84.29	1.07
8	Language, Learning and Technology	4	1.98	749	1.74	68.58	0.87
9	International Review of Research in Open and Distance Learning	4	1.98	1203	2.79	93.85	1.19
10	IEEE Network	4	1.98	914	2.12	246.67	3.14
11	International Journal of Mobile and Blended Learning (IJMBL)	3	1.485	630	1.46	48.46	0.62
12	IEEE Transactions on Vehicular Tech-nology	3	1.485	373	0.87	79.31	1.01
13	IEEE Transactions on Systems, Man, and Cybernetics	3	1.485	585	1.36	32.8	0.42

No	Source	Article Total	%	Cites	%	Cites Per Year	%
14	Applied Intelligence	3	1.485	157	0.36	15.7	0.2
15	Robotics and Autonomous Systems	2	0.99	327	0.76	52.01	0.66
16	Proceedings - IEEE International Workshop on Wireless and Mobile Technologies in Education, WMTE 2002	2	0.99	269	0.62	13.45	0.17
17	Proceedings - 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education	2	0.99	254	0.59	14.11	0.18
18	Procedia - Social and Behavioral Sciences	2	0.99	275	0.64	25	0.32
19	Mobile Learning: A Handbook for Educators and Trainers	2	0.99	544	1.26	32	0.41
20	Internet and Higher Education	2	0.99	833	1.93	101.28	1.29
21	International Journal of Robotics Research	2	0.99	337	0.78	56.16	0.71
22	International Journal of Mobile Learning and Organisation	2	0.99	387	0.9	37.47	0.48
23	IEEE Wireless Communications	2	0.99	273	0.63	105	1.33
24	IEEE Transactions on Mobile Computing	2	0.99	430	1	143.25	1.82
25	IEEE Transactions on Industrial Informatics	2	0.99	261	0.61	106.17	1.35
26	IEEE Internet of Things Journal	2	0.99	287	0.67	116.67	1.48
27	IEEE International Conference on Communications	2	0.99	501	1.16	157.17	2
28	IEEE Communications Surveys and Tutorials	2	0.99	1125	2.61	451.83	5.74
29	IEEE Access	2	0.99	364	0.84	102.92	1.31
30	Computer Assisted Language Learning	2	0.99	122	0.28	35.56	0.45
31	Australasian Journal of Educational Technology	2	0.99	306	0.71	30.6	0.39
32	Artificial Intelligence	2	0.99	865	2.01	45.26	0.58
33	Telematics and Informatics	1	0.495	173	0.4	43.25	0.55
34	Technology-Enhanced Learning: Principles and Products	1	0.495	314	0.73	24.15	0.31
35	Soft Computing	1	0.495	251	0.58	41.83	0.53
36	RUSC Universities and Knowledge Society Journal	1	0.495	134	0.31	16.75	0.21
37	Research in Learning Technology	1	0.495	380	0.88	38	0.48
38	Remote Sensing Letters	1	0.495	120	0.28	17.14	0.22
39	Proceedings-IEEE International Conference on Robotics and Automation	1	0.495	280	0.65	14	0.18
40	Proceedings of the Annual International Conference on Mobile Computing and Networking, MOBICOM	1	0.495	111	0.26	27.75	0.35

There are 92 journals that publish research articles on mobile learning topics. From Table 5, it can be seen that the Scopus journal that publishes the most mobile learning topic articles is Computers and Education with a total of 32 or as many as 19.05% of all articles, next is the Journal of Computer Assisted Learning with 18 articles or as many as 8.91%, Educational Technology and Society 10 articles (4.95%), the British Journal of Educational Technology has 8 articles (3.96%), Computers in Human Behavior has 6 articles (2.97%), Turkish Online Journal of Educational Technology, Re-CALL, Language, Learning and Technology, International Review of Research in Open and Distance Learning, IEEE Network, each with 4 articles (1.988%).

The highest number of citations is the journal Computers and Education with 8592 citations (19.9%), followed by the Journal of Computer Assisted Learning with 3812 citations (8.85%), the British Journal of Educational Technology with 2482 citations (5.76%), and the Educational Technology and Society with 1843 citations (4.28%). Computers in Human Behavior produces the most citations per year with 1999,995 per year (25.4%), followed by Computers and Education with 976.42 per year (12.4%), IEEE Communications Surveys and Tutorials with 451.83 per year (5.74%) and Journal of Computer Assisted Learning with 289.47 articles per year (3.68%).

4.4 The top article mobile learning for all year

The authors with the highest number of citations and their research findings can be seen in Table 6.

Table 6. The top article mobile learning for all year

Document title	Authors	Finding	Recommendations
The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis.	Yao-Ting Sung	A portable robot that was set up at the Deutsches Museum in Bonn in collaboration with the University of Bonn. The robot's job at this location is to interact with and guide tourists on excursions. In six days, the robot successfully traversed more than 18.5 km along a densely populated route at a maximum speed of 80 cm/set and an average speed of 35 cm/set. This extremely dynamic environmental robot proved to be successful thanks to the ability of robots to map their surroundings in real-time and re-plan simultaneously utilizing some of the strategies outlined in this study. Inquiry-oriented learning is more effective than joint use with lectures, self-study, cooperative learning, and game-based learning; environmental informal education is more effective than their formal counterparts, and medium and short-duration interven-	Based on the study's findings, it is suggested that in order to fully utilize the potential educational benefits of using mobile devices, more complex instructional designs must be developed. According to three implications. The suggestions made below will be extremely helpful in facilitating and achieving these objectives.

Document title	Authors	Finding	Recommendations
		tions are better than long-term interventions. The influence of such use is greater for handheld devices than laptops.	
Learning metric-topological maps for indoor mobile robot navigation	S. Thrun	This article describes a strategy that combines the grid-based and topological paradigms. grid-based maps that were learned utilizing naive Bayesian integration and artificial neural networks. Grid-based maps are converted into topology maps by dividing them into cohesive regions. The approach described here benefits from both accuracy/consistency and efficiency by merging the two paradigms. In a crowded, multi-room environment, this study presents results for the exploration, mapping, and autonomous operation of car robots.	A portable robot was set up at the Deutsches Museum in Bonn in collaboration with the University of Bonn. The robot's job at this location is to interact with and guide tourists on excursions. In six days, the robot successfully traversed more than 18.5 km along a densely populated route at a maximum speed of 80 cm/set and an average speed of 35 cm/set. This extremely dynamic environmental robot proved to be successful thanks to the ability of robots to map their surroundings in real-time and re-plan simultaneously utilizing some of the strategies outlined in this study.
Investigating the determinants and age and gender differences in the acceptance of mobile learning	Y. Wang	The behavioral intents to use mobile learning are significantly influenced by performance expectations, effort expectations, social influences, perceived enjoyment, and self-management of learning. We also discovered that gender differences moderated the impacts of social influences and self-management of learning on m-learning intent use and that age differences moderated the effects of effort expectation and social influence on the use of m-learning. These findings have some significant ramifications for how research and practice will approach the acceptability of m-learning.	Self-Impact Managements on Learning. The intention was substantial across all groups, however, it was more significant for women than for men due to gender moderation. The results of this study will assist M-learning practitioners in creating M-learning systems that users will more readily accept and in promoting this new IT to potential users. They will also provide insight into research Acceptance of M-Learning.
Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media	J. Gikas	Two details Emerging themes from the interview data include (a) benefits of mobile computing for student learning and (b) difficulties with mobile computing for learning. Because of their constant connectivity, mobile computing devices and social media use enable students to create and communicate using social media and Web 2.0 tools, which opens up opportunities for interaction and collaboration.	Despite the limitations that were noted, such as the concern that technology won't perform as intended, the small keyboard on mobile devices, which makes typing difficult, and the possibility of device distraction, the students in this study admitted that learning has changed. However, it is significant to remember that the individuals gave their information voluntarily. Because they believe mobile gadgets have an impact on their learning, their experiences support this.

Document title	Authors	Finding	Recommendations
Deep Learning in Mobile and Wireless Networking: A Survey	C. Zhang	We briefly discuss the fundamental ideas and cutting-edge concepts from several deep learning models before reviewing particular work on mobile networks in a range of application scenarios. We discuss how to modify deep learning models for popular mobile network applications—aspects that the prior survey disregarded. We end by outlining several unresolved issues in the literature and possible future research avenues.	We hope that this article will serve as the ultimate resource for researchers and practitioners who are interested.solving complex issues with artificial intelligence in a mobile network environment
The design of personal mobile technologies for lifelong learning	M. Sharples	With the help of new technology, kids and adults have more opportunities to connect with rich learning resources and simulated environments, communicate with teachers and other students around the globe, and access information and expertise when needed a prolonged process of collecting and organizing contextual activity is required to generate "personal learning narratives," which are a way for people to reflect on and share their experiences with others. Soon, all of the necessary technology for this new learning environment will be available. This essay has shown how these elements might be combined to create potent tools for supporting mobile lifelong learning.	The project has generated a number of questions and issues that need further investigation, such as how to adapt the mentor's role and appearance to suit learners of different ages, contexts, and abilities; how to match the system and interface to the learner's cognitive and social abilities; how to manage a lifetime's worth of learning resources; and the role of businesses and institutions in supporting personal mobile learning.

The overall impact of using mobile devices in education is better than when using a desktop computer or not using a mobile device as an intervention, with a moderate effect size of 0.523, according to Yao-Ting Sung's analysis of empirical research on the use of mobile devices as a tool in educational interventions. We discovered that numerous distinct combinations of hardware, software, and length of intervention for mobile devices have been used to varied user ages, implementation settings, instructional methodologies, and domain subjects through the analysis of the moderator factors. [53]. The impact of such use was greater for handheld devices than for laptops; use in inquiry-oriented learning was more effective than use in conjunction with lectures; use in self-directed study, cooperative learning, and game-based learning was more effective than use in formal educational settings; and medium- and short-duration interventions were superior to long-duration interventions. These results will help us understand where, for whom, and how the use of mobile devices in the learning environment will highlight the benefits of specific instructional strategies and highlight the drawbacks of using mobile devices in education.

As can be seen in Table 6, one of the key empirical findings of [54] research relates to the cost-benefit evaluation of topological representations. While planning with more abstract topological maps is orders of magnitude more efficient, grid-based maps produce more accurate control. A series of tests showed that the planning efficiency can be raised on a medium-sized map by three to four orders of magnitude while the performance is barely affected (for instance, 1.82%). We anticipate being able to manage autonomous robots on various floors in our university buildings thanks to the topology map that has been described here. However, no sex or age differences were detected in the study by [55], which indicated that the effects of perceived performance expectations and pleasure on behavioral intentions were highly significant. That is, regardless of a person's gender or age, individuals who have high expectations for their performance and playful opinions of the usage of M-learning are more likely to use it than those who have lower expectations. Based on the research, it has been determined that the best way to encourage the use of M-learning is to persuade potential users that these systems are enjoyable and helpful to them.

5 Discussion

5.1 Co-authorship

Analysis Finding links between diverse investigations that draw from study materials created by scholars is possible with co-authorship analysis. Analysis of co-authorship networks can help with these issues, significantly advancing scholarly development [56]. Co-authorship networks are a tool to reveal the direction of collaboration and identify scholars and institutions driving research [57].

file in the RIS format will be received (downloaded) after the article data mining process using the Publish or Perish (PoP) tools is finished, and this file will be the input data required by VOSviewer to carry out a bibliometric analysis. Co-authorship analysis is one of the bibliometric analyses that will be performed.

The findings of VOSviewer's co-authorship analysis are summarized in the table below (Figure 5). In general, it can be read that the relationship between one author and another is the line that connects one author's name with another author's name. The more lines connecting one name to another indicate that the author has collaborated to research the same research article [48]. More details will be explained as follows. (a). Figure 5a: there is no relationship link between authors in one article with another article. This can be seen from there is no line connecting one author to another. (b). Figure 5b: depicts the timeline of publication from 2008 to 2022; indicated by the more yellow color, the more recent the year of publication, on the contrary, the darker bluish color indicates the longer the publication year [48]. Author with the most recent article published by Wang, J, published in 2021. (c). Figure 5a with the largest circle shows the most productive authors who have written the most documents. The most prolific writer is Kukulska-Hulme with five documents. (d). Figure 6: is the publication density of the author, the clearer the yellow color indicates that the author has a lot of published articles, while with the faded color, the fewer articles are published. The writer has appeared in most Kukulska-Hulme publications.

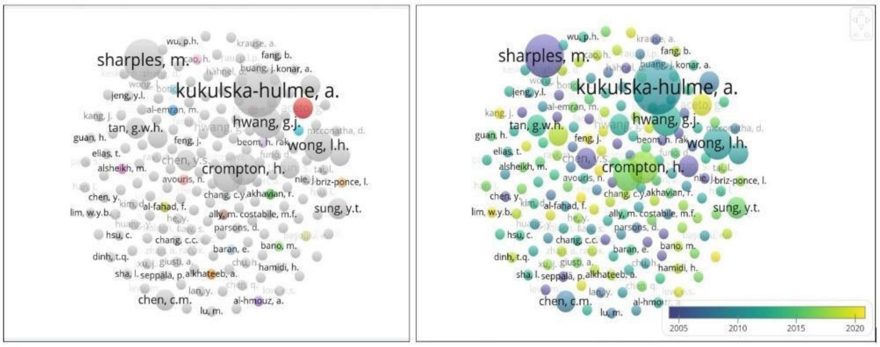


Fig. 5. (ab). Network visualization and overlay visualization

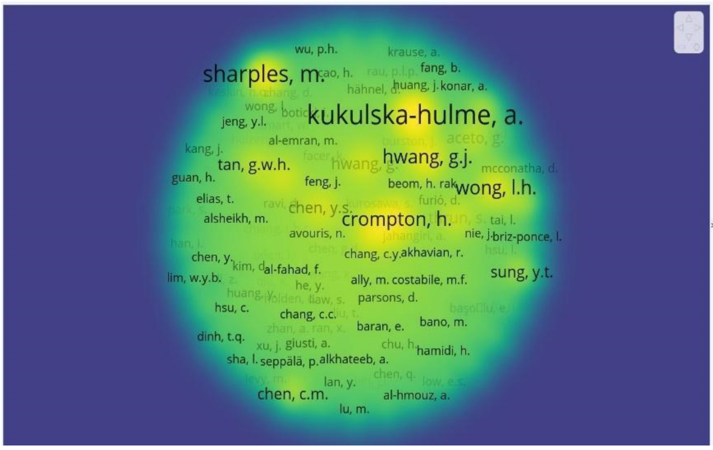


Fig. 6. Density visualization

5.2 Co-word

Analysis The outcomes of co-word analysis using keywords serve as a guide for co-occurrence mapping of significant or particular terms found in particular publications. Knowledge mapping is a technique for representing a scientific field in bibliometrics. A landscape map that may depict scientific themes is created for visualization [58].

VOSviewer will display terms related to mobile learning as many as 60 terms with a minimum of 2 occurrences. By default, VOSviewer will display 60% of the 60 terms [48], but in this analysis, it is determined that all 83 terms will appear. The most frequently used terms are mobile learning (42), learning (23), and mobile (18).

VOSviewer raises the keyword terms and then displays a network visualization based on these keyword terms (Table 7). Some of the important findings discussed in this study are as follows. (1) In comparison to other terms, the phrases mobile learning, learning, approach, student, mobile technology, framework, education, and review are commonly employed in the field of mobile learning research and are characterized by large circular nodes. (2) Consists of 83 items and 10 term clusters marked with different colors from each cluster (Figure 7). (3) Examples of network visualization; Table 7 shows how the concepts are represented by the symbols 1 for a mobile phone, 2 for a mobile network, 3 for acceptance, 4 for a machine learning classifier, and 5 for a classifier (art). In looking for novelty from research, something new is needed and has never been connected at all between the terms in the network. The terms that were notated from 1 to 5 previously were five separate keywords and had never been connected at all. When one to five of the notations is connected inside the same study, it shows that new relationships were established during the research that is expected to lead to more new findings.

Table 7. Frequently appearing keyword terms

No	Term	Occurrences	%	Relevance Score	No	Term	Occurrences	%	Relevance Score
1	mobile learning	42	8.9	0.19	43	publication	4	0.85	0.75
2	learning	23	4.87	0.23	44	research	4	0.85	0.69
3	mobile	18	3.81	0.45	45	theory	4	0.85	0.73
4	approach	17	3.6	0.67	46	art	3	0.64	2.07
5	system	17	3.6	0.27	47	caching	3	0.64	2.4
6	student	15	3.18	0.2	48	case study	3	0.64	0.31
7	education	13	2.75	0.15	49	challenge	3	0.64	1.63
8	mobile technology	13	2.75	0.26	50	cognitive load	3	0.64	0.66
9	review	11	2.33	0.65	51	deep	3	0.64	0.94
10	study	10	2.12	0.23	52	design	3	0.64	0.36
11	mobile device	9	1.91	0.39	53	english	3	0.64	0.57
12	higher education	8	1.69	0.29	54	experience	3	0.64	0.73
13	mobile robot	8	1.69	1.1	55	machine learning	3	0.64	3.81
14	perspective	8	1.69	0.51	56	meta-analysis	3	0.64	0.45
15	use	8	1.69	0.24	57	mobile game	3	0.64	0.45
16	achievement	7	1.48	0.46	58	practice	3	0.64	0.41
17	application	7	1.48	0.32	59	science	3	0.64	0.32
18	framework	7	1.48	0.59	60	state	3	0.64	2.07
19	effect	6	1.27	0.33	61	teaching	3	0.64	0.34
20	impact	6	1.27	0.29	62	usage	3	0.64	0.28
21	language learning	6	1.27	0.91	63	acceptance	2	0.42	0.98
22	mobile edge computing	6	1.27	2.19	64	behavioral intention	2	0.42	0.46
23	mobile phone	6	1.27	1.67	65	determinant	2	0.42	1.36
24	motivation	6	1.27	0.42	66	efl student	2	0.42	0.86
25	navigation	6	1.27	1.1	67	engagement	2	0.42	0.45
26	systematic review	6	1.27	0.25	68	extended technology acceptance model	2	0.42	0.51
27	technology	6	1.27	0.2	69	investigation	2	0.42	1.53

No	Term	Occur-rences	%	Rele-vance Score	No	Term	Occur-rences	%	Rele-vance Score
28	attitude	5	1.06	0.24	70	machine learning classifier	2	0.42	3.11
29	computation of-floading	5	1.06	1.75	71	mobile age	2	0.42	2.21
30	deep learning	5	1.06	1.57	72	mobile app	2	0.42	0.82
31	effectiveness	5	1.06	0.44	73	mobile learning study	2	0.42	1
32	evaluation	5	1.06	1.43	74	mobile network	2	0.42	4.97
33	federated learning	5	1.06	3.49	75	natural science course	2	0.42	1.22
34	language	5	1.06	0.63	76	original article	2	0.42	0.78
35	mobile edges	5	1.06	2.1	77	research trend	2	0.42	1.28
36	model	5	1.06	0.52	78	roles	2	0.42	1.76
37	performance	5	1.06	0.31	79	self	2	0.42	1.5
38	reinforcement	5	1.06	1.89	80	social meaning	2	0.42	0.56
39	trend	5	1.06	0.72	81	traffic classifica-tion	2	0.42	1.88
40	deep reinforcement	4	0.85	2.15	82	ubiquitous learning	2	0.42	0.76
41	inquiry	4	0.85	0.44	83	university student	2	0.42	1.07
42	machine	4	0.85	1.74					

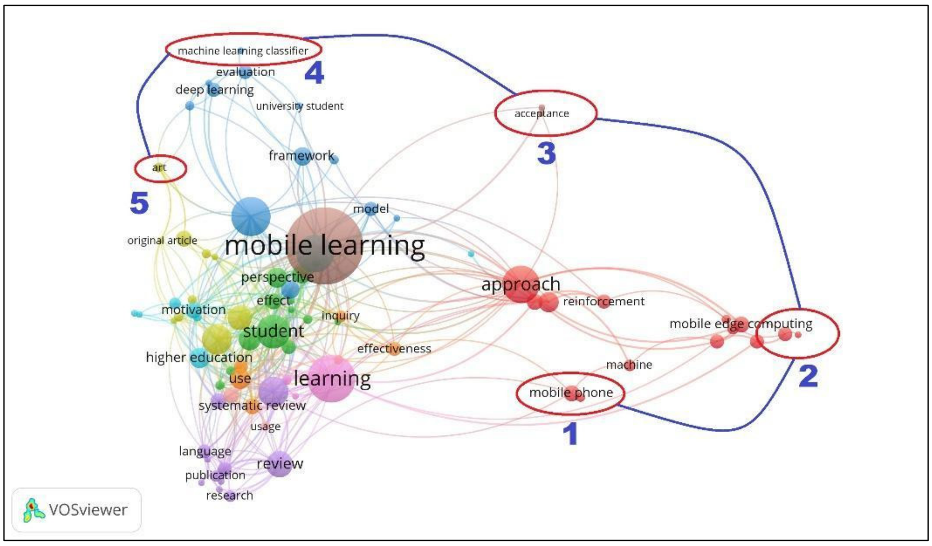


Fig. 7. Network visualization map of research developments in mobile learning

By mapping between Tables 7 and 8, which are then displayed in Figure 7, it is possible to determine where a phrase and keyword are placed. An example is the keyword term Learning (23 occurrences) entered into cluster 9 with red pink as the cluster color. In addition to the network visualization of mobile learning research developments, the overlay and density visualization of mobile learning research are also displayed which can be explained as follows. According to the keyword terms represented by color gradations ranging from dark blue to bright yellow in the overlay visualization, the new year of publication of each published article can be seen, or in other words, revealing traces of study history from year to year, for example for research with the keywords "mobile edge computing, computation of loading and deep learning" which is bright yellow. These three keywords were published in 2018 and 2019, making them reasonably recent articles that their authors have written. It will keep up with the most recent developments in global mobile learning research by completing a thorough study of each keyword that is highlighted in yellow in the visualization overlay.

Table 8. Keyword clusters and colors for each cluster

Cluster	Term	Cluster	Term
Cluster 1 (14 items) Colour: red	• approach • caching • mobile phone • computation of loading • federated learning • machine • deep reinforcement • machine learning • mobile edge computing • mobile network • mobile robot • navigation • reinforcement • mobile edge	Cluster 3 (12 items) Colour: dark blue	• application • behavioral intention • challenge • deep • deep learning • evaluation • framework • machine learning classifier • mobile • model • traffic classification • university student •
Cluster 2 (13 items) Colour: green	• achievement • cognitive load • effect • efl student • experience • meta-analysis • mobile device • performance • perspective • role • self • student • teaching	Cluster 4 (11 items) Colour: yellow	• art • design • engagement • english • extended technology acceptance model • language learning • mobile game • mobile technology • original article • state • study
Cluster 5 (11 items) Colour: violet	• education • language • mobile app • mobile learning study • publication • research • research trend • review • technology • trend	Cluster 6 (8 items) Colour: light blue	• higher education • investigation • mobile age • motivation • natural science course • practice • system • theory

	• ubiquitous learning		
Cluster 7 (6 items) Colour: orange	• attitude • effectiveness • inquiry • science • systematic review • use	Cluster 8 (3 items) Colour: brown	• acceptance • determinant • mobile learning
Cluster 9 (3 items) Colour: pink	• case study • learning • social meaning	Cluster 10 (2 items) Colour: bright red	• impact • usage

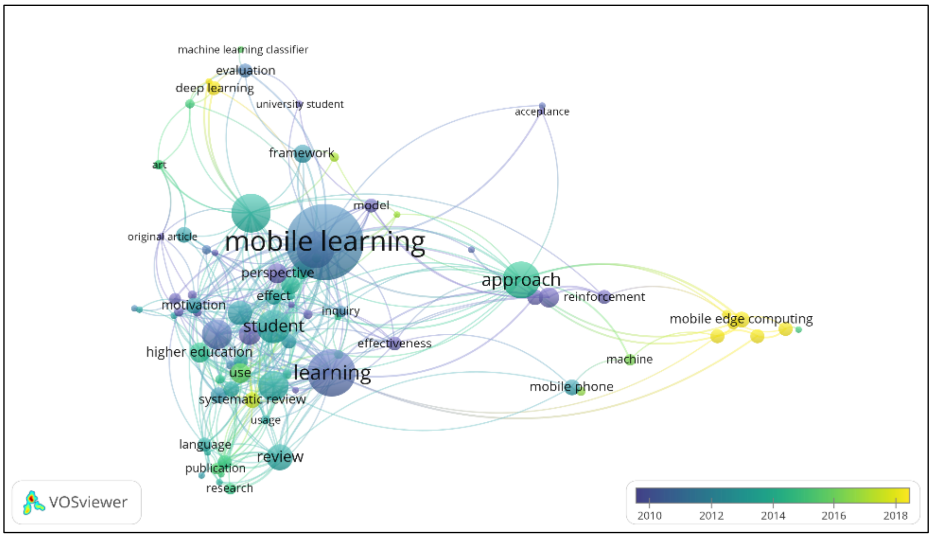
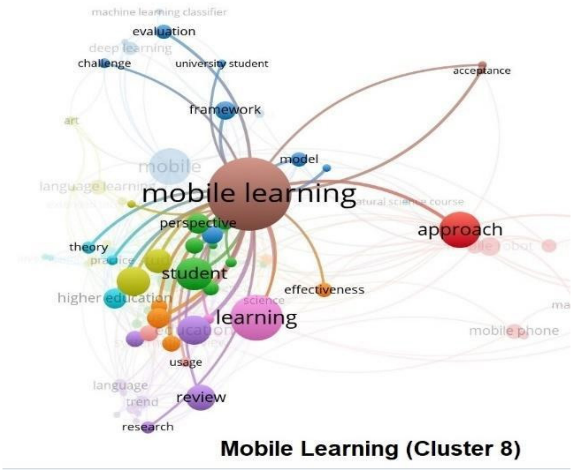


Fig. 8. Overlay visualization

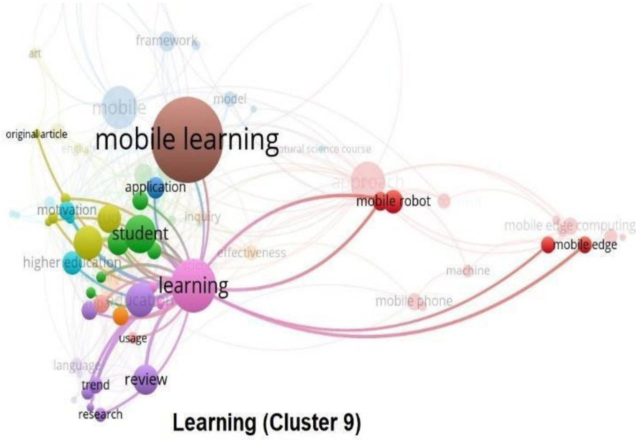
The following are some terms that are often used in mobile learning research and have many links including mobile learning, learning, approach, student, mobile technology, framework, education, and review. The description of some keywords with strong links is as follows:

Mobile learning. Keyword mobile learning is contained in Cluster 8 with a total of 38 links, Total Link Strength of 72, and Occurrences of 42. While the links include: learning, approach, student, framework, review, effectiveness, and model.



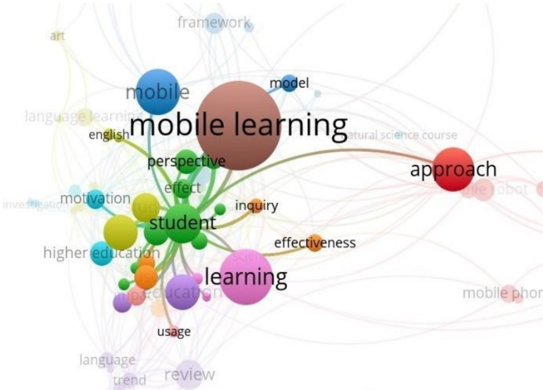
Mobile Learning (Cluster 8)

Learning. Keywords Learning keywords are contained in Cluster 9 with a total of 34 links, 49 Total Link strengths, and 23 Occurrences. While the links include: mobile learning, student, mobile robot, mobile edge, review, trend, research, and application.



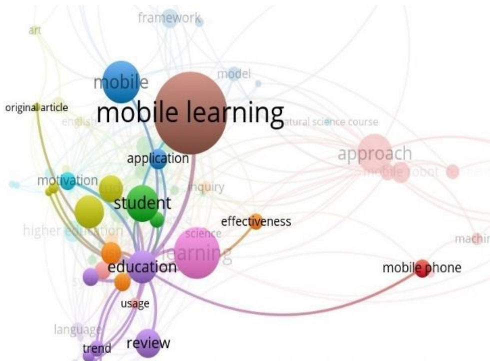
Learning (Cluster 9)

Student. Keywords Student keywords are included in Cluster 2 with a total of 31 links, 47 Total Link strengths, and 15 Occurrences. While the links include: mobile learning, learning, student, mobile, effectiveness, effect, and perspective.



Student (Cluster 2)

Education. The keyword is contained in Cluster 5 with a total of 26 links, 37 Total Link strengths, and 13 Occurrences. While the links include: mobile learning, student, mobile, effectiveness, mobile phone, review, trend, research, and usage.



Education (Cluster 5)

To complete the description above, Table 9 displays 10 keywords with the largest clusters, links, Total Link Strength, and Occurrences.

Table 9. Keywords with the largest number of links

No	Keywords	Cluster	Links	Total Link Strength	Occurrences
1	Mobile Learning	8	38	72	42
2	Learning	9	34	49	23
3	Student	2	31	47	15
4	Education	5	26	37	13
5	Mobile	3	26	30	18
6	approach	1	23	34	17
7	Mobile Technology	4	21	36	13

No	Keywords	Cluster	Links	Total Link Strength	Occurrences
8	Review	5	18	29	11
9	Motivation	6	15	19	6
10	Perspective	2	12	17	8

From table 9, it can be seen that the three keywords with the most significant total link strength in a row are: mobile learning, learning, and student. At the same time, the three keywords with the lowest total link strength in a row are review, motivation, and perspective. The potential opportunity for mobile learning research novelty can be seen from the low total link strength because there are still few researchers conducting research on this cluster. So mobile learning research with the topic of review, motivation, and perspective will have a high update for the next research plan. Research on this cluster is still minimal. For the next research gap, it can link mobile learning with mobile technology, mobile learning research is related to motivation and mobile learning research is pertaining to perspectives. This will give rise to novelty and a high research gap. Meanwhile, mobile learning research with the theme of learning, student and education is saturated and many researchers have done it.

Here are some research articles related to the three keywords: review, motivation, and perspective. The results can be seen in Table 10.

Table 10. Research articles with keywords review, motivation and perspective

Keywords	Authors	Title	Year	Cites	Cites Per Year
Perspective	M. Kearney	Viewing mobile learning from a pedagogical perspective	2012	380	38
	J. Gikas	Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media	2013	676	75.11
	Kukulska-Hulme	Innovation in Mobile Learning: A European Perspective	2009	249	19.15
	J. Huang	Elucidating user behavior of mobile learning: A perspective of the extended technology acceptance model	2007	239	15.93
	J. Tani	Model-based learning for mobile robot navigation from the dynamical systems perspective	1996	231	8.88
	H.C. Chu	Potential negative effects of mobile learning on students' learning achievement and cognitive load-a format assessment perspective	2013	156	17.33
	N.O. Keskin	The current perspectives, theories and practices of mobile learning	2011	112	10.18
	L. Sha	Understanding mobile learning from the perspective of self-regulated learning	2012	112	11.2
Motivation	J. Huizenga	Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game: Original article	2009	347	26.69

Keywords	Authors	Title	Year	Cites	Cites Per Year
	K. Ciampa	Learning in a mobile age: An investigation of student motivation	2014	188	23.5
	C.S.J. Huang	Effects of situated mobile learning approach on learning motivation and performance of EFL students	2016	116	19.33
	C.H. Su	A mobile gamification learning system for improving the learning motivation and achievements	2015	294	42
	T.H.C. Chiang	An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities	2014	296	37
	J. Huizenga	Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game: Original article	2009	347	26.69
	P.L.P. Rau	Using mobile communication technology in high school education: Motivation, pressure, and learning performance	2008	189	13.5
	G. Schwabe	Mobile learning with a mobile game: Design and motivational effects	2005	233	13.71
Review	W.H. Wu	Review of trends from mobile learning studies: A meta-analysis	2012	548	54.8
	J. Traxler	Defining, discussing, and evaluating mobile learning: The moving finger writes and having writ...	2007	481	32.07
	Y. Park	A pedagogical framework for mobile learning: Categorizing educational applications of mobile technologies into four types	2011	438	39.82
	G. Hwang	Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010	2011	409	37.18
	L.H. Wong	What seams do we remove in mobile-assisted seamless learning? A critical review of the literature	2011	355	32.27
	E. Baran	A review of research on mobile learning in teacher education	2014	231	28.88
	H. Crompton	The use of mobile learning in higher education: A systematic review	2018	224	56
	J. Zydney	Mobile apps for science learning: Review of research	2016	213	35.5
	G.J. Hwang	Applications, impacts and trends of mobile technology-enhanced learning: A review of 2008-2012 publications in selected SSCI journals	2014	200	25
	Y.L. Jeng	The add-on impact of mobile applications in learning strategies: A review study	2010	187	15.58
	C. Pimmer	Mobile and ubiquitous learning in higher education settings. A systematic review of empirical studies	2016	168	28

Keywords	Authors	Title	Year	Cites	Cites Per Year
	J.A. Meyer	Map-based navigation in mobile robots: II. A review of map-learning and path-planning strategies	2003	168	8.84
	Q.K. Fu	Trends in mobile technology-supported collaborative learning: A systematic review of journal publications from 2007 to 2016	2018	155	38.75
	H. Crompton	The use of mobile learning in PK-12 education: A systematic review	2017	143	28.6
	Q. Chen	Does multitasking with mobile phones affect learning? A review	2016	137	22.83
	N. Avouris	A review of mobile location-based games for learning across physical and virtual spaces	2012	134	13.4
	R. Shadiev	Review of research on mobile language learning in authentic environments	2017	110	22

Based on the results of this bibliometric analysis, keywords related to research on the use of mobile learning are increasingly prevalent every year. It is hoped that by utilizing these discoveries, researchers can correlate keywords in more detail with each other, resulting in empirically significant conclusions. Researchers and academics can use publications with the most citations, which are the biggest contributors to this research, as the main reference source in studying and producing new discoveries in the study of the application of mobile learning. Following the discovery of this study, authors who have a keen interest in the relevant field of study may find themselves in the position of becoming specialists in public speaking or other forms of presentation as a result of their conclusions.

The density visualization of mobile learning research results of VOSviewer analysis is shown in Figure 9. Density visualization describes the density or emphasis of the research group [48]. Density can be used as a basis for looking at research topics that are still rarely done. In contrast, if the color is becoming brighter yellow, it suggests that the subject of study on the topic has been done frequently and very often. The more faded or hazy the colors define the phrases or keywords of the topic, the fewer studies there are. The examples shown in Figure 9 are topics that are still rarely researched, which are circled in white. On these five topics, the underlying color is very faded and almost invisible. Learning, student, approach, higher education, affect, motivation, and perspective are themes that have undergone study saturation, as evidenced by the vivid yellow color, which denotes that there has been an abundance of research on them. However, topics with the keywords learning, student, evaluation, deep learning, art, university students, framework, mobile phones, and reinforcement have the potential to produce high novelty if research is carried out.

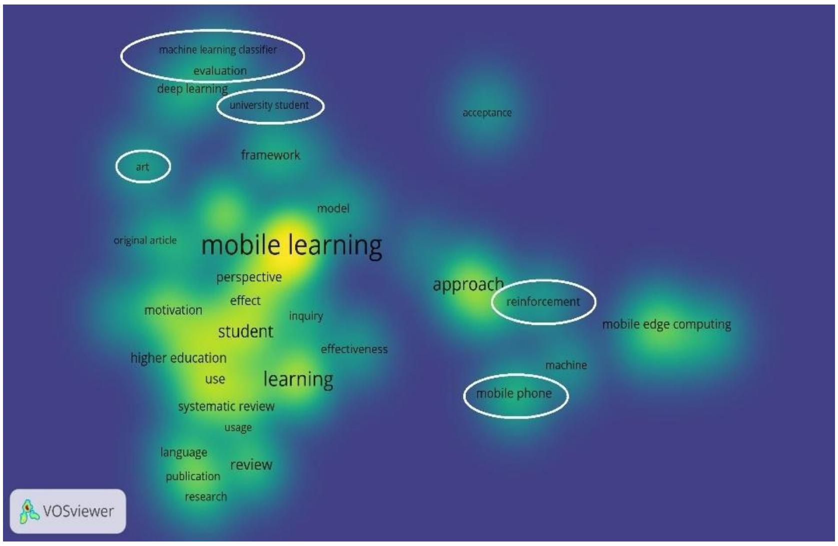


Fig. 9. Density visualization

6 Conclusion

Broadly speaking, the development of mobile learning research in the Scopus database experienced an increasing trend from 2000 and reached its peak in 2018. Information regarding the evolution of article development from the Scopus database from 1995 to 2021 was gleaned from the development of mobile learning research, with Scimago JR ranking among the top 10 journals (author, journal name, article title, and article citation). Several bibliometric analyses, including co-authorship analysis and co-word analysis, can be viewed using VOSviewer. The bibliometric analysis offers a summary and knowledge of what will be done for additional study. This analysis yields several keywords or topics that might serve as the foundation for additional study. In addition, it is crucial to further deepen and enrich the findings of the literature review by developing chosen keywords (compared-analyzing-elaborating), using a larger (trusted) database, and using other comparable tools or software with superior capabilities, like Citespace. Features like visual research area exploration, structural and temporal overview, finding trending subjects, and expanding citations in spiral scholarly literature are subjected to a methodical visual inspection. knowledge domain's intellectual landscape, and constant monitoring of scientific advancements (updates) on relevant themes.

7 Acknowledgment

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8 References

[1] W. H. Wu, Y. C. Jim Wu, C. Y. Chen, H. Y. Kao, C. H. Lin, and S. H. Huang, "Review of trends from mobile learning studies: A meta-analysis," *Comput. Educ.*, vol. 59, no. 2, pp. 817–827, 2012. https://doi.org/10.1016/j.compedu.2012.03.016

[2] Y. Zhang and D. Cristol, *Adoption of Mobile Technology in Higher Education: An Introduction*, Second Edi. Springer International Publishing, 2019.

[3] E. Ozcelik and C. Acarturk, "Reducing the spatial distance between printed and online information sources by means of mobile technology enhances learning: Using 2D barcodes," *Comput. Educ.*, vol. 57, no. 3, pp. 2077–2085, 2011. https://doi.org/10.1016/j.compedu.2011.05.019

[4] R. Christensen and G. Knezek, "Readiness for integrating mobile learning in the classroom: Challenges, preferences and possibilities," *Comput. Human Behav.*, vol. 76, pp. 112–121, 2017. https://doi.org/10.1016/j.chb.2017.07.014

[5] K. N. Chee, N. Yahaya, N. H. Ibrahim, and M. N. Hasan, "Review of mobile learning trends 2010-2015: A meta-analysis," *Educ. Technol. Soc.*, vol. 20, no. 2, pp. 113–126, 2017.

[6] X. Liu, N. A. Samah, and S. M. Salleh, "The Impact of Using a Mobile App on Improving Students' Creative Thinking in Business English Writing with Self-regulated Learning," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 15. pp. 46–61, 2022. https://doi.org/10.3991/ijim.v16i15.31477

[7] S. Papadakis and M. Kalogiannakis, "Mobile educational applications for children. What educators and parents need to know.," *Int. J. Mob. Learn. Organ.*, vol. 11, no. 2, p. 1, 2017. https://doi.org/10.1504/IJMLO.2017.10003925

[8] K. Zhampeissova, I. Kosareva, and U. Borisova, "Collaborative Mobile Learning with Smartphones in Higher Education," *Int. J. Interact. Mob. Technol.*, vol. 14, no. 21, 2020. https://doi.org/10.3991/ijim.v14i21.18461

[9] G. Volkovitckaia, Y. Tikhonova, and O. Kolosova, "Educational Experience in the Mobile Learning Environment: Consumer Behaviour Perspective," *Int. J. Interact. Mob. Technol.*, vol. 14, no. 21, pp. 92–106, 2020, doi: 10.3991/ijim.v14i21.18441.

[10] S. Papadakis, M. Kalogiannakis, and N. Zaranis, "The effectiveness of computer and tablet assisted intervention in early childhood students' understanding of numbers. An empirical study conducted in Greece," *Educ. Inf. Technol.*, vol. 23, no. 5, pp. 1849–1871, 2018. https://doi.org/10.3991/ijim.v14i21.18441

[11] D. Keegan, *Theoretical Principles of Distance Education*. London and New York: Routledge Taylor & Francis Group, 2005. https://doi.org/10.4324/9780203983065

[12] A. Herrington and J. Herrington, "Authentic mobile learning in higher education," *Int. Educ. Res. Conf.*, no. November, p. 10, 2007. https://doi.org/10.4018/978-1-59140-594-8.ch001

[13] J. Valk, A. T. Rashid, and L. Elder, "International Review of Research in Open and Distributed Learning Using Mobile Phones to Improve Educational Outcomes : An Analysis of Evidence from Asia Using Mobile Phones to Improve Educational," 2020.

[14] J. Traxler, "Will Student Devices Deliver Innovation, Inclusion, and Transformation?," *J. Res. Cent. Educ. Technol.*, vol. 6, no. 1, pp. 3–15, 2010.
[15] A. C. Jones, E. Scanlon, and G. Clough, "Mobile learning: Two case studies of supporting inquiry learning in informal and semiformal settings," *Comput. Educ.*, vol. 61, no. 1, pp. 21–32, 2013. https://doi.org/10.1016/j.compedu.2012.08.008
[16] J. A. Hyman, M. T. Moser, and L. N. Segala, "Electronic reading and digital library technologies: Understanding learner expectation and usage intent for mobile learning," *Educ. Technol. Res. Dev.*, vol. 62, no. 1, pp. 35–52, 2014. https://doi.org/10.1007/s11423-013-9330-5
[17] A. Garcia-Cabot, L. De-Marcos, and E. Garcia-Lopez, "An empirical study on m-learning adaptation: Learning performance and learning contexts," *Comput. Educ.*, vol. 82, pp. 450–459, 2015. https://doi.org/10.1016/j.compedu.2014.12.007
[18] G. Woodill, "The Mobile Learning Edge: Tools and Technologies for Developing Your Teams (Google eBook)," p. 288, 2010, [Online]. Available: http://books.google.com/books?id=65bKPeCNaTEC&pgis=1.
[19] M. Ally, M. Samaka, L. Ismail, and J. Impagliazzo, *Use of mobile learning apps in workplace learning*, vol. 15, no. 4. AU PRESS Issues in Distance Education series, 2013.
[20] T. h Brown, "Towards a model for m-learning in Africa.," *Int. Jl. E-Learning*, vol. 4, no. 3, pp. 299–315, 2005.
[21] K. Peters, "m-Learning: Positioning educators for a mobile, connected future | Peters | The International Review of Research in Open and Distance Learning," *Int. Rev. Res. Open Distance Learn.*, vol. 8, no. 2, 2007. https://doi.org/10.19173/irrodl.v8i2.350
[22] Y. Park, "A Pedagogical Framework for Mobile Learning : Categorizing Educational Applications of Mobile Technologies into Four Types," *Int. Rev. Res. Open Distrib. Learn.*, vol. Volume 12, no. Issue 2, pp. 78–102, 2011. https://doi.org/10.19173/irrodl.v12i2.791
[23] S. Schuck and D. Maher, "Creating opportunities for untethered learning," *Technol. Pedagog. Educ.*, vol. 27, no. 4, pp. 473–484, 2018. https://doi.org/10.1080/1475939X.2018.1510788
[24] N. M. Seel, *Encyclopedia of the Sciences of Learning*. Springer Reference, 2012. https://doi.org/10.1007/978-1-4419-1428-6
[25] H. Crompton, D. Burke, K. H. Gregory, and C. Gräbe, "The Use of Mobile Learning in Science: A Systematic Review," *J. Sci. Educ. Technol.*, vol. 25, no. 2, pp. 149–160, 2016. https://doi.org/10.1007/s10956-015-9597-x
[26] L. Avraamidou, "Prospects for the Use of Mobile Technologies in Science Education," vol. 16, pp. 347–365, 2008.
[27] S. Schöbel, M. Saqr, and A. Janson, "Two decades of game concepts in digital learning environments – A bibliometric study and research agenda," *Comput. Educ.*, vol. 173, no. July, 2021. https://doi.org/10.1016/j.compedu.2021.104296
[28] S. R. Sobral, "Mobile learning in higher education: A bibliometric review," *Int. J. Interact. Mob. Technol.*, vol. 14, no. 11, pp. 153–170, 2020. https://doi.org/10.3991/ijim.v14i11.13973
[29] I. Goksu, "Bibliometric mapping of mobile learning," *Telemat. Informatics*, vol. 56, no. March, p. 101491, 2021. https://doi.org/10.1016/j.tele.2020.101491
[30] M. M. Elaish, L. Shuib, N. A. Ghani, G. Mujtaba, and N. A. Ebrahim, "A bibliometric analysis of m-learning from topic inception to 2015," *Int. J. Mob. Learn. Organ.*, vol. 13, no. 1, pp. 91–112, 2019. https://doi.org/10.1504/IJMLO.2019.096470
[31] M. Churiyah, S. Sholikhan, and F. Filianti, "Mobile learning uses in vocational high school: A bibliometric analysis," *World J. Educ. Technol. Curr. Issues*, vol. 14, no. 2, pp. 484–497, 2022. https://doi.org/10.18844/wjet.v14i2.6990

[32] J. A. Moral-muñoz *et al.*, "Software tools for conducting bibliometric analysis in science: An up- to-date review," *El Prof. la Inf.*, vol. 29, no. 1, pp. 1–20, 2020. https://doi.org/10.3145/epi.2020.ene.03
[33] H. L. T. Thu, T. Tran, T. T. T. Phuong, T. L. T. Tuyet, H. Le Huy, and T. V. Thi, "Two decades of stem education research in middle school: A bibliometrics analysis in Scopus database (2000–2020)," *Educ. Sci.*, vol. 11, no. 7, 2021. https://doi.org/10.3390/educsci11070353
[34] V. K. Singh, P. Singh, M. Karmakar, J. Leta, and P. Mayr, "The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis," *Scientometrics*, vol. 126, no. 6, pp. 5113–5142, 2021. https://doi.org/10.1007/s11192-021-03948-5
[35] B. Pham-Duc, T. Tran, T. P. T. Trinh, T. T. Nguyen, N. T. Nguyen, and H. T. T. Le, "A spike in the scientific output on social sciences in Vietnam for recent three years: Evidence from bibliometric analysis in Scopus database (2000–2019)," *J. Inf. Sci.*, 2020. https://doi.org/10.1177/0165551520977447
[36] L. Yang, Z. Chen, T. Liu, Z. Gong, Y. Yu, and J. Wang, "Global trends of solid waste research from 1997 to 2011 by using bibliometric analysis," *Scientometrics*, vol. 96, no. 1, pp. 133–146, 2013. https://doi.org/10.1007/s11192-012-0911-6
[37] F. J. Agbo, S. S. Oyelere, J. Suhonen, and M. Tukiainen, "Scientific production and thematic breakthroughs in smart learning environments: a bibliometric analysis," *Smart Learn. Environ.*, vol. 8, no. 1, pp. 1–25, 2021. https://doi.org/10.1186/s40561-020-00145-4
[38] M. I. Adegoriola, J. H. K. Lai, E. H. Chan, and D. Amos, "Heritage building maintenance management (HBMM): A bibliometric-qualitative analysis of literature," *J. Build. Eng.*, vol. 42, no. March, p. 102416, 2021. https://doi.org/10.1016/j.jobe.2021.102416
[39] Y. Q. Du, G. D. Zhu, J. Cao, and J. Y. Huang, "Research supporting malaria control and elimination in China over four decades: a bibliometric analysis of academic articles published in Chinese from 1980 to 2019," *Malar. J.*, vol. 20, no. 1, pp. 1–12, 2021. https://doi.org/10.1186/s12936-021-03698-y
[40] A. Kulakli and V. Osmanaj, "Global research on big data in relation with artificial intelligence (A bibliometric study: 2008-2019)," *Int. J. online Biomed. Eng.*, vol. 16, no. 2, pp. 31–46, 2020. https://doi.org/10.3991/ijoe.v16i02.12617
[41] L. Niu *et al.*, "Hotpots and trends of covalent organic frameworks (COFs) in the environmental and energy field: Bibliometric analysis," *Sci. Total Environ.*, vol. 783, p. 146838, 2021. https://doi.org/10.1016/j.scitotenv.2021.146838
[42] D. M. Xia, X. R. Wang, P. Y. Zhou, T. Le Ou, L. Su, and S. G. Xu, "Research progress of heat stroke during 1989–2019: a bibliometric analysis," *Mil. Med. Res.*, vol. 8, no. 1, pp. 1–11, 2021. https://doi.org/10.1186/s40779-021-00300-z
[43] S. H. Zyoud, "The Arab region's contribution to global COVID-19 research: Bibliometric and visualization analysis," *Global. Health*, vol. 17, no. 1, pp. 1–10, 2021. https://doi.org/10.1186/s12992-021-00690-8
[44] J. Wang, M. K. Lim, C. Wang, and M. L. Tseng, "The evolution of the Internet of Things (IoT) over the past 20 years," *Comput. Ind. Eng.*, vol. 155, 2021. https://doi.org/10.1016/j.cie.2021.107174
[45] L. Yang, T. Sun, and Y. Liu, "A bibliometric investigation of flipped classroom research during 2000-2015," *Int. J. Emerg. Technol. Learn.*, vol. 12, no. 6, pp. 178–186, 2017. https://doi.org/10.3991/ijet.v12i06.7095
[46] M. Sidiq, I. Hanafi, and F. J. Ekaputra, "SEforRA: A bibliometrics-ready academic digital library search engine alternative," *KnE Soc. Sci.*, vol. 2020, pp. 206–218, 2020. https://doi.org/10.18502/kss.v4i14.7877

[47] R. Herdianto, N. Windyaningrum, B. Masruroh, and M. A. Setiawan, "Filsafat pendidikan dan perkembangannya: kajian bibliometrik berdasarkan database Scopus [Philosophy of education and its development: bibliometric studies based on Scopus database]," *Belantika Pendidik.*, vol. 4, no. 1, pp. 44–56, 2021. https://doi.org/10.47213/bp.v4i2.101
[48] N. J. Van Eck and L. Waltman, *Visualizing bibliometric networks*. 2014. https://doi.org/10.1007/978-3-319-10377-8_13
[49] N. J. van Eck and L. Waltman, "VOSviewer manual version 1.6.16," *Universiteit Leiden*, no. November, pp. 1–52, 2020. https://www.vosviewer.com/download/f-33t2.pdf
[50] H. Rak Beom and H. Suck Cho, "A Sensor-Based Navigation for a Mobile Robot Using Fuzzy Logic and Reinforcement Learning," *IEEE Trans. Syst. Man. Cybern.*, vol. 25, no. 3, pp. 464–477, 1995. https://doi.org/10.1109/21.364859
[51] Wikipedia, "Internet traffic," *Wikipedia*. 2020. https://en.wikipedia.org/wiki/Internet_traffic
[52] B. C. Björk, P. Welling, M. Laakso, P. Majlender, T. Hedlund, and G. Gudnason, "Open access to the scientific journal literature: Situation 2009," *PLoS One*, vol. 5, no. 6, pp. 1–10, 2010. https://doi.org/10.1371/journal.pone.0011273
[53] Y. T. Sung, K. E. Chang, and T. C. Liu, "The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis," *Comput. Educ.*, vol. 94, pp. 252–275, 2016. https://doi.org/10.1016/j.compedu.2015.11.008
[54] S. Thrun, "Learning metric-topological maps for indoor mobile robot navigation '," *Artif. Intell.*, vol. 99, no. 1, pp. 21–71, 1998. https://doi.org/10.1016/S0004-3702(97)00078-7
[55] Y. S. Wang, M. C. Wu, and H. Y. Wang, "Investigating the determinants and age and gender differences in the acceptance of mobile learning," *Br. J. Educ. Technol.*, vol. 40, no. 1, pp. 92–118, 2009. https://doi.org/10.1111/j.1467-8535.2007.00809.x
[56] C. M. Morel, S. J. Serruya, G. O. Penna, and R. Guimarães, "Co-authorship network analysis: a powerful tool for strategic planning of research, development and capacity building programs on neglected diseases," *PLoS Negl. Trop. Dis.*, vol. 3, no. 8, pp. 1–8, 2009. https://doi.org/10.1371/journal.pntd.0000501
[57] B. de P. F. E Fonseca, R. B. Sampaio, M. V. de A. Fonseca, and F. Zicker, "Co-authorship network analysis in health research: Method and potential use," *Heal. Res. Policy Syst.*, vol. 14, no. 1, pp. 1–10, 2016. https://doi.org/10.1186/s12961-016-0104-5
[58] Y. Royani, M. Bachtar, K. Tambunan, Tupan, and Sugiarto, "Pemetaan karya tulis ilmiah LPNK: Studi kasus LIPI Dan BPPT (2004-2008) [Mapping of LPNK scientific papers: Case studies of LIPI and BPPT (2004-2008)]," *J. Dokumentasi Dan Inf.*, vol. 34, no. 1, pp. 1–28, 2013.

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