JPPIPA 11(2) (2025)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Global Research on Emerging Mobile Learning for Senior High School Students: A Bibliometric Approach

Lili Safitri Diati[1], Fadhilah*[1], Muhammad Giatman[1], Dedy Irfan[1]

[1]Vocational technology education study program, Universitas Negeri Padang, Padang, Indonesia.

Received: December 28, 2024
Revised: January 27, 2025
Accepted: February 25, 2025
Published: February 28, 2025

Corresponding Author:
Fadhilah
fadhilah@ft.unp.ac.id

DOI: 10.29303/jppipa.v11i2.10517

Abstract: This study aims to explore the global trends and research contributions related to mobile learning for high school students through a bibliometric approach. The PRISMA method and bibliometric tools (R Studio and biblioshiny) were employed to analyze 70 documents from Scopus and Web of Science databases. Results indicate significant growth in publications, with an annual growth rate of 12.93% from 2008 to 2024, highlighting increasing interest in mobile learning. Indonesia, Taiwan, and China were the most productive countries, with journals such as Computers and Education (IF: 8.5; Q1) being the most influential source. Keyword co-occurrence analysis revealed key themes, including learning personalization, mobile learning effectiveness, and critical thinking skill development. The results show that mobile learning contributes significantly to improving students' motivation and learning outcomes without adding pressure, especially through the integration of mobile technology with e-learning approaches. This study provides strategic insights for educators, policymakers, and researchers to optimize mobile learning implementation in high school education, while identifying future research opportunities.

Keywords: Bibliometric; Biblioshiny; Mobile learning; Senior high school students

Introduction

Global education continues to evolve along with technological advances, one of which is the use of mobile learning as an innovative learning method (Alam, 2023; Alam & Mohanty, 2023; Qashou, 2021). Mobile learning has become an increasingly relevant topic in the last decade, especially with the increasing accessibility of mobile devices such as smart phones and tablets (Eliza et al., 2024; Goundar & Kumar, 2022; Hartley & Andújar, 2022) or high school students, mobile learning provides opportunities to support formal and informal learning with great flexibility. This paradigm shift affects not only how students learn, but also how teachers manage classrooms and curricula to address the needs of the digital generation.

High school students are a critical group in the context of education, as they are at the stage of preparation for higher education or the world of work (Akour & Alenezi, 2022; Alenezi, 2023). At this stage, engaging and relevant learning methods are important to improve learning motivation and academic outcomes. Mobile learning is considered as one of the approaches that can fulfill this need, as it provides access to learning resources anytime and anywhere (Camilleri & Camilleri, 2023; Yosiana et al., 2021). However, research on mobile learning specifically for high school students still needs more attention, especially in understanding how this approach can be effectively integrated in their education system.

In the global context, research on mobile learning shows great variation in its adoption, approach, and impact on students. Some developed countries have adopted mobile learning as an integral part of their education system (Wang et al., 2024; Zhang & Hu, 2024), while developing countries still face challenges such as limited technological infrastructure and uneven internet access (Bala, 2024). Bibliometric research allows us to understand these trends and patterns, provide an overview of how mobile learning is evolving in different

How to Cite:
Diati, L. S., Fadhilah, F., Giatman, M., & Irfan, D. (2025). Global Research on Emerging Mobile Learning for Senior High School Students: A Bibliometric Approach. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 19–29. https://doi.org/10.29303/jppipa.v11i2.10517

parts of the world, and help identify research gaps that still exist.

Bibliometric analysis is an effective method to systematically explore the research literature (Fadillah et al., 2024; Muskhir et al., 2024; Passas, 2024). In the context of mobile learning, this analysis can reveal global trends, collaboration networks between researchers, and topics that are the main focus of research. By utilizing academic databases such as Scopus and WoS (Web of Science), this analysis provides deep insights into publication patterns and potential future research directions. This approach is highly relevant in understanding how mobile learning is applied in various educational contexts, especially at the high school level.

Mobile learning offers various benefits, including personalized learning, access to digital resources, and the development of students' digital skills (Dahri et al., 2024; Usmonova, 2024). However, its integration in senior secondary school education also faces challenges, such as technology gaps, students' and teachers' digital literacy levels, and school budget constraints (Kembuan & Batmetan, 2024; Mustafa et al., 2024; Ofosu-Asare, 2024). Therefore, systematic and data-driven research is needed to evaluate how mobile learning can be optimized to support student learning at this level.

In the past two decades, the number of publications on mobile learning has increased significantly, indicating a great academic interest in this topic (Owidi et al., 2024). However, research specifically addressing mobile learning applications for high school students is still relatively limited. Using bibliometric analysis, we can identify how the focus of this research has changed over time and reveal potential new areas of study that could be further explored.

It is important to understand how key themes in mobile learning research have evolved. For example, themes such as learning app design, the influence of mobile learning on academic outcomes, and integration with traditional curriculum have been the main focus of several studies. However, not much research has addressed its specific implications for high school students, such as how this technology can help them prepare for future educational and employment challenges.

Bibliometric research also helps in identifying collaborations between institutions and researchers in mobile learning research. In a global context, these collaborations are crucial for sharing best practices and addressing common challenges, such as the development of educational technology infrastructure. This study can provide insights into how collaboration networks can help accelerate the adoption of mobile learning in high school education.

The novelty of this research lies in its focus on high school students, a demographic often overlooked in mobile learning studies, and its attempt to systematically map global research trends through bibliometric analysis. By identifying research gaps and emerging patterns, this study provides valuable insights for educators, policymakers, and researchers on how to effectively integrate mobile learning into secondary education.

In addition, by understanding global trends in mobile learning research, we can evaluate research gaps in specific regions. For example, developing countries may have different research priorities compared to developed countries, given differences in access to technology and educational resources. This analysis can help policy makers and academics in designing more effective strategies to adopt mobile learning locally and globally.

Therefore, the main objective of this study is to identify and visualize various aspects of research, including the evolution of publication development, most cited papers, top countries, authors, and sources related to the exploitation of mobile learning in education. In addition, this study also tries to explore the trends and issues that are developing in this research through co-occurrence analysis. The following list summarizes the Research Questions (RQ) that identify the main objectives of this study:

RQ1. What are the main information results and publication evolution generated by the overview analysis in bibliometric analysis?
RQ2. Who are the authors, affiliations, countries of origin, and research sources that have produced the most publications related to this topic?
RQ3. Which research documents are most frequently cited by other researchers?
RQ4. How to visualize the co-occurrence analysis of authors' keywords on this topic?

Method

This study utilized the PRISMA method and bibliometric analysis, to ensure a methodologically sound approach. PRISMA, known for its meticulous guidelines, guides systematic literature reviews and meta-analyses (Agrawal et al., 2024). R Studio, biblioshiny and MS Excel software tools facilitate intuitive data analysis and visualization. Following the steps outlined by PRISMA, including literature search, study selection, data extraction and synthesis. The study aimed to minimize bias and increase the reliability of its findings. This approach upholds the highest standards, providing accurate insights into the analysis of literature and trends related to the use of social media in

education. Figure 1 illustrates the flowchart and procedural steps of the review process.

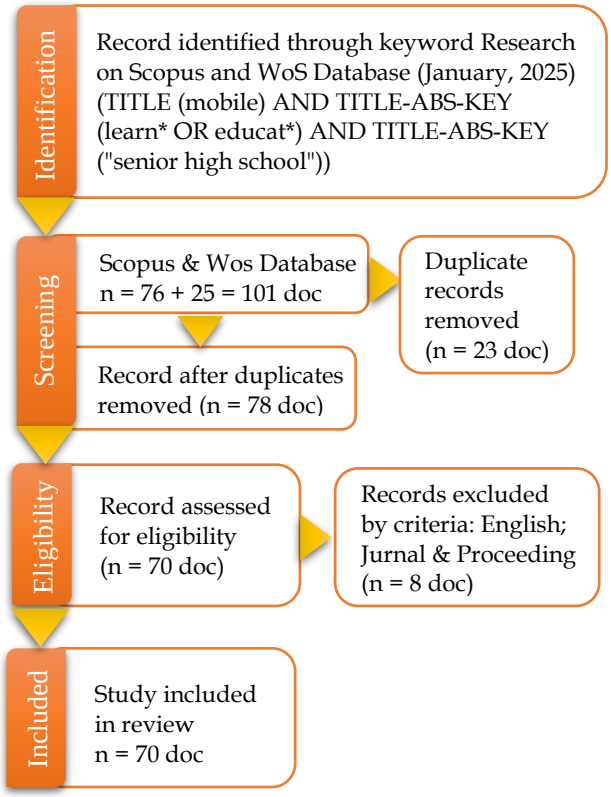

Figure 1. PRISMA flow diagram

Figure 1 is a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart that explains the literature selection process in the related study "Global Research on Emerging Mobile Learning for Senior High School Students: A Bibliometric Approach". This diagram shows four main stages: identification, screening, eligibility and inclusion. In the identification stage, 101 documents were found through searching the Scopus and WoS databases using the query (TITLE (mobile) AND TITLE-ABS-KEY (learn* OR educat*) AND TITLE-ABS-KEY ("senior high school")). After the filtering process, 23 documents were identified as duplicates and removed, leaving 78 unique documents for further processing.

The next stage, the eligibility evaluation, assessed 78 documents based on criteria such as the use of English and the type of publication (journal or proceedings). Eight documents were eliminated at this stage as they did not meet the criteria. Finally, 70 relevant documents were included in the review. This diagram reflects a systematic approach to bibliometric research to analyze global developments in mobile learning among high school students, focusing on the quality and relevance of appropriate literature to support a better understanding of the field.

The final dataset was created for visualization, interpretation, analysis, and synthesis. Trends, challenges, opportunities, implications, and recommendations for integrating mobile learning into learning in senior high schools. This approach ensures that the research results are based on precise, relevant, and reliable data.

Result and Discussion

Overview

An overview of global research on emerging mobile-based learning for high school students was analyzed through bibliometric methods. RQ1 addresses what are the main information results and evolution of publications produced by the overview analysis in the bibliometric analysis. The analysis started with an overview that included three main aspects: main information and evolution of publication. The results of the main information provide an overview of key elements, such as the number of publications, leading authors, and the most influential journals in research related to mobile-based learning for high school students. The evolution of publications shows the trend of publication growth over time, reflecting the increasing attention to this topic, especially with the rapid adoption of mobile technology in education.

This overview of key elements provides insights that can be used to understand the evolution of mobile learning-related research conducted and published by researchers around the world. This information helps identify key trends, research contributions, and collaborations among authors on this topic. Table 1 presents a summary of key information obtained from Scopus and WoS metadata.

Table 1. The main information on bibliometric analysis

Description	Results
Timespan	2008-2024
Sources (Journals, Books, etc.)	48
Documents	70
Annual Growth Rate (%)	12.93
References	34
Authors	177
Author of single-authored docs	7
Co-Authors collaboration per Doc	3.06

Based on Table 1: The Main Information on Bibliometric Analysis, research related to Global Research on Emerging Mobile Learning for Senior High School Students showed significant growth during the period 2008-2024. A total of 70 documents from 48 sources (including journals, books and others) have been published, with an annual growth rate of 12.93%. This reflects the increasing interest and attention to the topic

of mobile learning in the context of senior high school students. A total of 177 authors were involved in this research, with only 7 documents written by a single author, indicating a high level of collaboration in this field. The average collaboration between authors reached 3.06 per document, indicating the importance of cross-disciplinary and institutional cooperation in the development of global mobile learning research. This data provides an in-depth picture of the collective contribution in driving the development and application of mobile learning to support a more inclusive and technology-driven 21st century education.

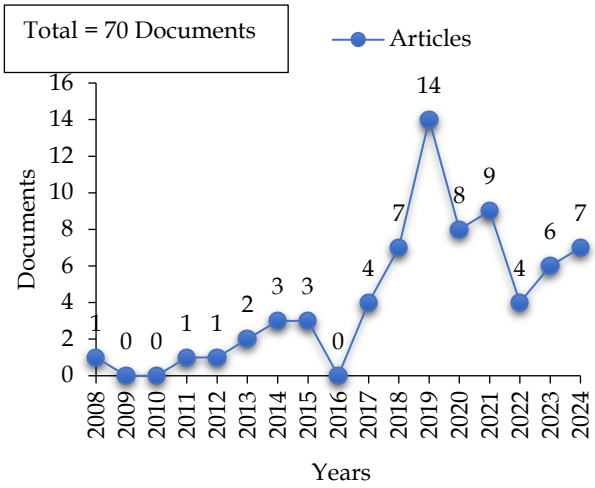

Figure 2. Evolution of publication (2008-2024)

Based on Figure 2: Evolution of Publication (2008-2024), research related to Global Research on Emerging Mobile Learning for Senior High School Students shows a significant increasing trend in the number of publications from year to year. In the early period of 2008-2016, publications tended to be minimal with an average of only 1-3 documents per year. The first research document was published in 2008 with the title "Using mobile communication technology in high school education: Motivation, pressure, and learning performance". The study found that mobile communication technology, especially instant messaging, effectively strengthens interaction between students and instructors, increasing learning motivation without increasing pressure when combined with internet communication tools. However, communication tools that require public expression should be used with caution as they can increase pressure for students.

In 2017 there was a significant spike, which peaked in 2019 with 14 publications. After that, the number of publications remained consistent at around 6-9 documents per year until 2024. This trend reflects the increasing attention to mobile-based learning, especially in supporting high school students in the era of digital transformation. The surge in 2019 is likely driven by advances in mobile technology and the growing need for innovative and flexible education solutions. This data shows that mobile learning has become an increasingly important global research focus to address 21st century education challenges.

Top-Productive Authors, Affiliations, Countries, and Sources

To answer RQ2 about who are the most prolific authors, affiliations, countries, and sources of research publications related to the use of mobile learning in senior high schools. Table 2 lists the top five which provides important insights into the contributions of the most prolific authors, affiliations, countries, and sources in this field. The findings demonstrate the central role of key actors in shaping the direction and development of global research on mobile learning for high school students. The analysis also reveals the close relationship between individual contributions, institutional collaborations, and key publication sources that serve as platforms for knowledge dissemination on this topic. As such, it provides a solid basis for understanding the global dynamics and cross-national collaborations that support the development of mobile learning, especially in the context of an increasingly technology-dependent 21st century education. The table lists the top 5 most prolific authors, affiliations, countries, and publication sources related to Global Research on Emerging Mobile Learning for Senior High School Students, which can serve as a reference for further research and collaboration on this topic.

Based on Table 2: Top-productive authors, affiliations, countries, and sources, the study on Global Research on Emerging Mobile Learning for Senior High School Students shows significant contributions from leading authors, affiliations, and countries. The most productive author is Chang, C., who produced 5 documents and is affiliated with National Taiwan Normal University (Taiwan), which is also the most productive affiliate with 10 contributions. This reflects the strong role of Taiwanese institutions in leading research development related to mobile-based learning for high school students. Other authors such as Amelia, T., Cavhana, U., and Hariadi, B., with affiliations from Indonesia, also showed prominent contributions, underlining the active involvement of Indonesian researchers in this topic.

The countries that contributed the most to this study were Indonesia (38 documents), followed by China (19 documents) and the Philippines (11 documents). Indonesia's dominance in the number of publications indicates the high interest of local researchers in this topic, especially due to its relevance to the country's rapidly growing educational context. In terms of publication sources, Journal of Physics: Conference

Series is the most productive source with 8 documents, despite having a low Impact Factor (0.56) and being in the Q4 quartile. On the other hand, the journal Computers and Education, with a high Impact Factor (8.5) and in the Q1 quartile, shows higher academic quality, despite having fewer publications from this source (4 documents).

Table 2. Top-productive authors, affiliations, countries, and sources

Rank	Authors	N	Affiliations	N	Countries	N	Sources (IF; Q)	N
1	Chang, C	5	National Taiwan Normal University (Taiwan)	10	Indonesia	38	Journal of Physics: Conference Series (0.56; Q4)	8
2	Amelia, T	3	Universitas Negeri Yogyakarta (Indonesia)	7	China	19	ACM International Conference Proceeding Series (0.25; Non-Q)	4
3	Cahyana, U	3	Universitas Negeri Jakarta (Indonesia)	4	Philippines	11	Computers and Education (8.5; Q1)	4
4	Hariadi, B	3	Bina Nusantara University (Indonesia)	3	Austria	2	AIP Conference Proceedings (0.41; Non -Q)	3
5	Jin, W	3	National Taiwan University of Science and Technology (Taiwan)	3	Australia	1	International Journal of Instruction (2.1; Q2)	3

These data provide important insights into the global collaboration dynamics and distribution of research in the field of mobile learning for high school students. The presence of authors from different countries and the use of high-quality sources such as Computers and Education and the International Journal of Instruction (2.1; Q2) demonstrate the potential for cross-national collaboration that can accelerate the development of innovative learning methods. By looking at the authors' key roles and productive affiliations, this study highlights the importance of a global approach in meeting the challenges of 21st century education through mobile learning technology.

Top 10 Most Cited Article

To answer RQ3, the documents with the highest number of citations worldwide can be seen and identified in Table 3. The table lists 10 articles out of 70 total articles related to the use of mobile learning in high schools, detailing the article title, DOI (Digital Object Identifiers)/Link, number of citations received, and a column labeled TC (Total Cited) per year or average total citations per year.

Table 3. Top ten most cited article

Title	DOI/Link	Cited	TC
A personalized recommendation-based mobile learning approach to improving the reading performance of EFL students (Hsu et al., 2013)	10.1016/j.compedu.2012.12.004	234	18.00
Using mobile communication technology in high school education: Motivation, pressure, and learning performance (Rau et al., 2008)	10.1016/j.compedu.2006.03.008	213	11.83
Learning English reading in a mobile-assisted extensive reading program (Lin, 2014)	10.1016/j.compedu.2014.05.004	97	8.08
Taiwanese high school teachers' conceptions of mobile learning (Hsieh & Tsai, 2017)	10.1016/j.compedu.2017.07.013	67	7.44
The influence of perceived convenience and curiosity on continuance intention in mobile English learning for high school students using PDAs (Chang et al., 2013)	10.1080/1475939X.2013.802991	44	3.38
Trends and research issues of mobile learning studies in physical education: a review of academic journal publications (Yang et al., 2020)	10.1080/10494820.2018.1533478	39	6.50
Improving the Competence of Diagrammatic and Argumentative Representation in Physics through Android-based Mobile Learning Application (Liliarti & Kuswanto, 2018)	10.12973/iji.2018.1138a	39	4.88
Android-assisted physics mobile learning to improve senior high school students' divergent thinking skills and physics HOTS (Mardiana & Kuswanto, 2017)	10.1063/1.4995181	18	2.00
Higher Order Thinking Skills Based Learning Outcomes Improvement with Blended Web Mobile Learning Model (Hariadi et al., 2022)	10.29333/iji.2022.15231a	18	4.50
Are Mobile Devices More Useful than Conventional Means as Tools for Learning Vocabulary? (Lee, 2014)	10.1109/MCSoC.2014.24	16	1.33

Table 3 shows the ten highest-cited articles related to the topic of mobile learning for high school students. The most cited article is "A personalized recommendation-based mobile learning approach to improving the reading performance of EFL students," with 234 citations. This article shows great relevance in the development of mobile-based learning tailored to students' needs, especially in improving reading

performance (Hsu et al., 2013). This is relevant to Song et al. (2021) who pointed out that mobile learning provides significant opportunities in personalized learning.

The second most cited article, "Using mobile communication technology in high school education: Motivation, pressure, and learning performance," with 213 citations, discusses how mobile-based communication technology affects students' motivation, pressure, and learning outcomes in high school (Rau et al., 2008). This shows that mobile learning is not only about technology access but also its impact on students' psychological and academic aspects (Hsu & Lin, 2022; Togaibayeva et al., 2022).

Some articles, such as "Learning English reading in a mobile-assisted extensive reading program" (97 citations) and "The influence of perceived convenience and curiosity on continuance intention in mobile English learning for high school students using PDAs" (44 citations), show that mobile learning has a significant impact on English learning, especially in reading and learning motivation (Chang et al., 2013; Lin, 2014). This highlights the importance of mobile learning in supporting students learning foreign languages, a critical need for high school students in a globalized world (Chen, 2022; Rajendran & Yunus, 2021).

Articles such as "Taiwanese high school teachers' conceptions of mobile learning" (67 citations) highlight teachers' views on mobile learning in high schools, which is an important component in successful technology adoption (Hsieh & Tsai, 2017). In addition, "Trends and research issues of mobile learning studies in physical education" (39 citations) shows that mobile learning applications are also applied in physical education, highlighting that this technology is not limited to academic subjects but is also relevant for practical learning (Yang et al., 2020).

Some of the articles on the list focus on developing critical and higher order thinking skills (HOTS), such as "Improving the Competence of Diagrammatic and Argumentative Representation in Physics through Android-based Mobile Learning Application" (39 citations) and "Higher Order Thinking Skills Based Learning Outcomes Improvement with Blended Web Mobile Learning Model" (18 citations). These articles show how mobile learning can be used to support deep conceptual understanding, especially in subjects such as physics (Hariadi et al., 2022; Liliarti & Kuswanto, 2018).

The table also shows that mobile learning research at the high school level covers a wide range of themes, from language learning to science. However, while there are some standout studies, the relatively lower citations of other articles indicate the need for further exploration in this area. For example, articles such as "Android-assisted physics mobile learning to improve senior high school students' divergent thinking skills and physics HOTS" (18 citations) still show room for more in-depth research (Mardiana & Kuswanto, 2017).

From a bibliometric perspective, this table shows the importance of understanding frequently referenced articles as a basis for identifying research trends and gaps. By mapping the most cited articles, we can see the main focus in mobile learning for senior high school students as well as opportunities to expand research in this area. This analysis is particularly relevant in the topic of "Global Research on Emerging Mobile Learning for Senior High School Students: A Bibliometric Approach," as it provides insight into how global research has evolved and in which direction it could be directed in the future.

Co-Occurrence Analysis

To answer RQ4 in the context of mobile learning for high school students, a keyword co-occurrence analysis was conducted using keywords provided by authors in related research. This analysis is a bibliometric method used to identify trends and patterns in global research related to mobile learning among senior high school students. With this method, trends can be revealed through recurring themes in the literature, while providing insight into the future direction of mobile learning research. By observing and analyzing publication patterns in the context of high school education, this method reveals the evolving academic interests, research methodologies, and topic focus in this field. This technique is an important tool for researchers to understand how mobile learning adapts to the needs of students at this level of education.

The co-occurrence analysis method in this study is a bibliometric technique that aims to identify trends and patterns in the global literature on mobile learning for high school students. This technique is based on the assumption that keywords that frequently co-occur in publications have strong and significant thematic linkages. In this context, the method was used to identify emerging topics, track the evolution of mobile learning for high school students research themes over time, and project the future direction of this research. The results of this analysis not only reveal global trends but also provide an important reference for researchers who want to identify research gaps in mobile learning for senior secondary education, so as to prioritize relevant studies and support the development of mobile-based educational technology.

Figure 3 presents a co-occurrence analysis that provides a visual representation of the relationship between keywords that frequently appear in research related to mobile learning for high school students. This analysis highlights the main keywords that are the center of attention in the literature, such as "students,"

"mobile learning," and "e-learning." The relationships between keywords indicate the level of relevance, frequency, and contribution of these topics to the academic discourse.

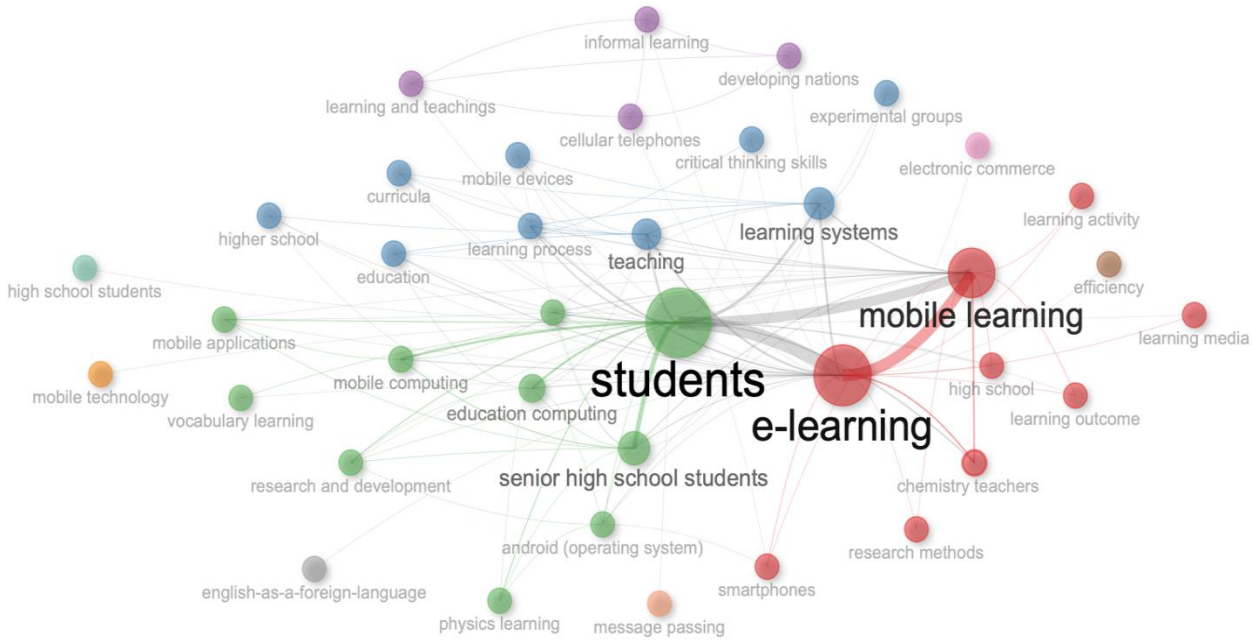

Figure 3. Co-occurrence analysis

The largest main node in the map is "students," which signifies the importance of students as the main focus of this research. This keyword is directly related to concepts such as "education," "learning systems," and "senior high school students." This suggests that the majority of research centers on students' experiences, the learning methods they use, and the learning outcomes that can be achieved through mobile learning approaches (Chen & Tsai, 2021; Criollo-C et al., 2021). This strong connection illustrates that the development of learning technologies is geared towards the needs and success of students as the primary users.

"Mobile learning" becomes a very important keyword, indicating that mobile device-based learning approaches play a major role in the transformation of modern education. This node has connections with "learning activity," "learning media," and "efficiency," indicating a research focus on how mobile technology supports high school students' learning activities, both efficiently and engagingly (Wang et al., 2023). In this context, mobile learning is positioned as an innovative solution that addresses the needs of education in the digital era.

In addition, the strong relationship between mobile learning and "education" suggests that research in this area focuses heavily on the practical application of mobile technologies in educational contexts. This includes the use of mobile technologies to support various aspects of education, from teaching to self-directed learning by students (Jeong, 2022; Lai et al., 2022; Zhang et al., 2024). Keywords such as "teaching" and "learning systems" also indicate the importance of exploring how learning systems can be optimized through mobile technology, as well as how teaching methods can be adapted to harness the full potential of mobile learning (Papadakis et al., 2021).

"Senior high school students" has a strong connection with 'mobile learning' and 'e-learning,' indicating that mobile technology devices and digital learning platforms are important components in supporting the education of senior high school students. These keywords reflect how mobile learning is designed to improve the accessibility and efficiency of learning, especially for students who are at a critical stage of education (Hameed et al., 2024; Zafrullah & Ramadhani, 2024). This is relevant to the research of Geverola et al. (2022) considering that high school students need flexible and modern learning solutions to prepare them for the challenges of higher education.

The nodes "research and development" and "critical thinking skills" indicate research directions that emphasize the development of students' skills through mobile learning. This shows that in addition to improving accessibility, mobile technology is also used to build students' critical and creative thinking skills (Curum & Khedo, 2021; Marini et al., 2022). This trend is highly relevant to the needs of modern education that demands students to be more adaptive to technological developments.

The connection of "senior high school students" with "education" and "learning outcome" shows that this research also focuses on the effect of technology-based learning on student learning outcomes (Ahmad et al., 2024; Kang, 2024; Wang et al., 2023). By using the mobile learning approach, students are expected to not only understand the material but also achieve optimal learning outcomes. This is relevant to the needs of high school students to prepare for final exams or college entrance requirements (AlAzzam et al., 2021; Yan et al., 2021).

Overall, "senior high school students" play an important role in mobile learning research, focusing on their specific needs in the technology-based learning process. Its association with keywords such as "mobile learning," "critical thinking skills," and "learning systems" shows that this research aims to create relevant, effective, and innovative educational systems. Through this analysis, we can understand how mobile learning is evolving as an important area of research and how these trends may influence the direction of future research.

Conclusion

The results of this bibliometric analysis indicate that research on mobile learning for secondary school students has experienced a significant increase since 2008, with a surge in publications in 2019 and an annual growth rate of 12.93%. Indonesia has emerged as the most productive country in this research domain, followed by China and the Philippines, with institutions such as National Taiwan Normal University and Universitas Negeri Yogyakarta serving as key contributors. The dominant research themes include the use of mobile learning applications, the impact of mobile learning on academic performance, and the integration of technology into secondary education systems. Keyword co-occurrence analysis reveals that studies primarily focus on the effectiveness of mobile learning, its role in enhancing learning outcomes, and its influence on students' critical thinking skills. However, challenges such as technological disparities, teacher and student preparedness, and budget constraints remain significant barriers to optimal implementation. The limitations of this study include the restricted scope of data, as it relies on publications from specific databases, which may not fully capture the global research landscape. These findings hold important implications for policymakers and education practitioners in developing data-driven strategies to optimize mobile learning implementation in secondary schools, particularly in developing countries with limited digital infrastructure.

Acknowledgements
All author would like to thank to all parties who has supported this research.

Author Contributions
Conceptualization, formal analysis, resources, data curation, L.S.D. and F.; methodology, L.S.D., F., M.G., and D.I.; investigation, writing—original draft preparation, writing—review and editing, visualization, L.S.D. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Agrawal, S., Oza, P., Kakkar, R., Tanwar, S., Jetani, V., Undhad, J., & Singh, A. (2024). Analysis and Recommendation System-Based on PRISMA Checklist to Write Systematic Review. *Assessing Writing*, *61*, 100866. https://doi.org/10.1016/j.asw.2024.100866

Ahmad, I. F., Setiawati, F. A., Prihatin, R. P., & Fitriyah, Q. F. (2024). Technology-Based Learning Effect on the Learning Outcomes of Indonesian Students: A Meta-Analysis. *International Journal of Evaluation and Research in Education (IJERE)*, *13*(2), 892-902. http://doi.org/10.11591/ijere.v13i2.25383

Akour, M., & Alenezi, M. (2022). Higher Education Future in the Era of Digital Transformation. *Education Sciences*, *12*(11), 784. https://doi.org/10.3390/educsci12110784

Alam, A. (2023). Media Multitasking with M-Learning Technology in Real-Time Classroom Learning: Analysing the Dynamics in Formal Educational Settings for the Future of E-Learning in India. *2023 2nd International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN)*. Villupuram, India, pp. 1-6. https://doi.org/10.1109/ICSTSN57873.2023.10151509

Alam, A., & Mohanty, A. (2023). Learning on the Move: A Pedagogical Framework for State-of-the-Art Mobile Learning. *International Conference on Data Management, Analytics & Innovation*, 735–748. https://doi.org/10.1007/978-981-99-1414-2_52

AlAzzam, M., Abuhammad, S., Abdalrahim, A., & Hamdan-Mansour, A. M. (2021). Predictors of Depression and Anxiety Among Senior High School Students During COVID-19 Pandemic: The Context of Home Quarantine and Online Education. *The Journal of School Nursing*, *37*(4), 241–248. https://doi.org/10.1177/1059840520988548

Alenezi, M. (2023). Digital Learning and Digital Institution in Higher Education. *Education Sciences*, *13*(1), 88. https://doi.org/10.3390/educsci13010088

Bala, P. (2024). The Impact of Mobile Broadband and Internet Bandwidth on Human Development—A Comparative Analysis of Developing and Developed Countries. *Journal of the Knowledge Economy*, *15*(4), 16419-16453. https://doi.org/10.1007/s13132-023-01711-0

Camilleri, M. A., & Camilleri, A. C. (2023). Learning from Anywhere, Anytime: Utilitarian Motivations and Facilitating Conditions for Mobile Learning. *Technology, Knowledge and Learning*, *28*(4), 1687–1705. https://doi.org/10.1007/s10758-022-09608-8

Chang, C.-C., Tseng, K.-H., Liang, C., & Yan, C.-F. (2013). The Influence of Perceived Convenience and Curiosity on Continuance Intention in Mobile English Learning for High School Students Using PDAs. *Technology, Pedagogy and Education*, *22*(3), 373–386. https://doi.org/10.1080/1475939X.2013.802991

Chen, C.-H., & Tsai, C.-C. (2021). In-Service Teachers' Conceptions of Mobile Technology-Integrated Instruction: Tendency Towards Student-Centered Learning. *Computers & Education*, *170*, 104224. https://doi.org/10.1016/j.compedu.2021.104224

Chen, Y.-M. (2022). Understanding Foreign Language Learners' Perceptions of Teachers' Practice with Educational Technology with Specific Reference to Kahoot! and Padlet: A Case from China. *Education and Information Technologies*, *27*(2), 1439–1465. https://doi.org/10.1007/s10639-021-10649-2

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile Learning Technologies for Education: Benefits and Pending Issues. *Applied Sciences*, *11*(9), 4111. https://doi.org/10.3390/app11094111

Curum, B., & Khedo, K. K. (2021). Cognitive Load Management in Mobile Learning Systems: Principles and Theories. *Journal of Computers in Education*, *8*(1), 109–136.

Dahri, N. A., Yahaya, N., Al-Rahmi, W. M., Almogren, A. S., & Vighio, M. S. (2024). Investigating Factors Affecting Teachers' Training Through Mobile Learning: Task Technology Fit Perspective. *Education and Information Technologies*, *29*, 14553-14589. https://doi.org/10.1007/s10639-023-12434-9

Eliza, F., Fadli, R., Ramadhan, M. A., Sutrisno, V. L. P., Hidayah, Y., Hakiki, M., & Dermawan, D. D. (2024). Assessing Student Readiness for Mobile Learning from a Cybersecurity Perspective. *Online Journal of Communication and Media Technologies*, *14*(4), e202452. https://doi.org/10.30935/ojcmt/15017

Fadillah, R., Ganefri, G., Yulastri, A., Luthfi, A., Hidayat, H., Samala, A. D., & Rawas, S. (2024). Digital Entrepreneurship Research for Learning and Teaching in Education: A Bibliometric Analysis. *TEM Journal*, *13*(3), 1997–2011. https://doi.org/10.18421/TEM133-28

Geverola, I. J. R., Mutya, R. C., Siason, L. M. B., & Bonotan, A. (2022). Challenges and Struggles of Public Senior High School Science Teachers During the New Normal. *Journal of Research, Policy & Practice of Teachers and Teacher Education*, *12*(1), 49–68. https://doi.org/10.37134/jrpptte.vol12.1.4.2022

Goundar, M. S., & Kumar, B. A. (2022). The Use of Mobile Learning Applications in Higher Education Institutes. *Education and Information Technologies*, *27*(1), 1213–1236. https://doi.org/10.1007/s10639-021-10611-2

Hameed, F., Qayyum, A., & Khan, F. A. (2024). A New Trend of Learning and Teaching: Behavioral Intention Towards Mobile Learning. *Journal of Computers in Education*, *11*, 149–180. https://doi.org/10.1007/s40692-022-00252-w

Hariadi, B., Jatmiko, B., Sunarto, M. J., Prahani, B. K., Sagirani, T., Amelia, T., & Lemantara, J. (2022). Higher Order Thinking Skills Based Learning Outcomes Improvement with Blended Web Mobile Learning Model. *International Journal of Instruction*, *15*(2), 565–578. https://doi.org/10.29333/iji.2022.15231a

Hartley, K., & Andújar, A. (2022). Smartphones and Learning: An Extension of M-Learning or a Distinct Area of Inquiry. *Education Sciences*, *12*(1), 50. https://doi.org/10.3390/educsci12010050

Hsieh, W.-M., & Tsai, C.-C. (2017). Taiwanese High School Teachers' Conceptions of Mobile Learning. *Computers & Education*, *115*, 82–95. https://doi.org/10.1016/j.compedu.2017.07.013

Hsu, C.-K., Hwang, G.-J., & Chang, C.-K. (2013). A Personalized Recommendation-Based Mobile Learning Approach to Improving the Reading Performance of EFL Students. *Computers & Education*, *63*, 327–336. https://doi.org/10.1016/j.compedu.2012.12.004

Hsu, H., & Lin, C. (2022). Extending the Technology Acceptance Model of College Learners' Mobile-Assisted Language Learning by Incorporating Psychological Constructs. *British Journal of Educational Technology*, *53*(2), 286–306. https://doi.org/10.1111/bjet.13165

Jeong, K.-O. (2022). Facilitating Sustainable Self-Directed Learning Experience with the Use of Mobile-Assisted Language Learning. *Sustainability*, *14*(5), 2894. https://doi.org/10.3390/su14052894

Kang, J. (2024). Benefits and Challenges of Mobile-Learning Brought to Student Learning Outcomes in

Higher Education: A Systematic Review from 2014-2023. *International Journal of Academic Research in Progressive Education and Development*, *13*(1), 2107-2123. http://dx.doi.org/10.6007/IJARPED/v13-i1/20698

Kembuan, D. R. E., & Batmetan, J. R. (2024). The Challenge in Implementation M-Learning on Post-Pandemic COVID-19 in North Sulawesi. *5th Vocational Education International Conference (VEIC-5 2023)*, 1258–1269. Atlantis Press. https://doi.org/10.2991/978-2-38476-198-2_179

Lai, Y., Saab, N., & Admiraal, W. (2022). Learning Strategies in Self-Directed Language Learning Using Mobile Technology in Higher Education: A Systematic Scoping Review. *Education and Information Technologies*, *27*, 7749–7780. https://doi.org/10.1007/s10639-022-10945-5

Lee, P. (2014). Are Mobile Devices More Useful Than Conventional Means as Tools for Learning Vocabulary? *2014 IEEE 8th International Symposium on Embedded Multicore/Manycore SoCs*, 109–115. https://doi.org/10.1109/MCSoC.2014.24.

Liliarti, N., & Kuswanto, H. (2018). Improving the Competence of Diagrammatic and Argumentative Representation in Physics Through Android-Based Mobile Learning Application. *International Journal of Instruction*, *11*(3), 107–122. https://doi.org/10.12973/iji.2018.1138a

Lin, C-c. (2014). Learning English Reading in a Mobile-Assisted Extensive Reading Program. *Computers & Education*, *78*, 48–59. https://doi.org/10.1016/j.compedu.2014.05.004

Mardiana, N., & Kuswanto, H. (2017). Android-Assisted Physics Mobile Learning to Improve Senior High School Students' Divergent Thinking Skills and Physics HOTS. *AIP Conference Proceedings*, *1868*(1), 070005. https://doi.org/10.1063/1.4995181

Marini, A., Nafisah, S., Sekaringtyas, T., Safitri, D., Lestari, I., Suntari, Y., … & Iskandar, R. (2022). Mobile Augmented Reality Learning Media with Metaverse to Improve Student Learning Outcomes in Science Class. *International Journal of Interactive Mobile Technologies*, *16*(7), 99–115. https://doi.org/10.3991/ijim.v16i07.25727

Muskhir, M., Luthfi, A., Watrianthos, R., Usmeldi, U., Fortuna, A., & Samala, A. D. (2024). Emerging Research on Virtual Reality Applications in Vocational Education: A Bibliometric Analysis. *Journal of Information Technology Education: Innovations in Practice*, *23*, 005. https://doi.org/10.28945/5284

Mustafa, F., Nguyen, H. T. M., & Gao, X. A. (2024). The Challenges and Solutions of Technology Integration in Rural Schools: A Systematic Literature Review. *International Journal of Educational Research*, *126*, 102380. https://doi.org/10.1016/j.ijer.2024.102380

Ofosu-Asare, Y. (2024). Developing Classroom ICT Teaching Techniques, Principles and Practice for Teachers in Rural Ghana Without Access to Computers or Internet: A Framework Based on Literature Review. *The International Journal of Information and Learning Technology*, *41*(3). https://doi.org/10.1108/IJILT-04-2023-0045

Owidi, S. O., Omieno, K. K., & Lyanda, J. N. (2024). Exploring the Potential of Immersive Technologies to Enhance Online Learning Experiences and Engagement: A Systematic Literature Review. *International Journal of Innovative Science and Research Technology*, *9*(9), 1862-1871. https://doi.org/10.38124/ijisrt/IJISRT24SEP1144

Papadakis, S., Kalogiannakis, M., & Zaranis, N. (2021). Teaching Mathematics with Mobile Devices and the Realistic Mathematical Education (RME) Approach in Kindergarten. *Advances in Mobile Learning Educational Research*, *1*(1), 5–18. https://doi.org/10.25082/AMLER.2021.01.002

Passas, I. (2024). Bibliometric Analysis: The Main Steps. *Encyclopedia*, *4*(2), 1014-1025. https://doi.org/10.3390/encyclopedia4020065

Qashou, A. (2021). Influencing Factors in M-Learning Adoption in Higher Education. *Education and Information Technologies*, *26*(2), 1755–1785. https://doi.org/10.1007/s10639-020-10323-z

Rajendran, T., & Yunus, M. M. (2021). A Systematic Literature Review on the Use of Mobile-Assisted Language Learning (MALL) for Enhancing Speaking Skills Among ESL and EFL Learners. *International Journal of Academic Research in Progressive Education and Development*, *10*(1), 586–609. https://doi.org/10.6007/IJARPED/v10-i1/8939

Rau, P.-L. P., Gao, Q., & Wu, L.-M. (2008). Using Mobile Communication Technology in High School Education: Motivation, Pressure, and Learning Performance. *Computers & Education*, *50*(1), 1–22. https://doi.org/10.1016/j.compedu.2006.03.008

Song, S. J., Tan, K. H., & Awang, M. M. (2021). Generic Digital Equity Model in Education: Mobile-Assisted Personalized Learning (MAPL) Through E-Modules. *Sustainability*, *13*(19), 11115. https://doi.org/10.3390/su131911115

Togaibayeva, A., Ramazanova, D., Yessengulova, M., Yergazina, A., Nurlin, A., & Shokanov, R. (2022). Effect of Mobile Learning on Students' Satisfaction, Perceived Usefulness, and Academic Performance When Learning a Foreign Language. *Frontiers in Education*, *7*, 946102. https://doi.org/10.3389/feduc.2022.946102

Usmonova, G. A. (2024). Exploring the Conceptual Framework of Mobile Learning Technology. *Texas Journal of Philology, Culture and History*, *28*, 18–20. https://doi.org/10.62480/tjpch.2024.vol28.pp18-20

Wang, C., Chen, X., Yu, T., Liu, Y., & Jing, Y. (2024). Education Reform and Change Driven by Digital Technology: A Bibliometric Study from a Global Perspective. *Humanities and Social Sciences Communications*, *11*(256), 1–17. https://doi.org/10.1057/s41599-024-02717-y

Wang, J., Tigelaar, D. E. H., Zhou, T., & Admiraal, W. (2023). The Effects of Mobile Technology Usage on Cognitive, Affective, and Behavioural Learning Outcomes in Primary and Secondary Education: A Systematic Review with Meta-Analysis. *Journal of Computer Assisted Learning*, *39*(2), 301–328. https://doi.org/10.1111/jcal.12759

Yan, L., Whitelock-Wainwright, A., Guan, Q., Wen, G., Gašević, D., & Chen, G. (2021). Students' Experience of Online Learning During the COVID-19 Pandemic: A Province-Wide Survey Study. *British Journal of Educational Technology*, *52*(5), 2038–2057. https://doi.org/10.1111/bjet.13102

Yang, Q.-F., Hwang, G.-J., & Sung, H.-Y. (2020). Trends and Research Issues of Mobile Learning Studies in Physical Education: A Review of Academic Journal Publications. *Interactive Learning Environments*, *28*(4), 419–437. https://doi.org/10.1080/10494820.2018.1533478

Yosiana, Y., Djuandi, D., & Hasanah, A. (2021). Mobile Learning and Its Effectiveness in Mathematics. *Journal of Physics: Conference Series*, *1806*(1), 012081. https://doi.org/10.1088/1742-6596/1806/1/012081

Zafrullah, Z., & Ramadhani, A. M. (2024). The Use of Mobile Learning in Schools as a Learning Media: Bibliometric Analysis. *Indonesian Journal of Educational Research and Technology*, *4*(2), 187–202. https://doi.org/10.17509/ijert.v4i2.65586

Zhang, M., Jiang, Q., Xiong, W., Li, Q., & Zhao, W. (2024). Self-Efficacy Predicting K–12 Students' Self-Directed Learning with Mobile Technology. *Educational Technology & Society*, *27*(3), 236–252. https://doi.org/10.30191/ETS.202407_27(3).SP03

Zhang, X., & Hu, J. (2024). A Study on the Learning Behaviors and Needs of Design-Maker Communities of Practice in the Era of Mobile Learning. *Library Hi Tech*, *42*(2), 580–606. https://doi.org/10.1108/LHT-12-2021-0486