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Article

Leveraging AI in mobile learning to support education: A taxonomy of AI applications

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Abstract: This study conducts a systematic review to explore the applications of Artificial Intelligence (AI) in mobile learning to support indigenous communities in Malaysia. It also examines the AI techniques used more broadly in education. The main objectives of this research are to investigate the role of Artificial Intelligence (AI) in support the mobile learning and education and provide a taxonomy that shows the stages of process that used in this research and presents the main AI applications that used in mobile learning and education. To identify relevant studies, four reputable databases—ScienceDirect, Web of Science, IEEE Xplore, and Scopus—were systematically searched using predetermined inclusion/exclusion criteria. This screening process resulted in 50 studies which were further classified into groups: AI Technologies (19 studies), Machine Learning (11), Deep Learning (8), Chatbots/ChatGPT/WeChat (4), and Other (8). The results were analyzed taxonomically to provide a structured framework for understanding the diverse applications of AI in mobile learning and education. This review summarizes current research and organizes it into a taxonomy that reveals trends and techniques in using AI to support mobile learning, particularly for indigenous groups in Malaysia.

Keywords: artificial inelegance; AI; mobile learning; M-Learning; taxonomy; education

1. Introduction

Mobile applications have become ubiquitous worldwide, serving varied functions that support human activities and learning approaches in both formal and informal settings (Izkair and Lakulu, 2021). In education, these apps act as tools to augment classroom teaching, reinforce knowledge outside traditional environments like wikis, provide instruction without teachers through MOOCs, and promote learner motivation and task management via blogs (Sánchez-Morales et al., 2020). The adoption of mobile learning (ML) is a rising technological trend, widely leveraged by universities for accessing materials and instruction (Izkair and Lakulu, 2023).

The significant and rapid progress in communications and information systems has led to increased innovation adoption by both companies and individuals. This, in turn, has elevated the role of technology as a primary means of communication and service provision for learners (Gazi et al., 2024).

Philosophers who aimed to describe human thought as the mechanical manipulation of symbols laid the groundwork for modern AI. This approach eventually led to the creation of the programmable digital computer in the 1940s. Influenced by mathematical logic, this invention inspired scientists to explore the concept of building an electronic brain (İpek et al., 2023; Kaplan and Haenlein, 2019).

The integration of artificial intelligence (AI) into education has accelerated in tandem with rapid advancements in AI. AI in Education (AIED) has emerged as a promising field of research within educational technology (Jia et al., 2022). Artificial Intelligence in Education (AIEd) aims to develop computer systems capable of cognitive tasks like human learning and problem-solving. This field has evolved through over 30 years of scientific research (Chen et al., 2020). As a transformative technology, AI is now shaping mainstream applications in the developed world (Cabrera-Sánchez et al., 2020).

Advanced information technology (IT), encompassing artificial intelligence (AI) and mobile technology, is revolutionizing educational philosophies, teaching methods, and the roles of teachers and students in higher education. There is an urgent need to integrate modern IT and AI technologies deeply into higher education institutions to continually enhance the quality of education. Numerous scholars are exploring innovative teaching modes, including online education, flipped classrooms, and blended teaching, leveraging big data mining and machine learning algorithms (Cruz-Jesus et al., 2020; Golenhofen et al., 2020; Xin et al., 2022).

AI's continuous evolution and growth make it challenging to accurately forecast its wide-ranging economic and social effects, particularly within developing nations across Asia and the Pacific (Okuda and Ofa, 2018). AI has transformed from merely a "technological fad" into a globally competitive field (Qu and Kim, 2022). The application of AI in education is gaining momentum and attracting significant attention from researchers, developers, and practitioners. Over the past decade, AI has demonstrated considerable promise in enhancing teaching and learning experiences for both educators and learners. With over 30 years of research and development in AI in Education (AIED), it has garnered interest from researchers in computer science and education alike, leading to its application in various teaching and learning domains (Chaipidech et al., 2022). However, there is still a lack of clarity among educational researchers, developers, and practitioners regarding how to leverage AIED for pedagogical advantages on a broader scale and how it can meaningfully impact teaching and learning outcomes (Zawacki-Richter et al., 2019). Recently, AIED, or Artificial Intelligence in Education, signifies the utilization of AI technologies or software applications within educational services. AIED assists teachers and policymakers in making informed decisions within educational environments (Hwang et al., 2020).

2. The challenges of AI in education

The evolving landscape of work, influenced by both the 4th Industrial Revolution and the Covid-19 pandemic, underscores the increasing importance of intelligent, networked smart products and the data they generate, as highlighted by Haderer & Ciolacu (2022). Smart products, comprising physical, intelligent, and networked components, offer functionalities such as monitoring, control, optimization, and automation. These functionalities can be leveraged in Education 4.0 to monitor learners, control learning systems, and personalize student experiences, particularly amid the anticipated surge in upskilling and reskilling programs and the growing demand for STEM education.

Traditional teaching methods are facing limitations, necessitating the adoption of new learning and training concepts, including a "smart" Engineering Education 4.0 process (Ciolacu et al., 2019). This involves the further development of digital teaching supported by artificial intelligence (AI) to create optimized teaching environments. AI can analyze learning behavior and proactively encourage students to engage in learning, thereby enhancing learning outcomes with the same workload.

The UNESCO report addresses the challenges and policy implications associated with the introduction of AI in education and the preparation of students for an AI-powered context (Pedro et al., 2019). These challenges include:

1) Developing a comprehensive public policy on AI for sustainable development.
2) Ensuring inclusion and equity in AI education.
3) Preparing teachers for an AI-powered education, including acquiring new digital skills and understanding how to use AI in pedagogically meaningful ways.
4) Developing quality and inclusive data systems.
5) Significantly enhancing research on AI in education.
6) Addressing ethics and transparency in data collection, use, and dissemination.

These challenges underscore the need for coordinated efforts to harness the potential of AI in education while mitigating potential risks and ensuring equitable access and ethical practices.

3. Materials and methods

This study conducts a systematic review to investigate how Artificial Intelligence (AI) is utilized in mobile learning to assist indigenous communities in Malaysia, while also examining its broader applications in education. The primary objectives are to explore AI's role in supporting mobile learning and education, develop a taxonomy illustrating the stages of the research process, and present the key AI applications in mobile learning and education. To identify relevant studies, four reputable databases (ScienceDirect, Web of Science, IEEE Xplore, and Scopus) were systematically searched using predefined inclusion/exclusion criteria.

4. Results and discussion

This section focusses on the results and the discussion.

4.1. Taxonomic analysis

An initial query yielded 338 articles from reputable databases between 2018-2023, including 241 from Science Direct, 34 from IEEE Xplore, 35 from Web of Science (WoS), and 28 from Scopus. Despite accessibility issues leading to 3 unavailable articles (2 from Science Direct, 1 from WoS), a systematic filtering process followed. First, 9 duplicate articles were removed. Title and abstract screening excluded 163 more papers. Finally, thorough full-text reading led to excluding 14 more articles. Ultimately, 50 articles underwent meticulous analysis to construct a comprehensive overview of research in this emerging field. The domains of AI applications in mobile learning are visually mapped in **Figure 1**.

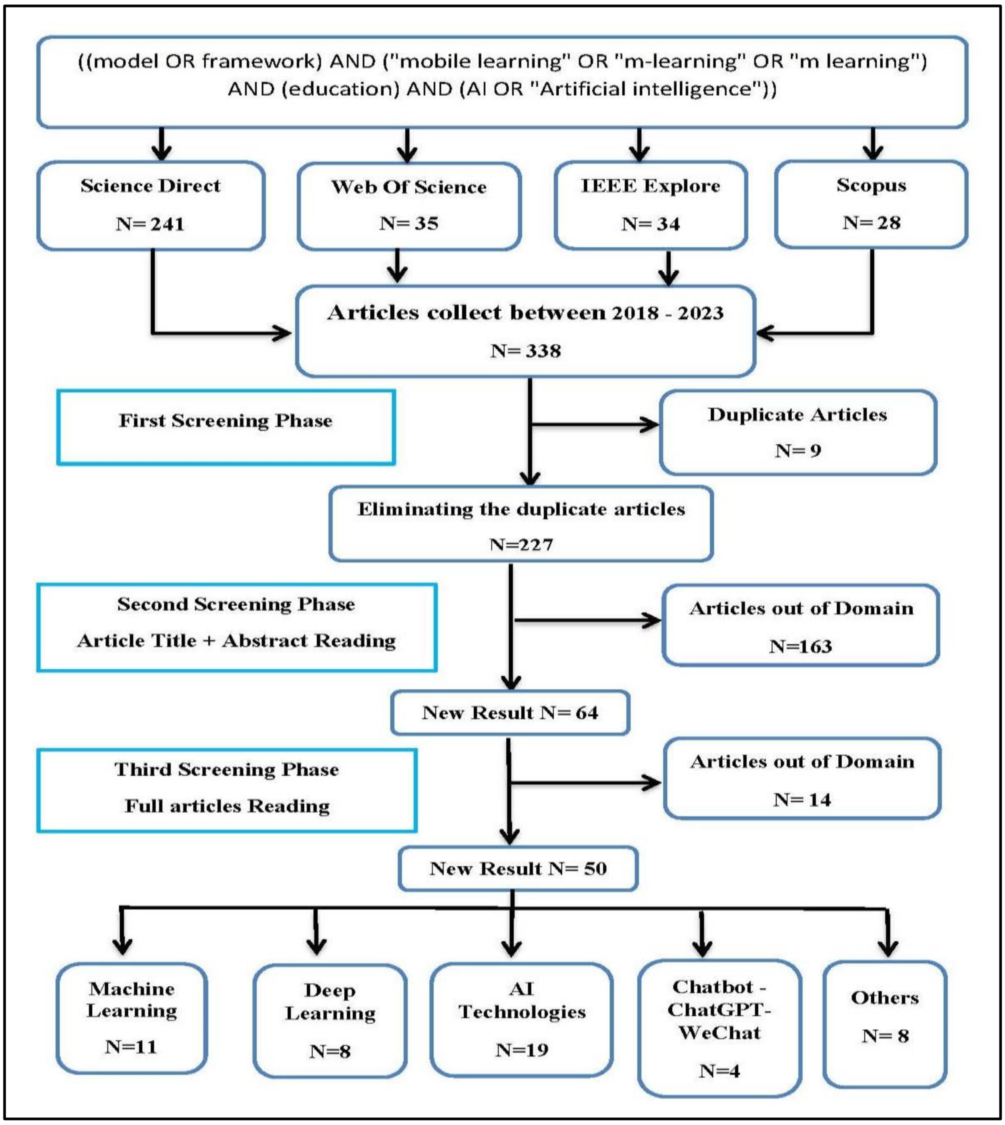

Figure 1. AI applications in mobile learning.

4.2. Discussion

This section discusses the four AI categories examined in this study: machine learning, deep learning, AI technologies, and chatbots/ChatGPT/WeChat. It also includes relevant graphs and analyses pertaining to the categorization and findings of the study.

4.2.1. Machine learning

Machine learning algorithms have played a pivotal role in the online collaborative learning process, facilitating real-time formative evaluation. This approach empowers learners to engage in learning reflection promptly and refine their strategies to attain high-quality collaborative learning outcomes (Chih-Ming and Ying-You, 2020). The essence of machine learning lies in enabling computers to learn from data. An illustrative instance of a machine learning challenge involves programming a computer to autonomously recognize handwritten postal codes on mail, a task achieved through learning from a set of examples (Matzavela and Alepis, 2021). AI-enabled learning environments encompass various technologies, including intelligent tutoring systems, adaptive learning systems, and recommender systems. An intelligent tutoring system employs artificial intelligence techniques to emulate a human tutor, aiming to enhance learning by offering improved support to the learner (Hasanov et al., 2019). Recommender systems, on the other hand, are software tools leveraging machine learning and information retrieval techniques to provide suggestions for items that align with a person's interests (Kabudi et al., 2021; Syed et al., 2017).

In the realm of machine learning algorithms, there exists a spectrum of explainability. Some algorithms, such as those associated with linear regression or k-nearest neighbors (neighborhood), are inherently explainable (Barredo Arrieta et al., 2020). Conversely, certain algorithms pose challenges in terms of interpretability and are often referred to as "black boxes" in literature (Doornenbal et al., 2022; Fung et al., 2021). Examples of such opaque algorithms include those employing multiple decision trees, support vector machines, or neural networks. The Random Forest algorithm, for instance, falls within this latter category (Cachero et al., 2023).

4.2.2. Deep learning

The integration of Artificial Intelligence (AI), particularly in the form of Deep Learning (DL) technology, into the consumer domain follows a distinct pattern compared to previous general-purpose technologies. DL tends to diffuse through infusion, wherein it is added to existing technologies already in use. Notably, DL algorithms for recommendations or ranking have been incorporated into the 15 most popular mobile applications in the United States (Engström and Strimling, 2020).

In the Gulf area, Akour et al. (2022) conducted research to explore students' perceptions of a smart educational system. The conceptual model incorporates adoption properties and Technology Acceptance Model (TAM) constructs. The study employs a two-stage analysis, utilizing the hybrid SEM-ANN (Structural Equation Modeling-Artificial Neural Network) technique to test relationships among theoretical model factors and validate research hypotheses.

Artificial Neural Networks (ANNs) represent a prevalent practice in the Educational Data Mining (EDM) domain (Coelho and Silveira, 2017). Despite initial challenges in extracting human-interpretable patterns from ANNs, many of these concerns were addressed in the last decade with the advent of Deep ANNs (Coelho and Silveira, 2017; Lecun et al., 2015). Deep learning, an evolution from machine learning, is characterized by multiple computational layers, allowing models to learn from examples, patterns, or events, surpassing traditional techniques that involve manually engineering features (Ananiadou et al., 2013; Nawaz et al., 2012; Poplin et al., 2018; Waheed et al., 2020; Wang et al., 2011).

4.2.3. AI technologies

Artificial Intelligence (AI) research has made significant strides across various fields, resulting in a growing body of literature, as evidenced by works such as those by (Burleson and Lewis, 2016; Kaplan and Haenlein, 2019). The impact of emerging technologies is also evident in the field of education, where AI has been instrumental in transforming teaching and learning methods. The proliferation of AI technology in education holds the promise of offering personalized learning experiences, dynamic assessments, and fostering meaningful interactions in online, mobile, or blended learning settings. Furthermore, in response to challenges such as the shortage of teachers in the USA, scholars like Edwards and Cheok (2018) have provocatively proposed the substitution of certain teaching roles with AI-driven robots (Zhang and Aslan, 2021). This underscores the evolving landscape of education as it embraces the potential benefits and challenges presented by AI.

AI learning has become a focal point in formal school curricula, recognized as a pivotal knowledge area crucial for students' future endeavors. The evolution of AI learning spans from early computer automation with abstract concepts, as discussed by McCarthy (2007), to the contemporary era of machine learning featuring intelligent algorithms, rules, and reasoning, exemplified by the work of Ng et al. (2021). Notably, AI conversational agents, such as those explored by Hsu et al. (2021), represent a manifestation of the advancements in this field. Recognizing the imperative to incorporate AI education, educators have responded by striving to keep pace with rapid developments. Initiatives include the formulation of national AI-related curricula, as demonstrated by efforts like those outlined by Sanusi et al. (2022), and endeavors to democratize AI education, as exemplified by the work of Van Brummelen (2019).

Additionally, educators have explored the use of free tools like Learning ML to teach AI, as evidenced by the contributions of Garcia et al. (2019) and Hsu et al. (2023). These efforts collectively underscore the commitment to integrating AI learning into educational settings to equip students with essential skills for the future.

Teachers make deliberate choices in adopting AI technology, considering various factors, particularly how the content can be seamlessly integrated into a collaborative learning environment. The utilization of AI has the potential to significantly enhance Collaborative Technical Education (CTE) by introducing cutting-edge technologies that enrich students' educational experiences and better prepare them for technical careers, as highlighted by (Donkin et al., 2019). In the context of education, the overarching goal of digital transformation is to fundamentally reshape how educational institutions operate and cater to their students through the widespread adoption of digital technologies. This transformative process is aimed at enhancing efficiency, learning outcomes, and overall educational experiences. Noteworthy contributions in this area include the works of Alhashmi et al. (2019), Alzahrani (2019), Wiggberg et al. (2022), and Zabasta et al. (2019). These studies collectively emphasize the pivotal role of digital technologies, including AI, in reshaping the landscape of education for the benefit of both educators and students.

Collaborative Technical Education (CTE) driven by artificial intelligence (AI) represents an educational approach that leverages AI technologies to provide students with personalized and dynamic learning experiences. Simultaneously, this approach fosters collaboration between academic institutions and business partners, as emphasized by Kneale (2018). The success of the Math-in-CTE concept has been identified to hinge on the crucial ability of teachers to collaborate effectively, as noted in the findings of Lakshmi et al. (2023). This underscores the importance of collaborative efforts among educators in implementing AI-powered educational initiatives for technical education.

4.2.4. Chatbots: ChatGPT and WeChat

The utilization of technology addresses challenges in students' reference preparation, with a notable decrease in plagiarism levels when referencing technology is employed, as observed in the study by Torres-Diaz et al. (2018). The swift progress in the development of mobile apps for higher education, highlighted by Sophonhiranrak (2021), underscores the significance of mobile devices as valuable tools in various educational contexts. These devices facilitate content access, support learning activities, provide easy document retrieval, aid in summarizing content, enable book reading, and facilitate information sharing.

Qahmash (2018) emphasizes the outstanding assistance that educational apps offer to teachers and the positive impact they have on students' knowledge acquisition when integrated into the educational process. Furthermore, smartphone-based chatbots, as discussed by Ahmed et al. (2021), hold promise for the future of education by making learning interactive and enjoyable for students. These chatbots are seen as effective tools in addressing students' frequently asked questions on educational or administrative matters, as highlighted by Zaky (2023). This collective integration of technology illustrates a transformative trend in leveraging digital tools to enhance the overall educational experience.

The integration of ChatGPT, developed by OpenAI, has the potential to revolutionize the practices of accounting professionals, offering heightened efficiency, increased productivity, and valuable insights with tangible impacts, as noted by Alshurafat (2023). In the realm of teaching and learning in accounting, ChatGPT can play a transformative role by providing an interactive learning experience. Its ability to answer questions and explain complex accounting concepts in natural language facilitates a more rapid understanding for students.

One of the significant advantages is the availability of ChatGPT 24/7, enabling students to access information and receive answers to their queries at any time. This continuous availability enhances the learning experience by providing flexibility and convenience. Furthermore, ChatGPT's capability to offer personalized feedback to students based on their specific questions and concerns, as highlighted by Al Ghatrifi et al. (2023), contributes to a more tailored and effective learning process. Overall, the incorporation of ChatGPT in accounting education demonstrates the potential to elevate both teaching and learning experiences in the field.

In the current era of rapid mobile internet development, the emergence of Mini Programs has brought about significant changes across various domains. WeChat, for instance, reports an impressive number of more than 1 million Mini Programs, spanning over 200 sub-industries. In the context of the "Internet + education" paradigm, online learning facilitated through WeChat Mini Programs represents a novel application compared to traditional online learning methods. This mode of learning, centered on mobile devices, effectively transcends the constraints of space and time, providing enhanced convenience for learners.

The increasing focus on education and the flourishing development of WeChat Mini Programs have spurred research activities in the field of education, as highlighted by (Yang et al., 2019). This indicates a growing recognition of the potential impact and utility of WeChat Mini Programs in reshaping educational practices and facilitating innovative approaches to online learning.

4.3. Data analysis

This section presents the data analysis for the selected scientific articles from four reputable databases: ScienceDirect, Web of Science, IEEE Xplore, and Scopus, focusing on AI categories such as machine learning, deep learning, AI technologies, and Chatbot - ChatGPT- WeChat. Additionally, it includes graphs and analyses related to authors and the year of publications.

Figure 2 illustrates the distribution of AI techniques across different categories based on the sources of database of the articles, specifically IEEE, ScienceDirect, and Scopus. The figure provides a breakdown of the number of publications for each AI category within these databases, totaling 50 papers. The data reveals that AI Technologies attracted the highest number of publications with 19 papers, followed by Machine Learning with 11 papers, and Deep Learning with 8. In the Chatbot-ChatGPT-WeChat category, there were 4 papers, while 8 papers were published in other fields related to AI. This breakdown offers insights into the distribution of AI-related research across various categories and databases, reflecting the diversity and focus areas within the field.

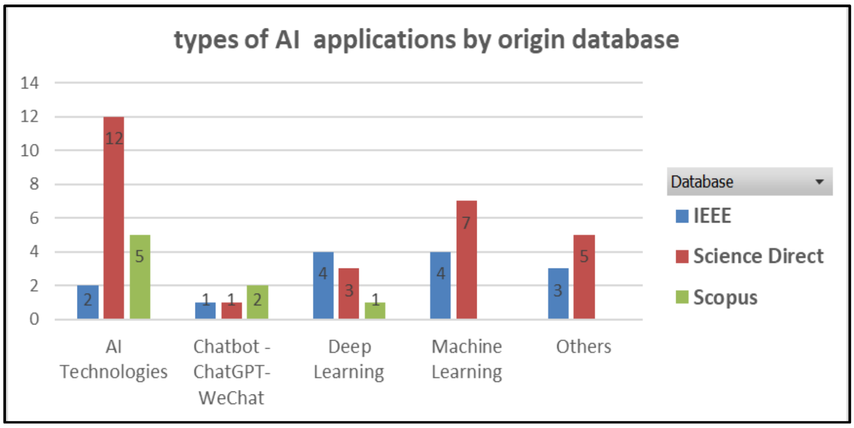

Figure 2. The categorization of AI techniques based on database source.

Figure 3 presents the number of classifications of AI techniques according to the year of publication. The distribution of the scientific papers from 2018 to 2023 is shown below.

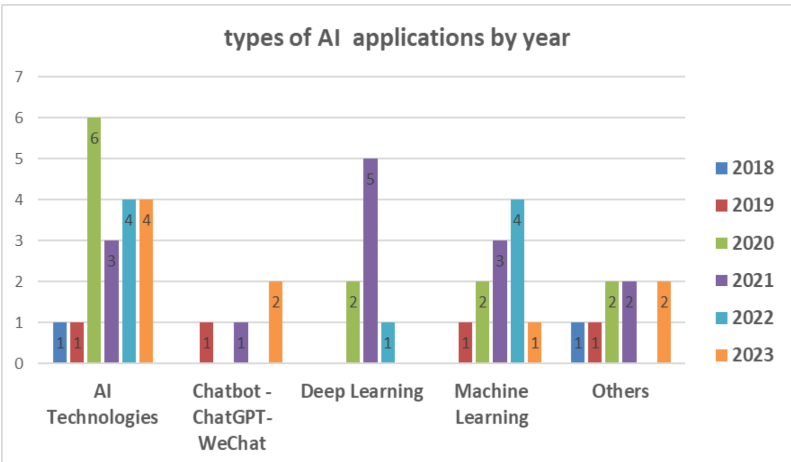

Figure 3. The type of AI applications by publication year.

Figure 4 provides a visual representation of the number of AI applications published each year. The data indicates a progressive trend in the publication of AI-related papers over the years:

- In 2018, two papers were published.
- The number increased to four papers in 2019.
- A significant rise is observed in 2020, with twelve papers published.
- The trend continued upward in 2021, reaching fourteen papers.
- In 2022, there were nine published papers.
- The year 2023 maintained the same level of activity with nine papers published.

This representation helps illustrate the evolution and increasing interest in AI applications, with a notable surge in the number of publications in 2020 and 2021, suggesting a growing focus and research activity in the field during those years.

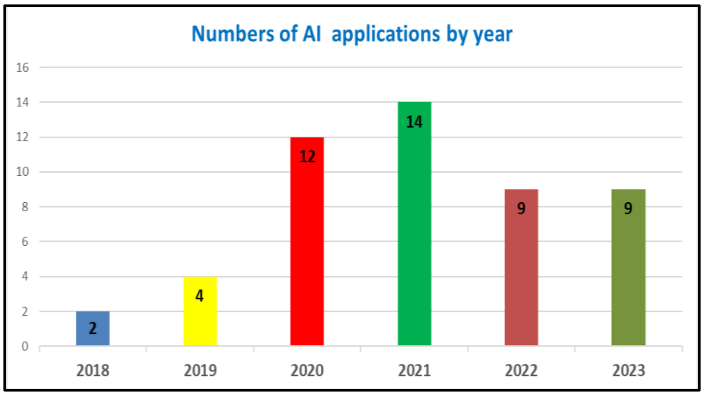

Figure 4. The number of AI applications by year.

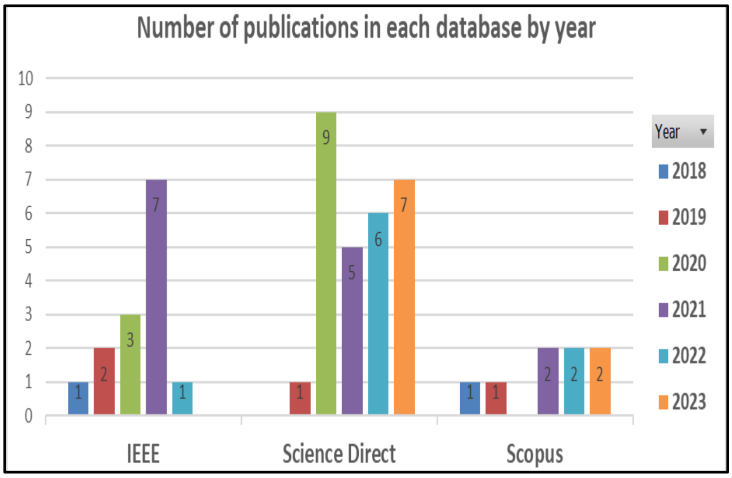

Figure 5. The number of publications in databases based on year.

Figure 5 provides a breakdown of the number of publications in each of the IEEE, ScienceDirect, and Scopus databases from 2018 to 2023. The total number of papers across these three databases during this period is nearly 50. The distribution of publications based on database is as follows:

- IEEE: 14 papers
- ScienceDirect: 28 papers
- Scopus: 8 papers

This breakdown offers insights into the distribution of publications across these major databases, with ScienceDirect being the most prominent source, followed by IEEE and Scopus.

Figure 6 presents the distribution of the nationality of authors involved in the publications of AI applications in the mobile learning domain. The data indicates the participation of authors from 20 different countries. The breakdown by the number of publications associated with each country or nationality is as follows:

- China: 10 publications
- USA and India: 5 publications each
- Taiwan: 4 publications
- Morocco, Oman, and Spain: 3 publications each
- Egypt, Norway, Pakistan, and United Arab Emirates: 2 publications each
- Czech Republic, Finland, Germany, Greece, Indonesia, Malaysia, Mexico, South Africa, and Sweden: 1 publication each

This distribution highlights the global involvement and collaborative efforts of researchers from various nations in contributing to the literature on AI applications in mobile learning.

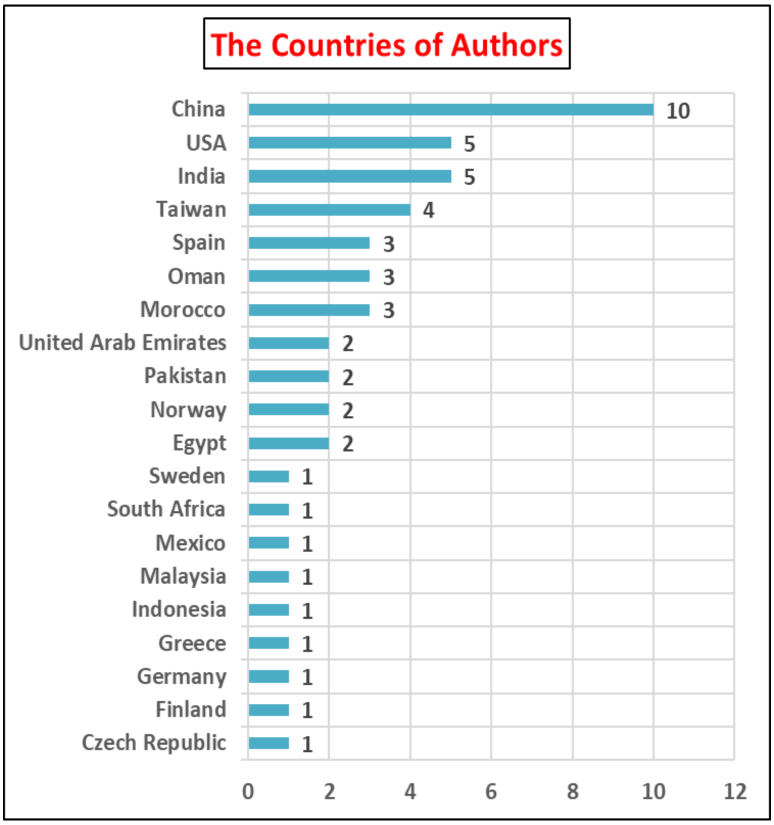

Figure 6. The countries of authors.

5. Conclusion

This study aims to review and organize the most relevant research on artificial intelligence (AI) applications in mobile learning and education. The goal is to provide a structured taxonomy that classifies the literature into meaningful categories, revealing key trends and gaps in this emerging field. Through an analysis of the collected literature, five primary AI application categories were identified: AI

Technologies, Chatbots/ChatGPT/WeChat, Deep Learning, Machine Learning, and Other. This taxonomy organizes the diverse body of literature into 19, 4, 8, 11, and 8 articles in each respective category. The taxonomy offers valuable insights into the distribution and emphasis of existing research on AI in mobile learning.

Introducing a taxonomy serves as an important tool for researchers by systematically organizing the multitude of activities and publications in this domain. The structured classification provides several key benefits. First, it highlights gaps in the literature by revealing areas with limited existing research that warrant further exploration. The taxonomy makes it easy to identify topics needing more attention. Second, the taxonomy provides a roadmap for future research by grouping literature on intelligent AI techniques for mobile learning and education. This guides both current and new researchers to underexplored areas ripe for investigation.

In essence, the taxonomy acts as a guiding framework, offering insights into the existing state of knowledge, identifying gaps, and suggesting pathways for future research in the domain of AI applications in mobile learning and education. The statistical data within the individual categories of the taxonomy plays a crucial role in identifying trends and reinforcing areas that may be less explored in AI applications in mobile learning. Similar to taxonomies in other fields, the proposed taxonomy in this study serves as a common language for researchers, facilitating communication and discussion around emerging works.

The results of this study align with existing literature on the role of AI in education, particularly focusing on machine learning, deep learning, AI technologies, and chatbots like ChatGPT and WeChat (Chih-Ming and Ying-You, 2020; Engström and Strimling, 2020; Qahmash, 2018; Yang et al., 2019; Zhang and Aslan, 2021).

By delving into the statistical data within each category, researchers can gain insights into the distribution of research efforts, identifying which categories are receiving more attention and which may require further exploration. This information is invaluable for researchers looking to align their work with current trends and address potential gaps in the literature. Furthermore, the taxonomy serves as a shared framework that researchers can use to categorize, discuss, and build upon each other's work. It provides a standardized language that fosters collaboration and enhances the collective understanding of AI applications in mobile learning in higher education institutions in Malaysia. Overall, the use of statistical data within the taxonomy contributes to a more informed and dynamic research landscape in this evolving field.

University administrators and practitioners must actively encourage students to understand the advantages of using AI tools and applications in education. Moreover, researchers are advised to concentrate their studies on a specific major area within AI, like machine learning, and examine its impact on education and mobile learning in education. Future research should explore machine learning or deep learning within AI applications to enhance support for mobile learning in education.

Author contributions: Conceptualization, ASI and MML; methodology, MML and ASI; software, ASI; validation, MFHAM and NAZ; formal analysis, ASI; investigation, MML; resources, MML; data curation, ASI; writing—original draft preparation, ASI; writing—review and editing, MML; visualization, ASI; supervision, MML; project administration, MFHAM and NAZ; funding acquisition, MML. All authors have read and agreed to the published version of the manuscript.

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