

PAPER

Interactive Mobile Technology in Education: A Systematic Mapping and Bibliometric Analysis

Muhammad Abdul Ghofur¹,
Binar Kurnia Prahani¹(✉),
Irgy Redityo Dawana¹,
Utama Alan Deta¹, Yeni
Anistyasari¹, Muhammed
Akif Kurtuluş²

¹State University of Surabaya,
Surabaya, Indonesia

²Alanya Alaaddin Keykubat
Universitesi, Antalya, Turkey

binarprahani@unesa.ac.id

ABSTRACT

Interactive mobile technology (IMT) has become an important element in the transformation of modern education, bringing a more open, dynamic, and responsive approach to learning for learners in the digital age. This study aims to explore the impact of using IMT in various educational settings, ranging from primary to tertiary levels. Through bibliometric analysis combined with a systematic review of a number of articles taken from the Scopus database and published over the last five years (2019–2023). This study identified key findings related to the purpose and focus of using IMT in education. The results indicate that these technologies aim to enhance student motivation, engagement, learning quality, critical thinking skills, and creativity, while also improving the accessibility and flexibility of learning. The findings imply that IMT has great potential to bring about positive changes in education, creating a learning environment that is more open, dynamic, and responsive to students' individual needs. By utilizing this technology effectively, education can deliver learning experiences that are more engaging, relevant, and adaptive to learners' development. Therefore, it needs to be continuously supported and developed to provide maximum benefits for the learning process and the advancement of education.

KEYWORDS

bibliometric, education, interactive mobile, systematic review, technology

1 INTRODUCTION

In the increasingly advanced digital era, mobile learning has become one of the key elements in the transformation of global education [1]–[3]. This phenomenon not only affects the way students learn but also expands the boundaries of the classroom and changes the role of teachers. The use of interactive mobile technologies (IMT), such as educational apps, online learning platforms, and interactive software, has opened the door to more engaging, powerful, and inclusive learning experiences [4]. The transformation of modern education cannot be separated from the

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important role that technology plays. Technology has enabled education to become more adaptive, personalised and affordable for the wider community [5]. The use of technology in education transformation covers various aspects, from innovative curriculum development to the implementation of new teaching methods [6].

In today's digital era, technology is not just a tool but also the foundation for learning that is based on student needs, increases accessibility, and enables global collaboration among educators and learners [7]–[9]. Technology supports the integration of project-based curriculum, global collaboration, and problem-based learning relevant to the real world [10]. It also opens up access to high-quality educational resources for remote communities [11]. By using the right technology, education can be tailored to individual needs, provide lifelong learning opportunities, and bring education to previously hard-to-reach areas. As with the development of innovative mobile technologies such as AR and VR, students can experience more engaging and fun learning [12], [13]. For example, in science learning, students can explore the solar system using VR technology or conduct virtual experiments in a safe and controlled environment [14], [15]. This opens up opportunities for in-depth exploration and more authentic learning experiences, increasing student motivation and engagement in the learning process.

Despite the many benefits offered by IMT in education, challenges also arise. One of them is the need for teachers to master the technology and the need to develop new skills that are in line with technological developments [16]. Nevertheless, with the right strategy and a sustainable approach, IMT has great potential to transform education to be more open, flexible, and productive in preparing future generations. Understanding this background allows us to further explore how IMT has evolved and will continue to influence education in the future.

Currently, research on innovative mobile technologies is growing rapidly. Various studies have examined the development of mobile learning applications, showing that these interactive applications can increase student engagement and motivation to learn and self-confidence [17]. Self-confidence possessed by students makes students confident to succeed in learning and makes them motivated [18]. Empirical research also found that students' problem-solving skills can be improved through the use of mobile learning and IMT in the learning process [19]. In addition, mobile learning applications also support collaborative learning through group discussions and joint projects [20]. These interactions allow students to work together in solving problems, sharing ideas, and learning from each other. Mobile apps often include simulations that allow students to practice problem-solving skills in environments that resemble real situations, such as virtual science laboratory simulations [21], [22]. While there are many research studies examining the benefits of IMTs in education, there are important gaps in the literature that need to be addressed. Most of the existing research focuses more on app development or the impact of technology on student motivation and engagement, but there are still few studies that systematically investigate how these technologies are being applied globally and how research trends in this area are evolving over time. What's more, while there is evidence showing improvements in students' problem-solving and collaboration skills, these studies tend to be limited to specific contexts, without providing a comprehensive view of how these technologies are used across different levels of education and different countries.

This study contributes by providing a comprehensive mapping of the development of IMT research in education through a bibliometric analysis approach. With this analysis, this research will identify emerging research trends [23], distribution of research topics, and the contribution of these technologies in the global education context. In addition, this study also used the systematic literature review (SLR)

method to further explore specific aspects of IMTs and their applications in education. The combination of bibliometric and SLR methods enabled this study to not only map the distribution of research in this area but also identify existing research gaps and provide [24]–[26]. By utilizing a combination of these two methods, this study is expected to provide a more complete picture of how IMT is used in education, its impact on the teaching-learning process, and future research directions. This study aims to explore the impact of using mobile learning technology innovation in education. To obtain the desired results, the main objectives of this study are:

1. To identify key information and trends in the development of literature related to interactive mobile technology.
2. To provide keyword trends and visualization mapping in the literature of interactive mobile technology.
3. To explore the impact of IMTs on learning processes and student learning outcomes at different levels of education.
4. To highlight the challenges and opportunities that IMT provides for the future.

2 DATA AND METHOD

In this study, an SLR approach was used to compile, evaluate, and synthesise the literature relevant to the research topic. In addition, this study also conducted a bibliometric analysis to identify publication trends and citation patterns, as well as collaboration networks among researchers, institutions, and countries related to the topic. This method makes it possible to gain a more comprehensive understanding of the development of the research field, identify the most influential key concepts, and recognise knowledge gaps that require further attention [27], [28]. By integrating SLR with bibliometric analysis, this study can provide a solid foundation for data analysis and interpretation in the context of a methodologically sound framework.

This study uses an SLR. The use of SLR is due to systematic review research to summarise accurate evidence findings [29]. A literature review is a summary of knowledge that examines the scope and characteristics of research efforts related to a particular topic by mapping key concepts, themes, and references, which can serve as a source of information for a field of knowledge [30]. This type of literature on research, in particular, makes a significant contribution to aspects that have not been fully explored in certain topics. This systematic review approach involves a stepwise process consisting of 1) identification of research questions, 2) search for relevant literature, 3) selection of suitable articles, 4) data analysis, and 5) collation, description, and reporting of findings [31]. The collected data was then presented in tabular form using Microsoft Excel software to facilitate thematic analysis and comparison. The final stage or the fifth stage, involves compiling, summarising and reporting the findings from the literature review. At this stage, the general themes and conclusions of the publications are highlighted, and other important information, such as the research institution, year of publication, and other relevant aspects, are also described.

2.1 Inclusion and exclusion criteria

Inclusion and exclusion criteria were applied to ensure that only literature most relevant to the topic was analysed. The inclusion criteria used included: 1) articles published in peer-reviewed journals in the last five years (2019–2023), 2) articles

written in English, 3) studies relevant to the fields of technology, science, and computers. Table 1 presents details of these inclusion and exclusion criteria, which were designed to ensure that the selected articles were relevant, valid, and of high quality.

Table 1. Document inclusion and exclusion criteria

Criteria (Eligibility)	Exclusion
Literature → Journal	Conference review, Book chapter, Review
Year of Publication → 2019–2023	Earlier than 2019
Language → English	Other than English
Subject Area → Computer Science, Social Science, Engineering	Other than Computer Science, Social Science Engineering

2.2 Data collection

The document search using the Scopus database resulted in 242 articles with the search techniques described above. A total of 128 articles were excluded based on the publication years 2019–2023. After thoroughly analysing the remaining 114 documents, 80 documents were eliminated as they were not relevant to the purpose of the research study. Only 25 publications were selected after going through a thorough process based on the preferred reporting items for systematic reviews with the PRISMA method, as shown in Figure 1.

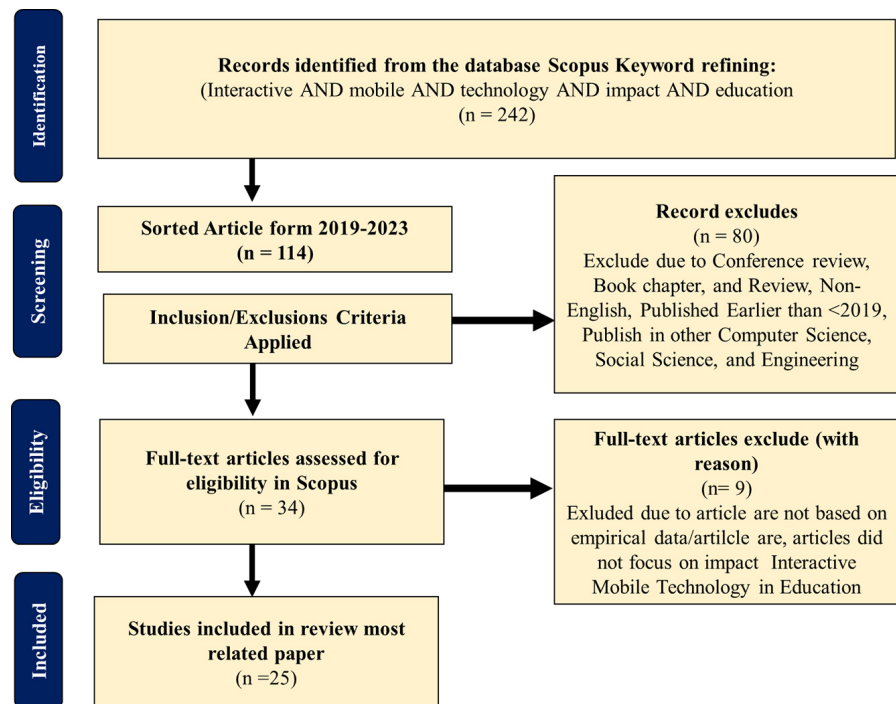


Fig. 1. PRISMA method selection process flow in research [32], [33]

The selection of articles was limited to empirical studies investigating education levels ranging from elementary school to higher education, published in journals within the last five years. Articles from conferences, reviews and books were

excluded due to the lack of systematisation and transparency caused by conventional evaluation methods [34]. This study also considered articles published within the last five years to find current issues in the research topic, maintaining the stability of the research subject [35]. Therefore, the selection of high-quality articles within the last five years was important for conducting this systematic review. In this study, a total of 25 articles were selected as samples for analysis.

3 RESULTS AND DISCUSSION

3.1 Trend in interactive mobile technology in the last five years

This research uses the keywords “Interactive AND mobile AND technology AND impact AND education”; the search yielded research trends on the use of interactive mobile technology in education over the past five years. A graph of the growth of related publications is shown in Figure 2.

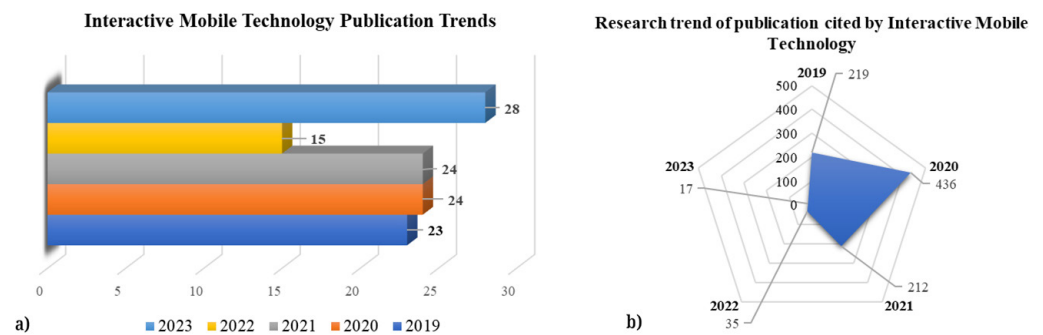


Fig. 2. Number of Scopus databases and citations of interactive mobile technology research publications

Based on Figure 2a, it can be seen that the trend of research publications on IMT in education has increased significantly. The number of published documents on IMT increased from 2019 to 2020 but then decreased in 2022. However, in 2023, there was a significant increase in the number of published documents. The increase in the number of publications reflects the growing interest of researchers in the use of interactive technologies in educational contexts [36]. This could be due to the accelerated adoption of technology in the learning process, especially with the advent of increasingly sophisticated mobile devices. The increase in publications also reflects the challenges and opportunities faced by education in integrating technology into teaching and learning. These publications may address the latest methods, strategies and research findings to effectively utilise the potential of interactive technologies in education. Moreover, the increased interest in interactive technologies in education may also reflect the drive to support distance learning, especially given the influence of the COVID-19 pandemic that forced many educational institutions to shift to online learning models [37].

In Figure 2b, the citation data of articles related to IMT in education research over the past five years. Based on the citation trends in the given data, it can be seen that the number of citations of publications IMT fluctuates from year to year. Although there was an increase in the number of publications in 2023, the number of citations received was relatively low compared to previous years. This suggests that despite the increase in research output, the publications may not have gained significant influence or wide acceptance in the scientific community. A high number

of citations may also indicate that the research has made a valuable and valid contribution to the existing literature [38]. Figure 3 shows the distribution of the number of Interactive Mobile Technology publications in education based on document type and document source. Based on the type of document, the most common types of publications are article (n = 50) and conference paper (n = 38). This shows that the results of IMT in education research are often presented in the form of articles and conference proceedings. In Source Type, publications came from journals (n = 59) and conference proceedings (n = 29), which shows that journals and conference proceedings are the main platforms for research in IMT. Meanwhile, book series and books also contributed publications with 21 and six publications, respectively.

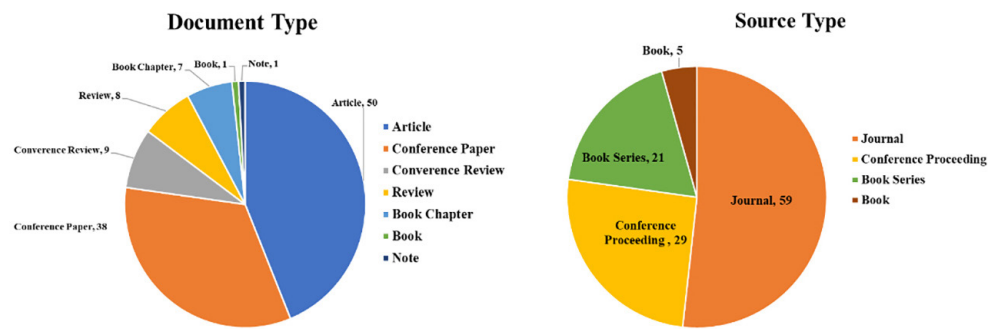


Fig. 3. Distribution types and source of IMT

3.2 Novelties of the interactive mobile technology during the last five years

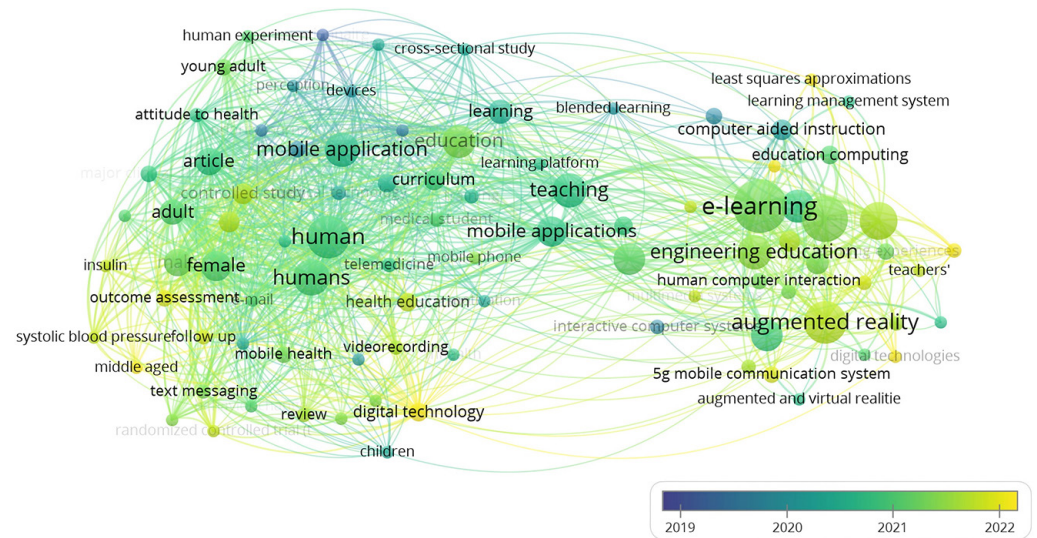


Fig. 4. Keyword visualization results of events across IMT

Figure 4 presents the results of the visualisation of research trends in IMT in education. This visualisation shows the latest innovations and research directions based on the trend mapping analysis conducted [32]. Different colours in the circles indicate the variation of keyword usage in research in certain years [39]. The colour difference illustrates that some research topics have long been the focus (indicated by a combination of purple and green colours) [40]. Old issues used in previous research, like mobile applications, computer-aided instruction, blended learning, and learning

management systems. While the yellow colour indicates that research on the topic is developing in current study, such as digital technology and augmented reality. This is in accordance with research by [41] which states that augmented reality technology is growing rapidly today and is a trend in education.

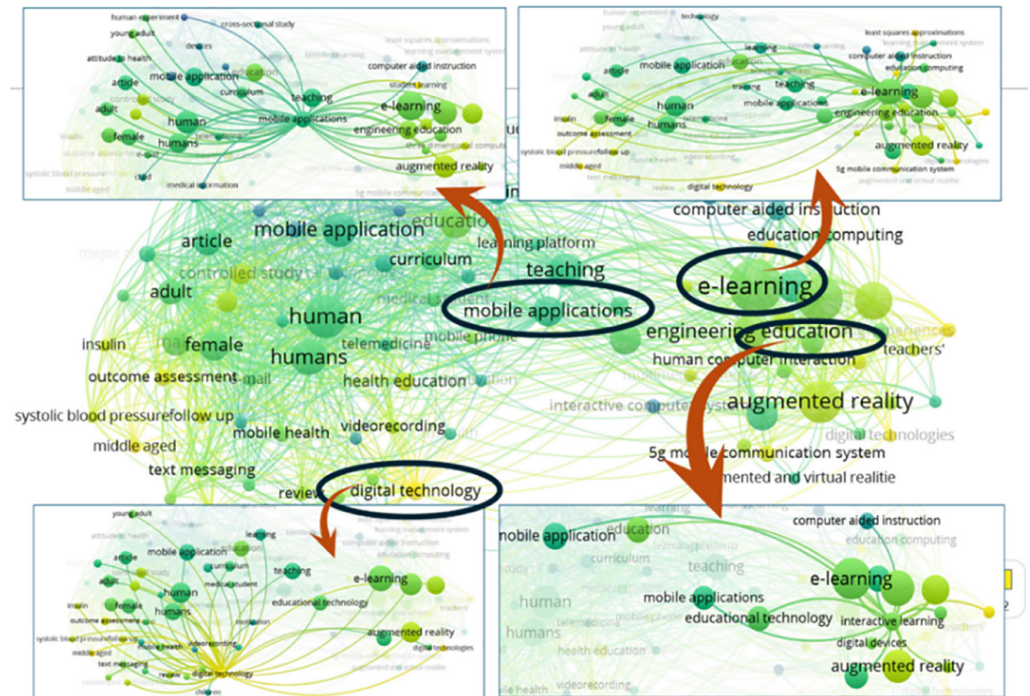


Fig. 5. Visualization results of more specific keyword mapping to the topic of interactive mobile technology

The visualisation results are shown in Figure 5 from several examples of more specific keyword mapping results, like mobile application, e-learning, interactive learning, and digital technology. Based on the visualisation results, there is a relationship between mobile applications and student learning, teaching, and curriculum. The relationship between student learning and mobile applications is that mobile applications can provide easy access to learning resources such as texts, videos, and interactive exercises [42], [43]. Educators can also provide a platform to participate in discussion forums or online learning groups. Teachers can use mobile apps to design and deliver learning materials, assign tasks, provide feedback, and manage classes efficiently [44]. They can also be used to communicate with students and parents. In addition, mobile applications are also related to the curriculum, where mobile applications can load the curriculum digitally, facilitating access to subject matter, lesson plans, and other resources in accordance with the established curriculum [45]. According to research by [46] mobile applications can provide direct access to learning materials in accordance with the established curriculum. This can be text, video, audio, images, or other interactives relevant to specific subjects and educational levels [47], [48]. In addition, mobile applications can be used to assign tasks, test student understanding, and provide additional practice according to the curriculum being studied. This allows teachers to provide immediate feedback and monitor student progress.

In addition, this topic is related to e-learning and learning platforms. IMT can be an important part of e-learning. This is due to the use of mobile technology to deliver learning materials electronically, facilitate interaction between students and learning

materials, and provide an interactive and engaged learning experience [1], [49], [50]. In addition, IMT is often connected with online learning platforms. It allows students to access learning materials and assignments through mobile devices. This platform can support interactive and mobile technology-based learning experiences [50]. E-learning often relies on online learning platforms to provide access to learning materials, assignments, interaction between students and teachers, and evaluation tools. These platforms can be LMS, MOOCs, or other specialised platforms designed for learning purposes [51]. In addition, the use of Google Classroom, Edmodo and Schoology are also online learning platforms that can support learning activities.

Furthermore, interactive learning is also related to mobile applications and augmented reality. Mobile applications are often designed to provide an interactive learning experience. Learners can include various features, such as learning videos, interactive exercises, educational games, and others. Users can interact with this learning content through the touch screen of their mobile device, enabling a more hands-on and dynamic learning experience [52]. In addition, the use of technology with interactive learning can use AR-based learning, which is a technology that allows the addition of digital elements to the real environment [40]. In the field of learning, AR can be used to create an interesting and fun learning experience. For example, AR applications can display three-dimensional objects that appear on top of textbooks, allowing students to interact directly with the subject matter visually [53], [54]. Then the visualisation results also link digital technology with educational technology and motivation. Educational technology utilises advances in digital technology to improve the learning and teaching process [55]. Digital technology enables the development of interactive learning tools, online platforms, and mobile applications that can motivate students by offering engaging and interactive learning experiences [56]. In addition, in education, digital technology enables the use of various digital tools such as multimedia presentations, interactive simulations, and online learning platforms to deliver learning materials in a more engaging and effective way to students [57], [58]. Thus, digital technology plays an important role in supporting educational technology, motivation, and teaching as a whole.

3.3 Publication of interactive mobile technology worldwide

This study uses a more in-depth literature study analysis using a systematic review that can provide a more comprehensive insight into a particular topic. By using a systematic review approach, researchers can investigate a range of relevant articles in a methodical and structured manner. In this case, by selecting eligible articles, researchers can collate data from different sources to gain a broader understanding of the topic under study [59], [60]. By conducting a more in-depth analysis, researchers can identify patterns, trends, differences, or similarities among previously conducted studies. This can help in formulating better conclusions and provide a solid foundation for further research development or practical implications.

Based on publications from several countries, it shows that in the last five years, China, Indonesia, Malaysia, and Taiwan are the most active countries in conducting research and publications related to learning using interactive mobile-based technology. Indonesia has the highest number of publications (N = 8) [12], [14], [59]–[64], followed by China (N = 7) [63]–[69], Taiwan (N = 4) [70]–[73], and Malaysia (N = 3) [74]–[76]; in addition, some articles also came from other countries such as the United States (N = 1) [81], India (N = 1) [13], and Bangladesh (N = 1) [82]. It is important to

analyse this publication pattern, as it can provide insights into research trends and developments related to the implementation of mobile-based technologies in education in different countries. This shows that mobile learning has become a significant focus of research in various countries, underlining the importance of technology integration in global education.

Research and publications on mobile technology in learning are not only developing in developed countries such as China and Taiwan, but also in developing countries such as Indonesia and Malaysia. This reflects the awareness of the importance of utilising technology to improve learning effectiveness and face educational challenges in the digital era. Thus, cross-country collaboration and knowledge exchange between researchers from different regions could be key in developing innovative and sustainable education solutions in the future.

3.4 Research subjects

The results of this study are based on the expected responses of research subjects at various levels of education, including elementary, junior high, high school, and university. Of the 25 relevant articles, the main focus of the research is mobile-based technology interaction in primary school (N = 7), junior high school level (N = 4), senior high school level (N = 2), and higher education (N = 12). The analysis of these research subjects illustrates the relevance of using IMT in learning at various levels of education. Furthermore, Figure 6 provides a summary of the paradigm of using interactive mobile technology in learning and its innovative impact on education. The impact of interactive mobile technology in education is an interesting and important topic to discuss. Various studies have shown that the use of IMT can improve learning effectiveness by facilitating wider access to educational resources, enabling more adaptive and personalised learning, and encouraging active student participation and engagement in the teaching-learning process. In addition, mobile technology can also enrich the learning experience through various interactive features such as multimedia, simulation, and access to online learning platforms.

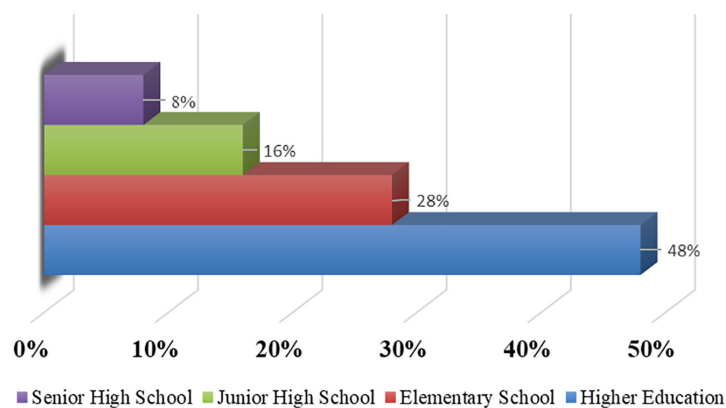


Fig. 6. Research subjects on interactive mobile technology publications

Overall, the use of interactive mobile-based technology has an impact on education. Thus, it can be concluded that interactive mobile technology has great potential to positively impact education by improving the quality of learning, facilitating innovation in teaching methods, and preparing students to face future challenges in the digital era.

3.5 Research subjects

Table 2. Impact of interactive mobile technology on education

Author	Year/Cited	Result
Wu et al.	2019/65	Mobile-based CRS technology helps to create an interactive and responsive learning environment, which facilitates better interaction.
Lau et al.	2020/46	Mobile technology has become an integral part of the student learning experience, mobile technology increases accessibility and flexibility to access learning resources and information anytime and anywhere without being bound by physical location.
Pan & Mow	2023/2	The use of mobile technology in gamified teaching can effectively improve students' learning outcomes and their engagement in the learning process, as well as offer solutions in building interactive teaching environments.
Chen et al.	2021/1	Teachers can obtain accurate student information during the learning process and provide feedback to teachers to adjust the teaching process according to students' cognitive conditions.
Niu, Y.	2023/0	Integrating the use of digital technology can provide motivation and motor skills and can increase learning effectiveness through group interaction.
Hong, G.	2023/0	The implementation of Mobile technology-based learning can improve teaching methods and student learning outcomes.
Cai et al.	2020/59	The use of AR technology in learning gains positive response for students and can improve learning outcomes.
Bakar et al.	2021/7	The use of interactive mobile technology is significantly positive in increasing knowledge and engagement.
Nasharuddin et al.	2021/7	Interactive mobile technology allows learners to understand complex concepts through immersive visualization and interaction, It helps in improving learners' understanding of the material being taught.
Kassim & Md Zubir	2019/7	Mobile technology has significant potential to enhance the learning experience.
Japar et al.	2021/3	Mobile technology can innovate learning and provide effective learning in education.
Arifin et al.	2021/4	Interactive Mobile can be an effective support tool in the problem-solving process.
Sulisworo et al.	2020/4	The use of interactive mobile-based technology can have a positive impact on improving students' critical thinking skills.
Trisiana & Utami,	2022/1	Technology-enabled learning facilitates students in learning by freely sourcing materials and information to complete class assignments, creating an innovative, unlimited, and customized learning culture.
Kurniawan et al.	2023/0	The use of mobile-based technology as an interactive learning media that can improve knowledge and skills.
Suhirman & Prayogi	2023/0	Technology-integrated learning, particularly mobile applications supported by virtual simulations, can be a valuable tool in supporting the development of students' critical thinking skills.
Bahar & Soegiarto	2020/1	Android-based mobile applications can develop thinking and creativity, with an interface that is easy to understand and operate at an early age.
Rahmat et al.	2023/1	Innovative mobile-based technology can create a more engaging learning environment and provide new learning experiences that enhance students' ability to understand concepts and achieve better learning outcomes.
Huang et al.	2019/25	AR-based technology is effective in improving both learning and desire to learn compared to traditional learning models.
Sung et al.	2022/13	Learning methods with E-Book-based mobile technology can be significant in learning achievement and student learning motivation and learning motivation.
Tung et al.	2020/1	Mobile-based learning platforms can improve student achievement and increase motivation and interest in learning.

(Continued)

Table 2. Impact of interactive mobile technology on education (*Continued*)

Author	Year/Cited	Result
Chen et al.	2019/34	The use of Mobile technology in learning can influence learning motivation and create an authentic learning environment.
Zhou & Lewis	2021/4	MBCL platform can support cooperative learning that provides deep learning.
Hossain & Ahmed	2021/7	The use of technology can make learning more interesting and effective for children and provide a new dimension to education.
Dash et al	2023/0	The use of mobile technology has been successful in increasing interaction and collaboration between students, enhancing the learning experience.

3.6 Discussion

Interactive mobile technology is a combination of mobile technology, such as smart-phones, with interactive elements that allow users to interact directly with applications or learning platforms [83]. With this technology, users can not only receive information but also actively engage in the learning process, collaborate with fellow users, and create a more dynamic and engaging learning experience [13], [64]. Interactive mobile technology has changed the way education is accessed and delivered, bringing a more independent, adaptive and flexible approach to learning [63], [65], [71]. With IMT, students can access learning materials anytime and anywhere and have access to various learning tools that support the development of skills and knowledge [12], [70].

Based on the results of the systematic review, it is known that most of the research on interactive mobile technology at various levels of education, ranging from elementary to higher education. In higher education, these technologies enhance student engagement and interaction, especially in entrepreneurship-based learning, as well as offer flexibility of access to learning resources anytime and anywhere. The use of mobile-based gamification has also been shown to increase student motivation to learn, while the integration of technology in cognitive skills assessment helps teachers customise teaching methods according to student needs. At the secondary school level, AR applications and mobile-based VR technology help students understand complex concepts, improve learning outcomes and critical thinking skills through problem-based learning (PBL). Meanwhile, in primary schools, AR technology provides more immersive visualisation, improves concept understanding and learning motivation, and helps students with special needs interact better in learning. From the synthesis, the level of students' familiarity with interactive mobile technology has a significant effect on the effectiveness of its use in education at different levels of education. In higher education, students who are already familiar with mobile technology tend to adapt more easily to various digital learning platforms [84]. High familiarity with technology allows them to more easily access learning materials flexibly, anytime and anywhere, which in turn increases their engagement in learning. At the secondary school level, the impact of students' familiarity with mobile technology tends to vary more. Students who are more familiar with mobile devices and applications have a tendency to adapt and use technology more easily in the learning process [85]. They can access teaching materials and educational resources more efficiently and develop better critical and analytical thinking skills. However, for students who are less familiar with technology, they may face difficulties in utilising the full potential of the technology [49]. At the primary school level, the impact of familiarity with mobile technology is crucial to ensure

that students can make the most of the technology. Students who are already familiar with mobile devices, such as tablets or smartphones, have a greater chance of developing motor skills, creativity, and logical thinking ability through technology-based learning applications [44]. However, students who are less familiar with technology or who have little access to mobile devices may experience difficulties in using technology effectively. Low familiarity with technology may limit their ability to utilise the full potential of technology-based learning, which in turn affects the effectiveness of technology use in improving their learning outcomes [77], [78].

Overall, students' familiarity with IMT affects their level of learning engagement and motivation. Students who are more familiar with technology tend to be more motivated to participate in technology-based learning because they feel more comfortable and confident in using it [86]. In contrast, students who are less familiar may feel pressured or struggle, which could reduce their interest in the learning. Therefore, this level of familiarity is crucial in creating a more dynamic, innovative and engaging learning environment. Thus, it can be concluded that students' level of familiarity with interactive mobile technology plays an important role in determining the effectiveness of its use in education. Students who are familiar with the technology can be more active and engaged in learning, which will lead to better understanding and more optimal academic outcomes.

Overall, interactive mobile technology provides innovative solutions that enrich learning experiences, encourage active student engagement, and improve the effectiveness of educational processes at various levels. In the review, it was found that some of the findings and objectives that became the main focus on the use of mobile technology in education are aimed at increasing student learning motivation and student engagement, improving learning quality, critical thinking skills and creativity and increasing accessibility and flexibility. The use of interactive mobile technology has a significant impact on education. Through research conducted, it is evident that the use of this technology is able to increase student engagement in learning. More active interaction with learning materials and a responsive learning environment makes students engage more deeply in the learning process [65], [67].

In addition, IMT can also increase students' motivation to learn. Innovative features such as gamification, simulation, and the use of AR-based applications make learning more engaging and fun for students, thus increasing their interest in learning [13], [14], [65], [69], [74], [80]. Not only that, the use of interactive mobile technology also has a positive impact on the overall quality of learning. With easy access to diverse learning resources and interactive features, students can gain a deeper understanding of the concepts being taught [79]. This enables learning to be more effective and thorough. In addition, interactive mobile technology facilitates the development of 21st-century skills such as collaboration, creativity and problem-solving skills. This is reinforced by research by [61]; the use of interactive mobile applications significantly improves critical thinking skills, with a p-value <0.05 which indicates a significant difference between classes using applications with a PBL approach and control classes. The experimental group showed an n-gain increase of 0.67 (medium category), while the control group only achieved an n-gain of 0.18 (low category). These results indicate a higher effectiveness of using interactive mobile applications in PBL compared to traditional teaching methods. Through the use of mobile-based applications and platforms, students can engage in learning that promotes these skills, which are crucial for their preparation for an ever-evolving world [11]. Overall, interactive mobile technology has an important role to play in the transformation of education. The use of these technologies not only helps to improve learning effectiveness but also opens up new opportunities

in the delivery of learning materials, broadens the scope of learning, and develops skills relevant to the needs of the times.

The use of IMT has a close relationship with the concept of TPACK in education. TPACK is a concept that helps teachers understand how to incorporate digital technology into the curriculum by taking into account knowledge of content, pedagogy, and technology [87]. In teaching with digital technology, these three aspects are interrelated, and teachers need to combine their knowledge of subject matter, learning strategies supported by technology, and mastery of technological tools and skills. The integration of interactive mobile technology with TPACK allows teachers to create a more dynamic and engaging learning environment for students. Through an understanding of mobile technology, teachers can select and use various applications, software and other tools to enrich the learning process [56]. In addition, the use of this technology allows teachers to develop more innovative and adaptive learning strategies, according to students' needs and learning styles [88]. They can utilise the interactive features of mobile technology to facilitate collaboration among students, present learning materials in a more visual and engaging manner, and provide more direct and personalised feedback to students. Thus, the integration of IMT with TPACK not only improves learning effectiveness but also helps to create a more meaningful and relevant learning experience for students in this digital era [89].

In the research collaboration teachers were instrumental in contributing their pedagogical knowledge related to the use of digital technology in the classroom environment. Teachers also integrate their understanding of how students learn with technology [90]. After the mobile learning development is completed, teachers undergo professional training to improve their understanding of the subject matter and the necessary technical skills. This process requires teachers to internalise new knowledge and skills and align them with the existing TPACK framework. Teachers' success in implementing mobile learning largely depends on how quickly they can adapt their TPACK to the changes brought by mobile learning.

3.7 Research implications

The implication of the results of this systematic research is that the use of interactive mobile technology has great potential to bring significant changes in education. The findings from this study show that this technology can not only increase student motivation and engagement but also have a positive impact on the overall quality of learning. This suggests that education can become more effective, engaging, and relevant by utilising IMT [56]. In addition, this research also shows that interactive mobile technology can be an effective tool to prepare students for the demands of an ever-evolving world by facilitating the development of 21st-century skills such as collaboration, creativity, and problem-solving skills. Another implication is that the use of interactive mobile technology can help address various challenges in education, including issues of accessibility, flexibility, and diversity in student learning styles.

Interactive mobile technology offers great opportunities for the future of education, especially in terms of accessibility, flexibility, and personalisation of learning [91]. With mobile devices, students can learn anytime and anywhere, transcending the limitations of traditional classrooms [49]. This technology enables learning personalisation, where materials can be tailored to each student's individual learning needs and pace, thus increasing learning effectiveness [92]. In addition, mobile technology also enables easier collaboration between students and teachers, as well as quick access to various global educational resources. As mobile technology continues

to evolve, opportunities to create more dynamic, flexible, and innovative learning experiences will open up in the future [7].

On the other hand, challenges include the digital divide, limited infrastructure, and the risk of ineffective use. Without adequate training, these technologies may not be fully utilised [93]. However, with proper handling of these challenges, IMT has the potential to transform education to be more inclusive, adaptive, and relevant to future needs [56]. To overcome the challenges in implementing IMT in education, comprehensive and collaborative solutions are needed [49]. In addition, intensive training for teachers in the use of these technologies is essential so that they can effectively integrate mobile technologies into the learning process [94], [95]. With these solutions, IMT has the potential to transform education to be more inclusive and adaptive to future needs.

Interactive mobile technology provides significant advantages in learning. First, its accessibility allows students to access materials anytime and anywhere, overcoming time and place constraints. Second, its interactive properties, such as gamification and simulation, make learning more engaging. Third, its personalisation allows customisation to students' individual interests, needs and learning styles. Fourth, it facilitates the development of 21st-century skills. Finally, it improves the quality of learning and student outcomes through easy access to resources and interactive features that support concept understanding.

3.8 Limitations and recommendations

This study has limitations, mainly related to the relatively small sample size (25 articles). This sample size may affect the generalisability of the results, especially as it only includes articles published in English and derived from the Scopus database. Potential language bias may lead to the exclusion of relevant studies from countries that published articles in other languages, leading to results that may not be fully representative. In addition, as the data was collected from some limited academic databases, these results may be biased towards publications that have a tendency to be published in certain journals. Other limitations include the use of articles published within a limited timeframe (2019–2023), which may overlook important studies published before or after that timeframe. To improve the validity and reliability of the results, future studies should expand the scope of data sources to include other databases such as Web of Science and ERIC. Also, the use of more articles in multiple languages may provide a more holistic picture of the application of interactive mobile technology in global education. However, the trends in this study indicate an increase in the number of publications that is likely to continue. This is due to the increasing popularity of the topic of interactive mobile technology and the increasing interest of researchers to further develop the field. Future studies should expand the data coverage by using more diverse sources such as ERIC, Web of Science, Science Direct, and Google Scholar. As stated by [96], [97], future researchers can utilise systematic literature reviews that involve the integration and evaluation of data from various qualitative and quantitative studies. This approach provides comprehensive answers to observational predetermined research questions [98]. Therefore, future research relating to IMT and its impact on education should incorporate more data sources to gain a more holistic understanding. Based on the findings of this study, future research could focus on the context of applying interactive mobile technology in various learning models, like PBL, collaborative learning, and the application of technology in inclusive education.

4 CONCLUSION

This bibliometric research and systematic literature review highlights significant trends in the use of interactive mobile technologies in education over the past five years (2019–2023). The findings suggest that interactive mobile technologies play an important role in supporting sustainable education. Indonesia and China emerged as the most prolific contributors in research publications on this topic. At the university level, research on interactive mobile technology is quite frequent, with Indonesia leading the way in this area. This research shows that interactive mobile technology has a major positive impact on education by improving students' motivation, engagement, learning quality, critical thinking skills and creativity. In addition, these technologies also increase the accessibility and flexibility of learning. These technologies have great potential to drive positive change for both students and educators. By integrating these technologies effectively, education can become more dynamic, and relevant to the demands of the times.

Educators, policy makers and technology developers should focus on concrete steps to maximize the benefits of interactive mobile technologies. Policymakers need to integrate these technologies into the curriculum and provide training for educators, while technology developers should create easy-to-use solutions. To address the digital divide, concerted efforts are needed, including government initiatives to provide devices and internet access in underserved areas, as well as partnerships between educational institutions and the government to accelerate the development of needed infrastructure. Further research is needed to explore the application of IMTs in various learning models, like PBL, collaborative learning and inclusive education, to better understand how these technologies can meet diverse learning environments and needs. Expanding data sources in future research, such as incorporating databases like Web of Science and ERIC, and considering research in multiple languages will also provide a more comprehensive global perspective on the impact of IMTs. By focusing on these areas, IMT can be a transformative tool that improves the quality of education and prepares future generations for the challenges ahead.

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6 REFERENCES

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7 AUTHORS

Muhammad Abdul Ghofur is a Lecturer at Faculty of Economics and Business, Universitas Negeri Surabaya, Indonesia. Apart from teaching, he is also active in conducting research and community service. Several international publications indexed by Scopus so far there are 6 titles (H Index 2), 2 books with ISBNs and 28 copyrights that have been produced by the research team. He focus on field of economics education, digital learning, and pre-service teacher (E-mail: muhammadghofur@unesa.ac.id).

Binar Kurnia Prahani is a Lecturer at Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Indonesia. Apart from teaching, he is also active in conducting research and community service. Several international publications indexed by Scopus so far there are 136 titles (H Index 16), 19 books with ISBNs and 117 copyrights that have been produced by the research team. He focuses on digital learning, science-physics innovative learning, bibliometric analyse, and educational design research (E-mail: binarprahani@unesa.ac.id).

Irgy Redityo Dawana is a postgraduate student in the Department of Science education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Indonesia.

Utama Alan Deta is a Lecturer at Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Indonesia. Apart from teaching, he is also active in conducting research and community service. Several international publications indexed by Scopus so far there are 80 titles (H Index 11), 21 books with ISBNs and 23 copyrights that have been produced by the research team. He focuses on STEAM Education especially on ethno-physics, physics local wisdom, science literacy, and quantum physics (E-mail: utamadeta@unesa.ac.id).

Yeni Anistyasari received her master's degree in informatics from Institut Teknologi Sepuluh Nopember (ITS) Surabaya. She then pursued doctoral studies in Vocational Education at Universitas Negeri Surabaya (UNESA). Since 2015, she has been a faculty member at the Information Technology Education program at UNESA. Her research interests include learning analytics, adaptive learning, computer science education, vocational education, and psychometric analysis. Her research contributions have been disseminated through numerous scientific publications, encompassing studies on artificial intelligence-based educational tools, computational models for student assessment, and the development of vocational curricula.

Muhammed Akif Kurtuluş is an academic researcher affiliated with Alanya Alaaddin Keykubat University, Antalya, Turkey. His research interests focus primarily on educational technology, STEM education, bibliometric analysis, interactive learning environments and the integration of innovative technological approaches into teaching and learning processes. With a special emphasis on interactive mobile technology and its impact on educational practices, he aims to enhance learning motivation, engagement, creative thinking skills and critical thinking skills through advanced technological applications. Additionally, he collaborates on interdisciplinary research projects that bridge the gap between pedagogy and technology to develop effective, inclusive, and future-oriented learning methodologies. His work also addresses the challenges and opportunities presented by mobile learning platforms in various educational contexts.