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Education and smart technologies: towards a new pedagogical paradigm

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ABSTRACT

Smart education, a new field of technology related to education, has emerged as a unique response to current educational challenges. This is becoming increasingly important for academic progress and aligns with the transformative impact of technology. This study addresses the transformative impact of smart technologies on education, focusing on the integration of the internet of things, big data, and artificial intelligence. Through a bibliometric and content analysis based on Scopus and Web of Science databases, we identify the most active researchers, leading universities, and the countries that contribute most significantly to the field of smart education. The findings reveal a significant increase in related publications, highlighting the growing importance of these technologies in enhancing teaching and learning experiences. The study shows the advantages and challenges of adopting such technologies, providing insights into their practical applications and the future direction of educational innovations. Integrating smart technologies in education is crucial for improving quality of life and academic outcomes, necessitating further research and development to fully realize their potential. This research contributes to the understanding of technological impacts on education and supports the development of strategies for their effective implementation.

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1. INTRODUCTION

In today's digital landscape, technology has become a central force in transforming the educational landscape, not only by capturing learning content but also by revolutionizing the evaluation of courses [1]. The integration of information and communication technology in education (ICTE) has made learning models more adaptable and flexible, enhancing the overall student learning experience [2]. Cutting-edge technologies such as the internet of things (IoT), big data, artificial intelligence (AI), and cloud computing have collectively advanced the concept of smart education, placing learning at the forefront of the ICT paradigm. Through e-learning and m-learning platforms, students can now engage in educational experiences that transcend traditional boundaries, allowing seamless knowledge transfer across different contexts, whether formal or informal [3].

In this context, "smart" denotes the effectiveness and purpose-driven nature of the technologies and devices used [4]. Connected, portable devices such as smartphones, laptops, and virtual reality (VR) headsets allow learners to engage in education anytime and anywhere [5]. On the software side, "smart" refers to

interoperability and flexibility, emphasizing the importance of personalized learning experiences tailored to individual needs through advanced technologies.

Smart education is a technology-driven system designed to enhance both educators' capabilities and students' learning experiences [6]. By creating more efficient, effective, and comfortable learning environments, it meets the evolving demands of 21st-century life and work. The integration of emerging technologies within this framework has attracted significant research interest, as it continuously evolves and redefines the educational landscape [7]. This model focuses on developing smart learning environments that offer personalized learning services and cultivate students' talents, preparing them for modern challenges [8]. The ongoing advancement of smart education highlights its transformative impact on educational infrastructure, making learning environments more engaging and intelligent [9]. By improving learning quality and fostering creativity and personal skills, smart education benefits both students and teachers, enabling the latter to refine their skills and deliver tailored learning experiences [10]. The core components of smart education include technology, innovative pedagogy, proactive teachers, and actively engaged students [11].

In light of these advancements, this study presents a comprehensive bibliometric analysis of smart education, focusing on the adoption and effectiveness of emerging technologies in enhancing learning environments. By examining current trends and developments, the research evaluates their global impact on the educational process and offers insights into how they are shaping the future of education. The main goal is to bridge the knowledge gap between the implementation of smart technologies and their impact on educational outcomes. The study also provides an overview of how these technologies are transforming educational practices and aims to project future trends as they continue to evolve, providing practical recommendations for educators, policymakers, and researchers on effectively integrating these tools to improve educational quality and accessibility.

2. METHOD

In this study, we undertook a comprehensive analysis of the trend of smart education, particularly in relation to the various technologies employed to enhance teaching and learning. To accomplish this, we amalgamated data from two databases, Scopus and Web of Science. This approach enabled us to gather a vast amount of data necessary for this study [12].

We defined specific search keywords to streamline our data collection process. These keywords included 'smart education', which was further combined with terms related to emerging technologies such as, 'big data', 'internet of things', 'artificial intelligence', 'virtual reality', and 'augmented reality'. These keywords were essential for guiding our search and collecting relevant data. We also established a time frame from 2012 to 2024 to offer a current perspective on advancements in smart education. Additionally, we focused on research articles and conference papers to keep the credibility and relevance of our sources. This approach allowed us to compile a large dataset, including 378 documents from 227 distinct sources, contributed by 241 authors. This comprehensive dataset formed the basis for our detailed analysis of trends and developments in smart education.

3. RESULTS AND DISCUSSION

3.1. Bibliometric analysis

This section presents the results of our bibliometric analysis, based on data from the Web of Science and Scopus databases. The analysis offers a comprehensive overview of the evolution of technologies related to smart education from 2012 to 2024. It also identifies the most active authors, institutions, and countries that have made significant contributions to publications in the field of smart education technologies.

3.1.1. Annual scientific production publishing

The advent of smart education through technology appears to have begun in 2013, marked by the pioneering contributions of several researchers [13]–[15]. These were the only three papers published that year. Our bibliometric analysis indicates a 15.53% annual growth rate in the scientific output of the smart education field from 2013 to 2024, with this trend observed from 2013 to 2023 as shown in Figure 1. However, in 2024, up to March, there were 10 articles published: four on AI technology in smart education [16]–[20]; three on the internet of things [1], [21], [22]; and one on big data and cloud computing [23].

In 2023, there was 82 articles published, marking the highest annual increase in publications and reflecting the field's significant growth. The surge in publications between 2019 and 2021 is due to the increased demand for education-related technology during the COVID-19. As the field of smart education continues to evolve with the integration of recent technologies, the number of scientific contributions is expected to rise annually, particularly driven by advancements in these emerging technologies.

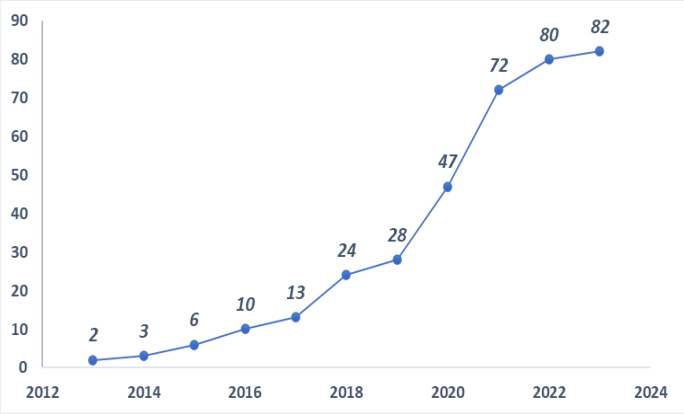

Figure 1. Annual scientific production of articles

Table 1 provides a comprehensive overview of the most prolific sources of publications in the realm of education technology. The data highlights both the productivity and impact of these sources over time. Leading the list is "Concurrency and Computation Practice and Experience" which stands out as the most influential source with 192 citations, averaging 27.45 citations per year. Following closely is "Future smart cities requirements, emerging technologies, applications, challenges, and future aspects" with 168 citations and a robust average of 21.25 citations per year.

"Future Generation Computer Systems" holds a notable position with 137 citations, reflecting an average of 19.80 citations annually. The "International Conference on Control, Instrumentation, Communication, and Computational Technologies" is also significant, accumulating 133 citations at an average rate of 13.30 citations per year. "Procedia Computer Science" also contributes substantially with 125 citations, sustaining an average of 13.60 citations annually. Additionally, the "International Journal of Communication Systems" is recognized for its impact, receiving 115 citations and averaging 16.75 citations per year. A key observation from the data is the presence of conferences among the listed sources. This trend highlights the significant role of conferences in the current research landscape of education technology, underscoring the dynamic and evolving nature of the field.

Table 1. Top 10 prolific publication citations

Publication sources	DOI	Total citations	Publication year
Concurrency and Computation: Practice and Experience	10.1002/cpe.4515	192	2019
Future smart cities requirements, emerging technologies, applications, challenges, and future aspects	10.1016/j.cities.2022.103794	168	2022
Future Generation Computer Systems	10.1016/j.future.2017.06.023	137	2018
International Conference on Control Instrumentation Communication and Computational Technologies	10.1109/ICCICCT.2015.7475301	133	2016
Procedia Computer Science	10.1016/j.procs.2018.05.095	125	2018
International Journal of Communication Systems	10.1002/dac.3981	115	2019
Behaviour and Information Technology	10.1080/0144929X.2018.1467967	66	2018
Education and Information Technologies	10.1007/s10639-020-10116-4	65	2020
Information Systems Frontiers	10.1007/s10796-022-10248-7	49	2022
International Journal of Multimedia and Ubiquitous Engineering	10.14257/ijmue.2013.8.6.31	49	2013

3.1.2. Most active authors and countries publishing articles

Figure 2 illustrates the geographical distribution of 378 documents, highlighting the top 10 countries with the most publications in technology-related education. Research interest in technologies associated with smart education spans 44 countries. However, it is noteworthy that only 18% of these countries have published more than 10 articles. As shown in Figure 2, China emerges as the most prolific contributor, accounting for over 38% of the total corpus with 144 articles. Other significant contributors include India (59 contributions), South Korea, and the United Arab Emirates (each with 14 contributions), as well as Japan, the United Kingdom, and the United States (each with 11 contributions), and Saudi Arabia with 10 contributions. These findings underscore the global dynamics of research in the field of smart educational technologies, highlighting a significant concentration of contributions in certain regions, particularly in China, while other countries also play a notable role in this scientific exploration.

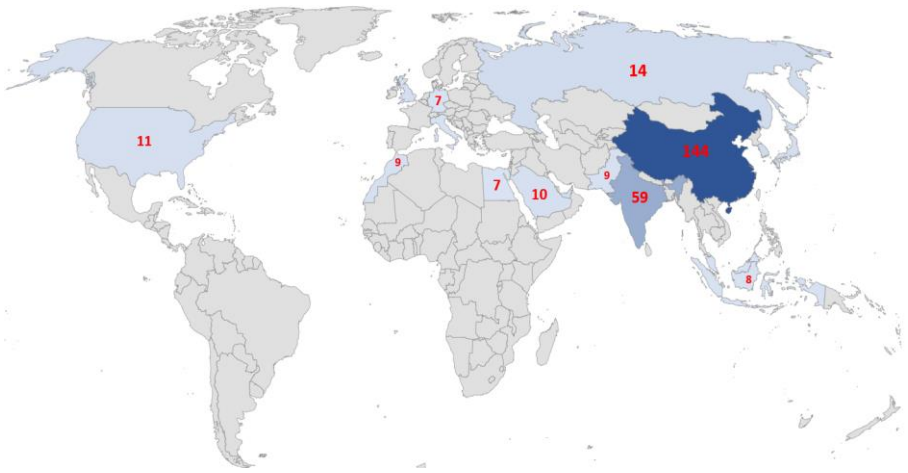

Figure 2. Top 10 countries with the most publications in technology-related education

Figure 3 provides an insightful overview of the top 10 authors who have played pivotal roles in shaping the landscape of technologies associated with education. A close examination of the data brings to light the noteworthy contributions of these influential authors. At the forefront, Guo emerges as a highly prolific contributor with a total of 5 articles and an H-index of 15. Following closely are Ogawa and Embarek, each having made a significant impact with 4 articles and H-indices of 11 and 7, respectively. What sets these authors apart is not only the volume of their contributions but also the consistent quality reflected in their H-indices, underscoring the scholarly impact of their work.

It is noteworthy that Guo, Ogawa, and Embarak began their research in this field in 2020 and 2022, respectively. This timing highlights the recent yet significant impact these authors have made in the realm of educational technologies. Their swift entry into the field underscores the rapid establishment of their influence within a brief period. Figure 3 not only acknowledges these prominent authors for their substantial contributions but also provides a chronological perspective, shedding light on the evolution of their scholarly involvement with education-related technologies.

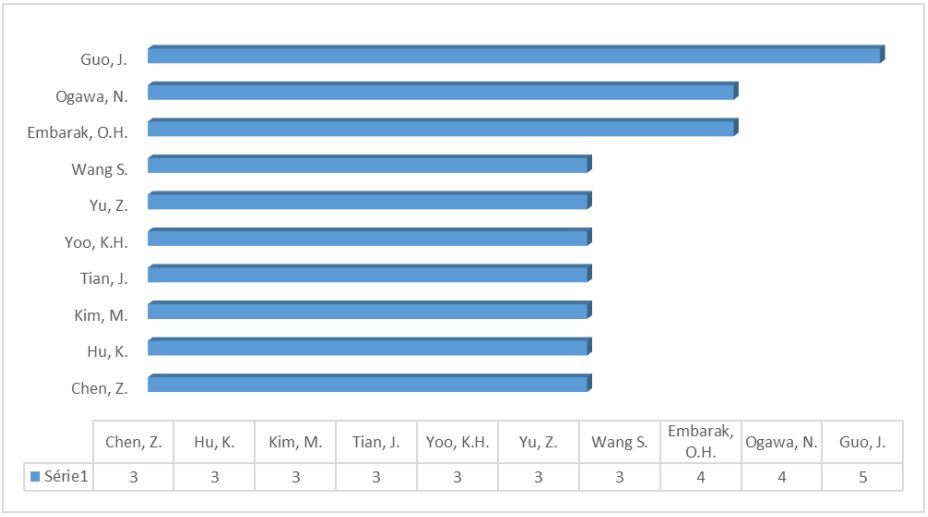

Figure 3. Top 10 authors' production over time

3.1.3. Analysis of keywords, mapping networks, and trending topics in this study

The keyword network map serves as a valuable tool for delving into the intricacies and structure of a scientific field, offering insights by dissecting the relationships among keywords within that domain. In Figure 4, we observe a visual representation of the intricate web of relationships formed among keywords in

studies related to the subject at hand. Analyzing the map involves considering factors such as color-coding, size, and connectivity of the keywords, from which we can draw significant inferences. It becomes evident that smart education stands out as a central and pivotal theme, highlighted by its prominence in the network. The interweaving of smart education with emerging technologies like the IoT, big data, AI, and VR is particularly noteworthy, forming a compelling nexus that holds immense potential for future research.

The amalgamation of these key elements not only underscores the contemporary focus of scholarly work but also hints at the trajectory of advancements in the field. Moreover, the analysis of keywords such as smart education in conjunction with specific emerging technologies like augmented reality, internet of things, and artificial intelligence points to a sustained and evolving emphasis on exploring the synergies and implications of these technologies within the educational landscape. This interconnectedness reveals a dynamic landscape, providing researchers and stakeholders with valuable insights to navigate the evolving contours of smart education and its intersection with cutting-edge technologies.

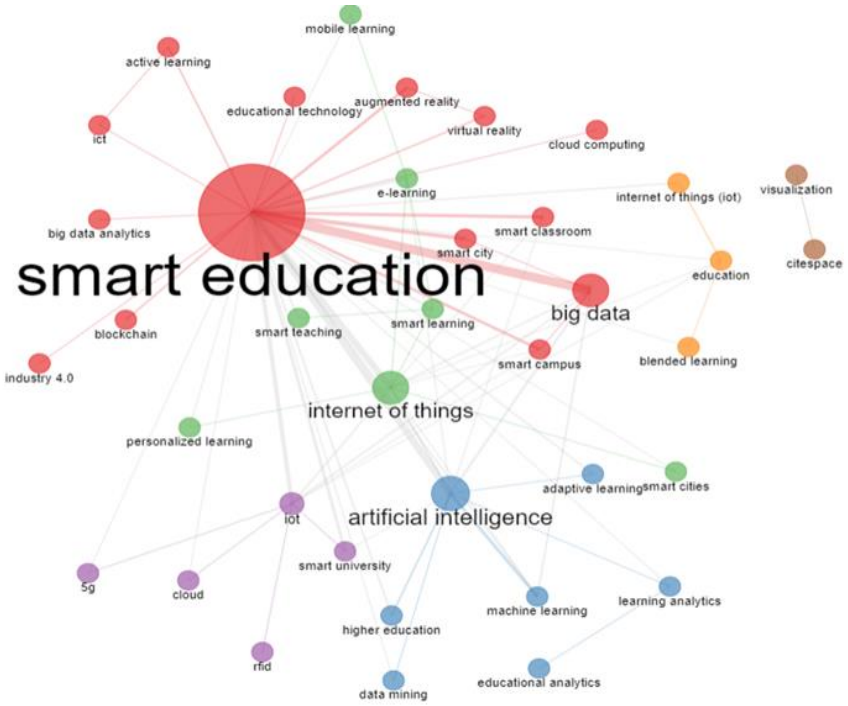

Figure 4. Co-occurrence keyword network highlighting the most used and recurring keywords

Over the past decade, from 2013 to 2023, the frequent use of keywords such as "internet of things," "big data," and "artificial intelligence" reflects a significant trend in integrating these cutting-edge technologies into smart education. The consistent appearance of these terms highlights their crucial role and increasing importance in discussions about technological integration in education. This temporal analysis underscores the ongoing interest in and exploration of the diverse applications of these technologies within the educational sector. Additionally, our network mapping visually represents the complex interconnections among these key terms and their related counterparts. This visualization captures the thematic relationships and offers a comprehensive view of the synergies and dependencies within the educational technology landscape. When combined with our detailed keyword analysis, as illustrated in Figure 5, this mapping offers valuable insights.

By integrating network mapping with keyword analysis, we provide a nuanced understanding of the prevailing knowledge in technology-related education. This dual approach enables scholars, researchers, and practitioners to navigate the complexities of technological integration in education, fostering a deeper appreciation of the current landscape, and paving the way for informed exploration and innovation in the future.

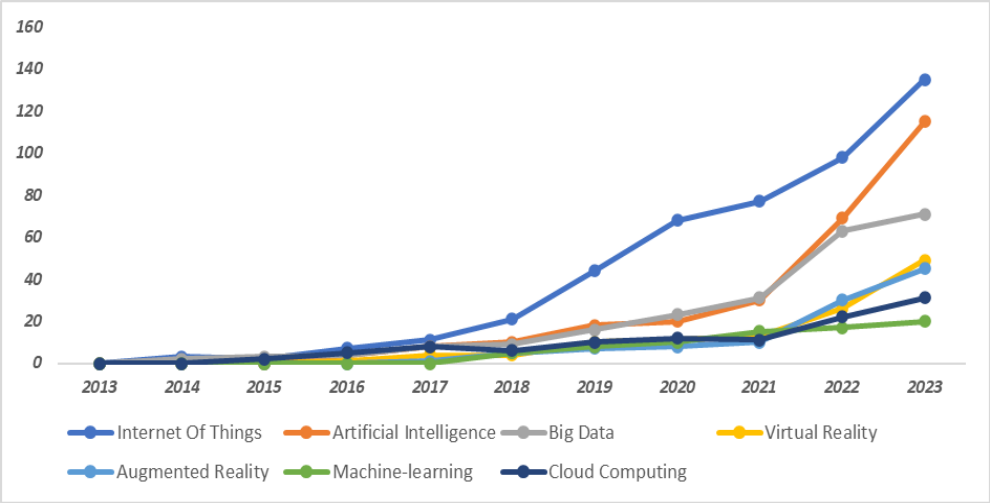

Figure 5. Evolution of dynamic keywords over time

3.2. Branch fields of smart education

Following our bibliometric study in the previous section, we have identified a range of technologies employed in the realm of education, along with pertinent articles brought to light by this initial bibliometric investigation. In this section, we will delve into each technology's relationship with education, highlighting the unique limitations of each. This section explores the diverse landscape of smart education, covering developments in infrastructure such as smart campuses and key technologies including the internet of things (IoT), artificial intelligence (AI), big data, virtual reality (VR), and augmented reality (AR).

3.2.1. Smart campus

A smart campus is an innovative concept that integrates education, technology, and services to create a comprehensive learning environment. This concept is founded on emerging technologies and next-generation infrastructures, including the IoT, big data, virtual technology, and mobile technologies. These technologies facilitate the integration and sharing of diverse educational information, as highlighted by Mahariya [24]. From an educational perspective, the smart campus aims to develop an appropriate pedagogy by constructing a digital and responsive platform. This platform primarily provides intelligent services to various stakeholders, including administrators, teachers, students, parents, and the public.

The smart campus introduces a new educational paradigm known as "smart education", which encompasses smart teaching, research, interaction, administration, classrooms, and services [25]. The goal is to establish an effective, practical, and comfortable teaching environment for the university community. This approach not only enhances the student experience but also bolsters the university's capacity to contribute to societal development. The proliferation of technologies and networks has significantly influenced numerous educational applications and platforms. At the same time, the widespread use of smartphones and smart cards, particularly those based on radio frequency identification (RFID), has reached a level that enables the virtualization of smart campus structures [26]. As the number of learners increases, traditional logistics services and campus administrators may struggle to meet students' daily needs. Therefore, integrating IoT and AI into the education sector is crucial for continually enhancing university operations.

However, several challenges associated with traditional campus management must be addressed to successfully build smart campuses. Digitizing campus services and utilizing appropriate technological equipment can provide instructional knowledge and stimulate innovative research within the campus. Furthermore, training students in network security can lead to significant community advancements and advanced cybersecurity training. Various technologies, such as home networks and sensor networks, have been developed and deployed to meet these needs. Network coverage is conceptualized as a virtual environment utilized in education to fully leverage technological advancements, ensuring that the benefits of these developments are realized within the educational context [27].

3.2.2. Big data in education

Data collection is not a new concept for educational institutions. For years, educators have gathered data on metrics, such as success rates, dropout rates, and student enrolment. These calculations have traditionally been straightforward, often not requiring technological intervention [28]. However, with the

advent of technology, the volume of data generated by various devices has increased, presenting new challenges in managing and interpreting this vast information. To address the challenges, several applications and technologies are being developed to effectively store and analyze data. Educational professionals are optimistic about the potential of big data analysis to offer deeper insights into student performance.

Big data, often defined by the "3 Vs"-variety, velocity, and volume, presents unique challenges when integrated into educational systems. Traditional methods often fall short in this regard, as they cannot typically provide immediate feedback to students and require teachers to spend considerable time on repetitive tasks. Moreover, these methods do not offer students practical guidance on improving their academic performance. In contrast, modern digital learning tools, which track students' learning patterns and provide real-time feedback, can significantly enhance student outcomes-skills that are generally absent in traditional educational approaches [29]. Understanding students' needs and challenges is crucial for universities, enabling them to better support students in their studies and assess course difficulty levels. Visualizing data plays a key role in this process, assisting teachers in guiding students' attention to specific areas. This is an essential aspect of responsible teaching and learning, which big data can facilitate [30].

Despite its significant benefits, the use of big data in education presents several challenges. First, the systematic collection of large volumes of data requires the development of specific technologies and applications for effective management and analysis. Second, integrating big data into existing educational systems can be complex, as traditional methods may not accommodate the need for immediate feedback and often demand excessive time from teachers for repetitive tasks. Third, the increase in data collection raises concerns about the confidentiality and security of student information. Finally, the current educational system has inherent weaknesses that can contribute to high student dropout or failure rates [31]. These challenges highlight the need for a balanced and thoughtful approach to incorporating big data into education.

3.2.3. Internet of things in education

The advent of the IoT marks a significant milestone in technological evolution. Introduced by Ashton, co-founder of the auto-ID center, in 1999, IoT refers to a smart technology that minimizes human intervention and facilitates easy access to physical devices. Essentially, IoT is a global network infrastructure and service that connects numerous devices via the internet [32]. In today's world, technology permeates every aspect of our lives. From RFID tags to smart devices, IoT merges the virtual and physical realms, enabling seamless data flow between the real and digital worlds, regardless of time or place [1]. When integrated with other technologies, IoT fosters a smart learning environment, enhancing students' knowledge and skills.

In a smart education environment, students can become active knowledge partners, accessing resources and materials from any location and on any device at any time. This effortless connectivity between learners and their tools transforms the traditional educational system, empowering students to access unlimited digital resources beyond the constraints of conventional education [33]. Despite its immense benefits, IoT also presents several challenges, including risks of data theft and privacy loss, which can significantly impede the implementation of IoT systems. Privacy breaches, for example, can delay the deployment of these systems for months. Additionally, IoT systems are vulnerable to malicious cyberattacks due to their internet connectivity [34]. Data security is a critical concern for IoT, as numerous devices, including remote and field devices like RFID, connect to the internet via 4G, 5G, and NFC. To prevent data leaks, falsifications, or thefts, major institutions must employ robust systems and architectures. This is particularly crucial as these institutions need to collect substantial data from multiple devices connected to the internet [35].

Understanding and collecting data pose significant challenges for institutions, complicating the scalability of IoT systems in educational settings. Research by Dhar, Khare, and Singh highlights that data scalability becomes problematic when IoT systems are implemented in a decentralized manner [36]. To ensure continuous operation and provide sustainable, accessible, and available solutions, institutions require significant funding for their IoT projects. Timely procurement of these services and applications is essential to avoid delays that could inconvenience users. Furthermore, the use of IoT technologies in education risks promoting standardized knowledge, which can diminish the diversity of cultural expressions among beneficiaries. Overcoming obstacles such as the unavailability of basic technological infrastructure is crucial for creating the necessary conditions to implement new strategies that leverage IoT to improve learning.

3.2.4. Artificial intelligence in education

Artificial intelligence is a new field that employs computer programming to create machines capable of performing tasks with a level of accuracy that often surpasses human capabilities. In the educational sector, AI technology can personalize a student's learning experience based on their individual needs and abilities. For instance, AI can generate exercises tailored to a student's learning level and capabilities, making education more accessible and effective [37]. Additionally, AI assists teachers by identifying students who

may be struggling, thereby enabling targeted intervention. It also helps reduce repetitive tasks, allowing teachers to focus on more critical aspects of teaching, such as developing customized and adaptive learning programs based on student feedback. This enhances the potential for personalized instruction and improves the overall learning experience. For example, AI can automate exam grading, significantly reducing the time teachers spend on this repetitive task [4]. However, while AI can enhance educational practices, it lacks human qualities such as empathy, benevolence, and cognitive flexibility. Therefore, AI serves more as an assistant to teachers rather than a replacement. Many students find e-learning classes practical and effective, largely because these classes offer personalized learning experiences. They allow students to learn at their own pace and according to their interests. Additionally, smart tutors powered by AI provide immediate feedback, helping students stay motivated and focused throughout their courses [38].

Artificial intelligence is making significant strides in education by analyzing students' learning styles and existing knowledge to provide personalized instruction. AI can create individualized lesson plans that target areas where students need more practice and offer tailored tutoring to enhance their knowledge and skills. One of the most significant advantages of AI is its ability to automate grading, even for abstract assessments like essays, saving teachers a considerable amount of time [39]. Moreover, AI can provide feedback on course quality by identifying trends in student performance, allowing educators to refine their teaching materials and methods. AI also plays a role in creating smart content and personalized learning programs based on learner input. Examples of AI in education include Duolingo, a language learning app that personalizes lessons; ALEKS, an AI-powered math learning platform that provides adaptive assessments and personalized learning plans; and Coursera, which uses AI to recommend courses to students based on their interests and previous learning history [40], [41]. These examples demonstrate how AI is revolutionizing education by making it more personalized, efficient, and effective.

Despite its many advantages, implementing AI in education presents unique challenges. The need for advanced infrastructures and an innovative ecosystem can be a significant obstacle, especially in developing countries. Additionally, issues of inclusion and equity arise, as AI could potentially widen existing technological, economic, and social divides [42]. Teachers must acquire new digital skills to use AI effectively, and AI developers need to understand pedagogical methods to create sustainable solutions. As education becomes increasingly data-driven, ensuring the quality of data is crucial, making it essential to improve data collection and systematization processes [43]. Ethical concerns also emerge with AI integration, as it could perpetuate systemic biases and exacerbate inequities. Furthermore, not all students or educational institutions have equal access to advanced technology, which can limit AI's effectiveness. Privacy is another significant concern, as AI systems often rely on collecting and analyzing large amounts of student data. Many educators may lack familiarity with AI technologies or the ability to integrate them effectively into their teaching practices [37]. Overreliance on AI can also impede the learning process by diminishing students' abilities to think critically and creatively. While AI provides personalized learning and instant feedback, it cannot replace the human and emotional support essential for student success.

3.2.5. Virtual and augmented reality in education

In the future, educational institutions are expected to integrate VR and AR into their curricula. This shift is anticipated due to continuous advancements in new technologies and mobile hardware, alongside the growing popularity of mobile devices and terminals. Creating a multi-sensory learning environment can significantly enhance learner comprehension by engaging multiple senses. Technology can convey information visually, supplemented by multimedia explanations provided by teachers, thereby enriching the learning process by involving all five senses [44]. VR technology offers immersive experience by simulating touch, sight, and hearing through its applications. It utilizes 3D graphics to generate artificial environments, allowing students to be fully immersed in a virtual world. This immersion can lead to significant changes in students' daily lives and activities, as VR creates the illusion of being in a different location altogether [45]. In educational settings, VR lessons incorporate vibrations, sounds, and graphics, enhancing the overall learning experience. One of VR's primary benefits is facilitating effective communication, as students can engage more deeply in discussions through virtual interactions. This novel form of communication between a virtual teacher and students is further enriched by the immersive nature of VR [46].

Both VR and AR are making significant strides in education. For example, google expeditions is a popular AR application that allows students to interact with 3D objects in the classroom, covering a wide range of topics from technological history to lunar expeditions. Another AR application, SkyView, enables students to explore the universe using AR overlays of the night sky [47]. VR, on the other hand, can facilitate virtual field trips, immersing students in historically significant events or exotic locations without leaving the classroom. Additionally, VR can simulate laboratory environments, providing a safe and controlled space for students to conduct experiments.

However, integrating VR and AR into educational curricula presents several challenges. The cost of implementation can be high, requiring specialized equipment and software, as well as significant investment in devices and training to ensure effective use [48]. Technical glitches or compatibility issues can disrupt the learning experience, and these technologies can be complex, necessitating advanced technical skills to develop and maintain. Many educational institutions may lack awareness of new EdTech trends, hindering their ability to adopt cutting-edge technologies such as VR [49]. Furthermore, as VR is a relatively new technology, there is a shortage of high-quality content, which can be a barrier to its implementation in schools. Extended use of AR/VR can also lead to health and safety concerns, such as headaches, motion sickness, and eye strain. Additionally, not all students have access to the necessary devices or internet connectivity to fully engage with VR and AR technologies. With the increase in data collection and analysis, concerns about the privacy and security of student data are also prevalent. These challenges underscore the need for careful planning and consideration when integrating VR and AR technologies into the educational curriculum [50].

3.3. Discussion

Education is in a constant state of evolution, driven by the development and implementation of new technologies. COVID-19 has accelerated this transition, pushing traditional educational approaches toward digital modalities. As we progress further into the digital age, students of the future will need to acquire 21st-century skills and master advanced digital technologies essential for new job roles. This shift towards digital technology is a key aspect of the ongoing industrial revolution. Future economies will increasingly rely on well-educated students, making the need for a smart learning system more critical than ever.

Effective education is heavily dependent on technological advancements. New tools and methods help teachers and students enhance their understanding. We believe that smart educational systems, which leverage technology to improve sustainability, are essential for preparing students for the future. Technology is driving the need for new educational systems, making learning more accessible and easier for everyone. Smart schools are focusing on technologies such as AR, AI, big data, IoT, and VR. From an educational perspective, teaching with technology allows students to understand course material across time and space and connect with the real or virtual world. This approach ensures that they can apply their knowledge to a variety of problems, even those far removed from the real world. Students and teachers can experience this through smart classrooms, laboratories, simulation centers, and other educational tools. According to Bajaj and Sharma [37], incorporating these intelligent environments into the learning process enables students to tackle more realistic problems. These tools help students visualize and simulate real-world situations and challenges. However, transitioning to a technological learning system can lead to issues in classroom management and administration, as well as financial constraints for universities. These difficulties often persist due to the complexities in understanding the systems being taught.

The implementation of new forms of technology in the education sector offers numerous benefits. These include the ability to predict solutions for the future of universities and the potential for changes in higher education methods. It is crucial to fully utilize e-learning technology. Students benefit from learning with technology, as they enjoy using it and are naturally inclined to understand what their teachers explain due to the availability of educational resources. The integration of technology into education allows individuals to realize their potential for creation and learning. Students learn more effectively when they use technology to understand what their teachers teach. This advantage of using technology in schools underscores why it should be included in the education system. Numerous studies show that students easily adapt to the technology they have access to, helping them adjust to their classes and learn new information and skills in their respective fields. Additionally, using technology helps students develop teamwork and metacognitive skills. This leads to a better understanding among students and their teachers by encouraging them to interact with different sources of data and information. Tools such as computers aid student learning by providing a way to measure progress, making it easier for tutors to identify struggling students.

However, the integration of technology into education systems presents several challenges. Teachers must enhance their understanding of technology and IT to effectively incorporate new technologies into their classrooms. This can lead to issues such as software bugs and hardware malfunctions. Teachers must rapidly adopt new technological trends to stay current and competitive, integrating technology into their lessons rather than replacing traditional teaching methods. Additionally, students need to make optimal use of the technology they already have, rather than diversifying their use of different technologies. Universities often face budget and financial constraints that hinder their ability to utilize new tools and technologies, which can impede the evolution of these technologies and increase the costs associated with acquiring new equipment.

Focusing on these technologies, we have identified that the IoT and AI are the most widely used cutting-edge technologies in the field of learning. Specific research has demonstrated that smart campuses utilizing IoT establish intelligent systems that enable smart parking and smart classrooms, as presented by Valks *et al.* [27]. The integration of data from IoT and physical devices emerges as a solution to address

various institutional challenges, as many schools require this technology to collect data from sensors and devices. The potential applications of IoT for students with special needs are extensive, encompassing collaborative learning tools and smart devices that create intelligence-enhanced learning environments. Continuing the exploration of the impact of technology on education, Table 2 presents a detailed comparison between traditional and smart education within the realm of emerging technologies. This comparative analysis aims to shed light on the transformative effects that technological advancements, particularly those related to IoT, AI, and other cutting-edge innovations, have on educational practices.

Table 2. Comparison between traditional and smart education

No	Properties	Traditional education	Smart education
1	Technological integration	Limited	Extensively
2	Progress monitoring	Classroom only	Through technology
3	Content creation	Classroom only	Through technology
4	Communication	Classroom only	Through technology
5	Blended learning	Not possible	Possible
6	Gamification	Limited	Higher
7	Absence	Limited	Enhanced
8	Collaboration tools	Limited	Higher
9	Evaluation	Prefixed	Continuous
10	Interaction	Limited	Enhanced
11	Learning environment	Fixed	Anytime & anywhere
12	Results display	Prefixed	Anytime & anywhere
13	Feedback	Classroom only	Anytime & anywhere
14	Affordability	leads to more cost	cost-effective
15	Flexibility	Limited	Much better

Our findings underscore the significant roles that the IoT and AI play in revolutionizing smart education. Smart campuses equipped with IoT capabilities not only enhance the functionality of educational facilities but also improve the management and security of educational data. Similarly, AI is transforming traditional educational methodologies by personalizing learning experiences and providing adaptive educational content. A comparison between traditional and smart education systems reveals that smart education offers extensive benefits, including increased flexibility, continuous assessment, and broader opportunities for interaction and engagement. These advantages highlight the necessity for educational institutions to embrace technologies to remain relevant in an increasingly dynamic educational landscape.

Furthermore, our study indicates that various technologies promote learning within the new constructivist pedagogical paradigm. By utilizing these technologies, student performance is enhanced as they can progress at their own pace and according to their individual needs. Current information systems, along with the development of tools to promote smart learning, enable both learners and teachers to maximize their potential for learning and creativity. As new protocols, standards, and technologies continue to emerge, continuous education about these advancements is essential to fully understand the potential of next-generation technologies. While the potential of smart education technologies to revolutionize the educational landscape is immense, their effective implementation requires ongoing research to explore their full capabilities and to ensure their integration is beneficial, secure, and equitable. Continuous investigation is necessary to understand and expand the possibilities offered by these technological advancements, ensuring that they are harnessed to their fullest potential.

Developing sustainable models for technological integration in education is a crucial next step. These models must account for the diverse needs of learners and focus on strategies that promote equity and accessibility for all students, regardless of their socio-economic background. In this context, it is also vital to enhance the digital skills of teachers. As key facilitators in the adoption of smart technologies, teachers require continuous training to integrate these tools meaningfully into their pedagogical practices. Additionally, with the increased use of technologies such as IoT and AI, prioritizing data security and protection becomes paramount. Educational institutions must establish robust infrastructures and security protocols to safeguard sensitive information about students and staff. Ensuring data protection will foster trust and enable more widespread and effective use of these technologies.

Promoting interoperability and system compatibility is equally important to maximize the benefits of smart technologies. Different systems and technological tools must be compatible and able to operate together seamlessly to enhance efficiency and fluidity in educational processes. This interoperability supports a more cohesive and integrated technological environment in schools and universities. Moreover, adopting a learner-centered approach is essential, as smart technologies offer significant opportunities to personalize learning based on individual student needs. Such pedagogical approaches can greatly enhance the educational

experience by catering to the unique learning styles and paces of each student. Finally, promoting equity and accessibility remains a fundamental objective. All technological initiatives must be inclusive and accessible to all students, ensuring that the benefits of smart technologies do not create new inequalities but instead help to reduce existing gaps. Educational policies must be designed to support this inclusivity, thereby fostering a fair and equitable learning environment for everyone.

4. CONCLUSION

The analysis reveals a clear upward trend in article production within this field, underscoring the importance of examining prolific researchers, frequently used keywords, and research hotspots. These insights not only highlight key research areas but also identify future priorities, offering valuable guidance for emerging scholars. Furthermore, the study explores various aspects of intelligence in education, including smart campus initiatives, big data, IoT, AI, VR, and AR, emphasizing their transformative impact on smart education. The integration of these technologies has led to more interactive and personalized learning environments, enhancing the efficiency and adaptability of knowledge acquisition. However, this transformation also introduces significant challenges related to infrastructure, teacher training, and data management. To fully harness the benefits of smart education, it is crucial to address these challenges through strategic development and ongoing research.

Educational institutions should focus on several key areas to successfully integrate smart technologies into education. First, they must invest in infrastructure, including hardware upgrades and secure data management systems. Comprehensive teacher training programs are also crucial, as they facilitate the effective incorporation of these technologies into teaching practices. Moreover, robust data security and privacy measures are necessary to safeguard sensitive information and build trust among users. As technology advances, protecting data becomes increasingly complex and essential. To complement these efforts, promoting interdisciplinary research can lead to innovative solutions, addressing various challenges associated with the integration of smart technologies. Furthermore, ensuring equity and accessibility is vital, as it allows all students to benefit from technological advancements, regardless of their background.

By addressing these priorities, educators, policymakers, and researchers can collaboratively advance the integration of smart technologies, enhancing the quality and inclusivity of education in the digital age. Continued research and development are essential for overcoming obstacles and refining implementation strategies. These ongoing efforts will establish a solid foundation for effectively incorporating these technologies into educational practices, ensuring they reach their full potential in transforming education.

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