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Repositioning Smart Classrooms in the AI Era: A Systematic Review of Online Interaction and AI-Driven Pedagogical Innovations

Hongze Bian[a] , Norasykin Mohd Zaid[a]

[a]Department of Science, Mathematics and Creative Multimedia Education, School of Education, Faculty of Educational Science and Technology, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

Corresponding Author Email: norasykin@utm.my

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Abstract

The COVID-19 pandemic has led to a technological advancement in online learning, and the emergence of ChatGPT has brought about a technological revolution in AI-enhanced learning. With smart classrooms at the forefront of educational innovation, this study aims to reevaluate their design to incorporate online learning and AI-enhanced tools effectively. It has become clear that incorporating online learning and AI-enhanced learning into smart classroom design process is important. This paper attempts to fill the research gap by providing a systematic review of the current state of conceptual research and theoretical practice in the smart classroom. The study selected target documents from the literatures of the past ten years covered 443 studies published from 2014 to 2023. Firstly, these studies are readily available for review to address the three sub-objectives about: (1) To analyze the development of the theoretical concept of smart classrooms over recent years; (2) To examine the advancements in smart classrooms equipped with educational technology in recent years; (3) To investigate the practical implementations and explorations of smart classrooms in the recent years. Secondly, these 443 articles were analyzed for the patterns and trends. These analyses helped to explain the status of research on smart classrooms that incorporate online learning and AI-enhanced learning in various nations and disciplines around the world, as well as the contemporary technological environment of smart classrooms. At last, this study examined approaches to incorporate traditional, online, and AI-enhanced learning to redefine the role of the smart classroom as a hub in the landscape of modern educational technologies.

Keywords: Smart Classroom, Online Learning, AI, ChatGPT

Introduction

The smart classroom has garnered considerable attention in recent years, with a significant increase in publications on the topic. Over time, research on smart classrooms has evolved to focus on various areas, including smart interaction and positive engagement, intelligent evaluation, and interconnected physical surroundings (Kaur & Bhatia, 2022). The

main areas of focus in smart classroom research include information and communication technology, machine learning, sensor networks, cloud computing, and hardware (Gandolfi et al., 2021). Key advancements in smart classrooms include the integration of advanced teaching technologies into the classroom environment, beyond the traditional setting, to enhance student learning abilities and engagement (Sarsar et al., 2023).To address this, much research on smart classrooms has been implemented to improve education systems and increase student engagement and empowerment (Yu et al., 2022).

However, since the COVID-19 outbreak in 2019, the pandemic has disrupted traditional classroom learning, necessitating the adoption of digital technologies for teaching and learning (Matczak et al., 2022). Students and teachers faced challenges with the transition to online learning. Online learning has shown significant results, but the overall learning outcomes are still inconclusive (Kajjimu et al., 2023). Further research is needed to improve online learning experiences for all students (Chiu, 2021).

At the same time, research about smart classrooms in integrating AI technology has gradually deepened, particularly OpenAI's ChatGPT, has gained popularity in the educational field (Foroughi et al., 2023). ChatGPT is an AI powered chatbot that has the potential to transform education by providing personalized and efficient learning experiences (Zhu et al., 2023). It can be used as a writing assistant, study tool, and personal tutor. The implementation of ChatGPT in the educational environment has shown positive impacts on the teaching-learning process (Kasneci et al., 2023). However, integrating it into the smart classroom and guiding students in navigation is a novel challenge.

In summary, smart classroom research has seen significant advancements in integrating advanced teaching technologies (Consoli et al., 2023). The focus has shifted towards exploring smart interaction, intelligent evaluation, and interconnected blend learning surroundings. The current main areas of focus in smart classroom research include information and communication technology, machine learning, sensor networks, cloud computing, and hardware. Every advanced research needs stronger accurate understanding of dynamic concepts theories and cutting-edge technology foundations. The motivation for this study stems from the transformative changes in education brought about by the COVID-19 pandemic and the integration of advanced AI technologies, such as ChatGPT, into educational practices. With smart classrooms at the forefront of educational innovation, this study aims to reevaluate their design to incorporate online learning and AI-enhanced tools effectively. To address the existing research gap, this study adopts systematically analyzing recent advancements in smart classroom practices, with a focus on their theoretical evolution, technological integration, and practical applications. The ultimate goal is to redefine the role of smart classrooms as hubs of modern educational technology, providing adaptable, interactive, and personalized learning experiences.

A systematic review of literature published between 2014 and 2023 was conducted to identify concept dynamic of smart classroom and recent trends in this field. The review and results will focus on the following research questions:

(1) How has the theoretical concept of the smart classroom evolved in recent years?
(2) How have smart classrooms equipped with educational technology evolved in recent years?

(3) What are the practical explorations of smart classrooms in recent years?
(4) How to redefine the role of the smart classroom in the landscape of modern educational technologies as cutting-edge technology integrates?

Literature Review

This study addresses the four questions mentioned in the introduction, and since the last question is summarizing, the first three questions respectively may be used as a category-oriented review of relevant articles.

The Evolution of Definitions and Theories Related to Smart Classrooms

The trajectory of smart classrooms is marked by the progressive integration of sophisticated technologies, which are recalibrating both tangible infrastructures and pedagogical methodologies. Initiating this paradigm shift, Chen et al. (2015) introduced the concept of 'Smart Classroom 2.0' in Taiwan, leveraging cutting-edge technological interventions to customize the educational experience, thereby aligning with the dynamic needs and preferences of university students. This innovation underscored the transformative potential of technology in amplifying student engagement and pedagogical efficacy. In a similar vein, Sarsar et al. (2023) delineated smart classrooms as ecosystems interwoven with a myriad of software and hardware apparatuses, expressly designed to foster and elevate student learning capabilities and proactive engagement. By way of contrast, Shen and Chen (2022) advocated for the vital integration of Internet+ technologies into smart classrooms to meet modern education's evolving demands, emphasizing the imperative driven by current tech-centric trends, educational reforms, and the practical needs of teaching.

Confronted with the unprecedented upheavals of the COVID-19 pandemic, the educational landscape underwent a radical overhaul from conventional face-to-face instruction to Emergency Remote Teaching and Smart Classroom modalities, a transition meticulously chronicled by Petchame et al. (2021) This emergent paradigm engendered a more inclusive and adaptable learning sphere, capacitating both direct and virtual pedagogic interactions, as expounded by Alfoudari et al. (2021) Furthermore, the pandemic cast a spotlight on the pivotal role of AI in the realm of online higher education, an area thoroughly investigated by Ouyang et al. (2022) who scrutinized AI's capacity to tailor educational content and enhance academic achievement. Concurrently, Hu (2023) accentuated the transition to dynamic data analytics as a means to customize educational strategies, signifying an evolution towards a more responsive, individualized, and data-centric educational paradigm.

Technological stratagems such as the cloud-edge computing model, advocated by Dai, Zhang, et al. (2023), contend with the prevalent challenges of data surfeit and network bottlenecks, assuring adept real-time data processing in smart classrooms. The confluence of virtual simulation training within smart classroom environments had been empirically corroborated to bolster pedagogical outcomes and effectiveness, as substantiated by Meng et al. (2023) Lastly, the transformative promise of AI in pedagogical practices was encapsulated by Zhu et al. (2023) and Zhang et al. (2023), who articulated the synthesis of smart classroom instruction with AI technologies, aiming to furnish immersive and culturally profound learning experiences. Meanwhile, Dimitriadou and Lanitis (2023) charted the

transformation of "Smart Classrooms" into technologically sophisticated spaces that facilitate interactive, AI-enhanced learning adaptable for both on-site and remote education. Similarly, Yan (2023) highlighted the positive impact of advanced AI technologies on the efficacy and engagement of L2 learners, aligning with the evolving smart classroom paradigm that embeds technology deeply into the educational fabric. Collectively, these scholarly contributions coalesce to underscore a resonant consensus—smart classrooms are indispensable in addressing the exigencies of contemporary education, channeling the prowess of technological innovations to equip learners for a rapidly unfolding future.

In summary , smart classrooms represent an evolution in educational environments, shifting from traditional methods to technology-enhanced, student-centered approaches (Cohen et al., 2022).These settings integrate advanced software and hardware, responding to the demands of digital learners and education reform, and are designed to augment traditional teaching with dynamic data analysis and real-time responsiveness. Technologies like extended reality and IoT are employed to foster immersive experiences, cognitive skill enhancement, and cultural understanding. These classrooms offer personalized learning, utilizing Internet of Things (IoT) and cloud computing to surpass conventional classroom limits. Additionally, in response to crises like the COVID-19 pandemic, smart classrooms, serve as vital educational platforms, swiftly adapting to emergency remote teaching needs (Alrawashdeh, 2023). The incorporation of AI further enhances these environments (Maciá-Pérez et al., 2023), promising improved culturally immersive experiences (Labadze et al., 2023).

The Evolution of Smart Classrooms Equipped with Modern Educational Technology

The literature on smart classrooms elucidates a multifaceted approach to integrating technology in educational settings. Popescu et al. (2018) delved into affective computing, involving sensors to gauge students' emotional and cognitive states, a precursor to the advanced tools for real-time data analytics discussed by Fakhar et al. (2022), who designed an emotion recognition system using facial feature detection and Convolutional Neural Network (CNN). This trajectory of increasing technological sophistication is echoed in the works of Tissenbaum and Slotta (2019), who envisioned classrooms equipped with interactive displays and responsive technologies to student positioning, and Huertas Celdran et al. (2020), who emphasized flexible technological infrastructures via software-defined networks for a variety of educational applications.

Continuing this theme, Alfoudari et al. (2021) underscored the use of intelligent systems and analytical tools for personalized learning, which aligns with Yan (2023) 's discussion of ChatGPT in supporting language acquisition. Similarly, Shoukry et al. (2022)'s ClasScorer platform gamifies learning, enhancing participation and interaction, while Jammeh et al. (2023) focused on Information Communication Tools like SMART Boards for engaging learning experiences. Zhu et al. (2023) and Dimitriadou and Lanitis (2023) further advanced the dialogue by advocating AI-driven applications and technologies for class management and performance assessment, suggesting a move towards more personalized and efficient educational processes.

Furthermore, the incorporation of IT services in classrooms, as highlighted by Hu (2023) and Alhasan et al. (2023) represented a significant push towards creating interactive

environments that adapt to educational needs. These IoT systems, alongside AI technologies discussed by Zhang et al. (2023) for English language and literature teaching, showcase a transformative shift in education towards environments that are not only technologically equipped but also sensitive to the pedagogical and cultural nuances of the learning process.

In summary, smart classrooms epitomize the integration of Information and Communication Technologies (ICT) and immersive technologies like virtual and augmented reality, which are redefining traditional learning spaces into adaptive, intelligent environments. These technologically enriched spaces—outfitted with learning tablets, laptops, mini-servers, wireless access points, interactive whiteboards, and online E-learning modules—not only facilitate uninterrupted, distance-defying learning experiences but also cater to diverse learning styles, thus enhancing educational engagement and effectiveness. Within the last year, the emergence of AI-driven applications such as ChatGPT has signalled a further evolution, offering personalized assistance and fostering a comprehensive, engaging, and culturally rich learning experience. This paradigm shift towards technology-driven pedagogy is geared towards optimizing educational outcomes and equipping students for a digitalized global milieu, with AI integration poised to further individualize learning through real-time feedback and increased interactivity.

Exploring Smart Classrooms Practices in a Different Era

Recent years scholarly inquired into smart classrooms technologies have meticulously charted the evolution of this domain, revealing pivotal advancements that redefine educational practices. At the forefront, Chen et al. (2015) highlighted the Speech-Driven PowerPoint system within Smart Classroom 2.0, utilizing automatic voice recognition to streamline the dissemination of instructional material. Advancing this technological narrative, MacLeod et al. (2018) devised and validated an instrument measuring student preferences regarding smart classroom attributes. Building on this framework, Huertas Celdran et al. (2020) advocated for a scalable MMLA architecture that permits flexible reconfiguration of classroom devices, dovetailing with Alfoudari et al. (2021) 's call for enhanced design consistency within smart classrooms.

Lu et al. (2021) adopted structural equation modelling to delineate the environment's influence on the cultivation of higher-order thinking skills, underscoring the symbiosis between pedagogical strategies and smart classroom infrastructure. Burunkaya and Duraklar (2022) contributed to this discourse by presenting an algorithm that supports customized learning trajectories, fortified by capabilities for remote classroom data access and management. Ouyang et al. (2022) 's work affirmed the efficacy of AI in online higher education, suggesting a strategic fusion of AI with educational methodologies. This technological expansion into education is complemented by Alhasan et al. (2023) 's quantitative analysis, which identified determinants of student engagement with IoT services in smart classrooms.

Moreover, Dai, Xiong, et al. (2023) explored the perceptions of undergraduates and educators towards smart learning environments, establishing a widespread approval irrespective of demographic differences. Nie et al. (2023) investigated the integration of human-computer interaction within educational settings, pinpointing its repercussions on cognitive load and academic emotions. Sarsar et al. (2023) projected a multifaceted smart

classroom model, integrating an array of technological tools to foster a dynamic learning milieu. In a practical vein, Wang et al. (2023) utilized the Experience Sampling Method to examine how seating arrangements impact student interactions within smart classrooms. Finally, Jammeh et al. (2023) scrutinized the TPACK framework's role in secondary education, specifically in the context of chemistry, to elucidate technology's role in elevating pedagogical practices. These studies collectively distill the essence of smart classroom development, accentuating the pivotal role of technology in crafting educational environments that are responsive, personalized, and conducive to interactive learning.

In summary, smart classrooms practices have undergone a transformative journey, with an ever-increasing focus on the integration of advanced technologies to cater to personalized learning experiences, engagement, and the cultivation of cognitive skills. Technologies such as the Speech-Driven PowerPoint system and ambient intelligence with thermal imaging epitomize this progression, reflecting a paradigm shift toward adaptable, student-centric learning environments. Research within this realm has diligently pursued the enhancement of student engagement and interaction, advocating for education systems that adapt to individual learning styles and foster higher-order thinking abilities. The impact of smart classroom design on social dynamics and the cognitive and emotional well-being of students further underscores the multifaceted influence of such technologically enriched environments. The rise of online learning platforms and large language model applications, signals a continued trajectory towards innovative, technology-driven educational models.

However, few people have explored the practice of smart classrooms in these two aspects. It's necessary to adjust smart classroom strategies to meet the evolving demands of education in a digital age. As Figure 1, firstly, this model is designed in the context of a smart classroom, to differentiate it from smart schools or smart environments, and to facilitate it in a way that can be controlled by a teacher as an individual. E-resources can be stored and shared in the cloud under the network. And then, in terms of technology integration, it is important to show that the smart classroom has been developed and matured in the context of a highly developed Internet era. In addition, it emphasises the fundamental role of the LMS and the central role of the IWB. Of course, the LMS will be upgraded with the development of the times by embedding new technologies such as AI (Artificial Intelligence), LLM (Large Language Modelling), Online learning, etc.

Meanwhile, sensors can capture the classroom implementation in real time through sound, image, temperature, humidity or other indicators and upload data to the LMS for processing. The presentation of IWB is also supported by projectors, computers, tablets, laptops, smartphones and other devices according to the local conditions. It is also important to stress the importance of data mining techniques and AL techniques for E-resources as well as for data processing in the teaching and learning process. In the case, teachers can gain clearer guidelines for next interventions.

Finally, the teacher is on the left side of the model as an initiator of teaching activities. All educational technologies are linked from teacher to the students and then feedback. The ubiquitous bi-directional arrows indicate that there is active interaction between students and teachers, as well as human-computer. In summary, this should be our latest insight into a modern smart classroom model.

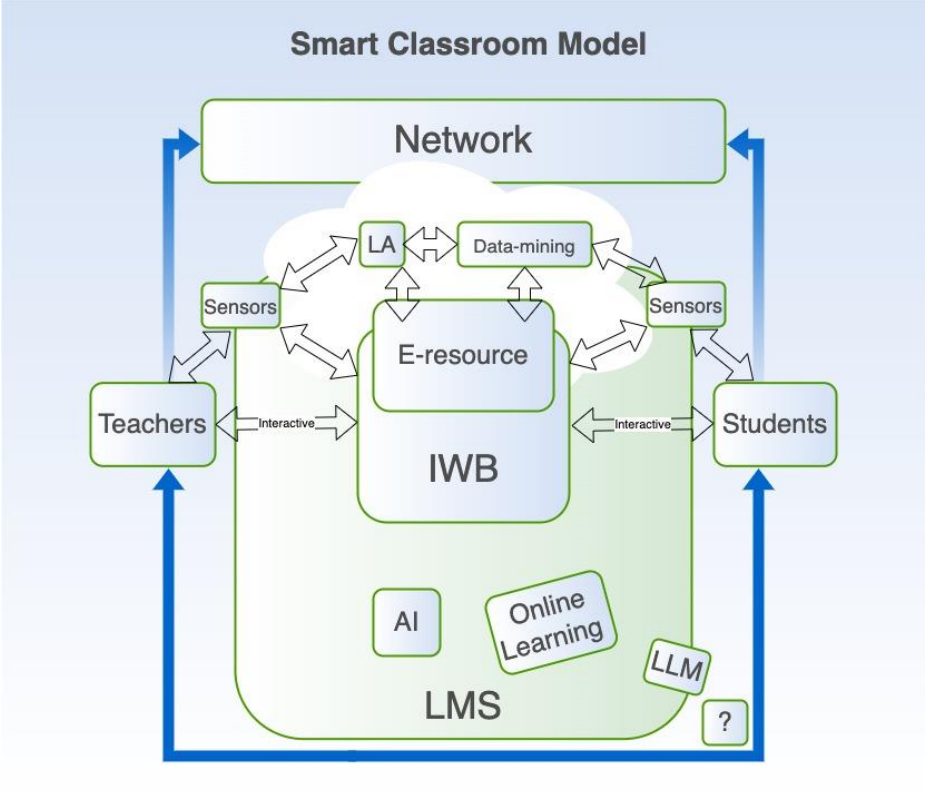

Figure 1. Morden Smart Classroom Model

(Note: LMS: Learning Management System, IWB: Interactive Whiteboard-Based, LA：Learning Analytics, AI: Artificial Intelligence, LLM: Large Language Modelling.)

In online learning, the smart classroom transcends its borders beyond the walls to unite students and educators worldwide. It eliminates geographic barriers via video conferencing and collaborative online platforms, providing a more diverse and all-encompassing educational experience (Johnson et al., 2022). Online learning elements support asynchronous learning, permitting students to access materials at their convenience and accommodate different time zones and schedules (Petchame et al., 2021). AI in the smart classroom is a game changer, transforming into a personalized learning facilitator. AI-based systems can adjust to the individual learning pace, provide customized resources, and offer immediate feedback for an individualized learning experience. The AI analytics can track student engagement and performance, guiding educators in real-time toward areas requiring more attention. AI is an immense entity that requires learners to master its power. Given that as of April 2023, large language models have proliferated and covered every field, transmitting knowledge is no longer limited to teachers. The ability to grasp and use knowledge is within learners' reach at any time. Hence, traditional teachers' roles should be more of guides or counsellors in their truest forms (Grammens et al., 2022) (Lin, 2023). Certainly, we need to reevaluate how we position smart classrooms in the context of this new technological revolution.

Methods

This article screened target literatures through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (Moher et al., 2009) for publication selection as following.

Search Strategy

Relevant articles pertaining to the topic of "smart classrooms" were searched using three widely used academic databases: Web of Science, Scopus, and ProQuest. The inclusion criteria for an article were that it focused on smart classroom; was written in English; document type was article or scholarly journal; published between 2014 and 2023. The article type selected was limited to "Article" in Web of Science and Scopus, and "Scholarly Journal" in ProQuest, ensuring a higher standard of academic rigor. For timeliness considerations, time rang was 2014-2023. As a result, there were 1297 articles total in the first search results, including 214 from Web of Science, 712 from Scopus, and 371 from ProQuest. To determine which of the 1297 publications should be reviewed, they were subjected to an additional set of inclusion criteria. An article's focus on "smart classroom" was a requirement for inclusion. Articles that didn't fit any of these requirements were removed. Consequently, 87 articles from Web of Science, 480 from Scopus, and 102 from ProQuest were retained. And then 443 articles were ultimately chosen for examination after 148 articles with overlaps were excluded. For further exploration, next we added keywords respectively " Online Learning"、"AI ", obtained the corresponding results 29 and 44. Figure 2 outlines the search and selection procedures utilized as follow.

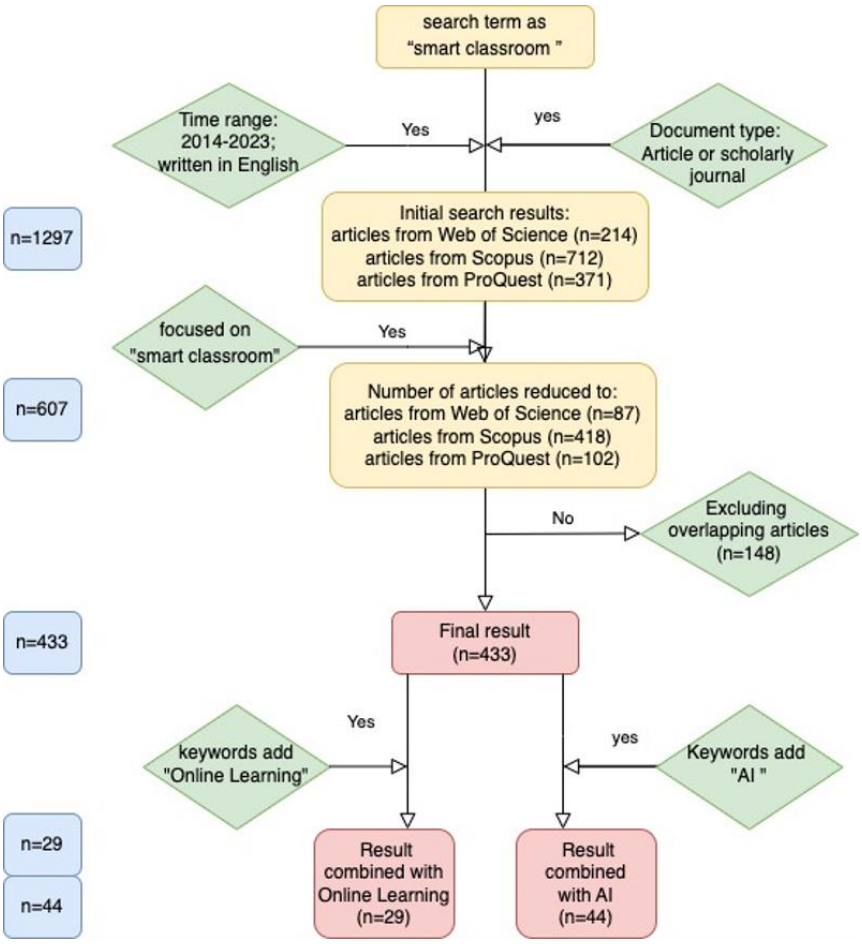

Figure 2. Procedures for search and selection of articles

Data Coding and Categorization

In order to explore the research situation of smart classrooms, this study obtained 443 articles through screening. Among these, this study respectively selects about 10 articles on

three categories that are readily available for review to address the first three questions presented in the introduction. These three categories are exactly as follow:

- The evolution of definitions and theories related to smart classrooms.
- The evolution of smart classrooms equipped with modern educational technology.
- Exploring smart classroom practices in a different era.

The screened "443 final articles", "29 combined with online learning articles ", and "44 combined with AI article" are used as the vertical header. Horizontal headings include "Publication Year", "Countries/Regions", "Academic Category ", and "Educational Technology involved". Horizontal header information and vertical header information are intersected to obtain the corresponding graphs or tables, the results of which will be described in the next chapter. Based on the information that has been obtained, this study made Table 1 as follows：

Table 1
Data Coding and Categorisation

Item	Publication Year	Countries/Regions	Academic Category	Educational Technology involved
443 final articles	Figure 3 .Trend Over Years with Smart Classroom Literature	Figure 4. Countries or Regions of the Smart Classroom Literature	Figure 5. Distribution of Smart Classroom-related literature by Academic Category	Figure 12. Distribution of Smart Classroom Literature by Technology
29 combined with Online Learning articles	Figure 6. Trend Over Years with Smart Classroom combined with Online Learning Literature	Figure 8. Countries or Regions of the Smart Classroom combined with Online Learning Literature	Figure 10. Distribution of Smart Classroom (combined with Online Learning) related literature by Academic Category	
44 combined with AI articles	Figure7. Trend Over Years with Smart Classroom combined with AI Literature	Figure 9. Countries or Regions of the Smart Classroom combined with AI Literature	Figure 11. Distribution of Smart Classroom (combined with AI) related literature by Academic Category	

Results and Findings

According to the screened "443 final articles", we can obtain Figure 3、4、5 as follows:

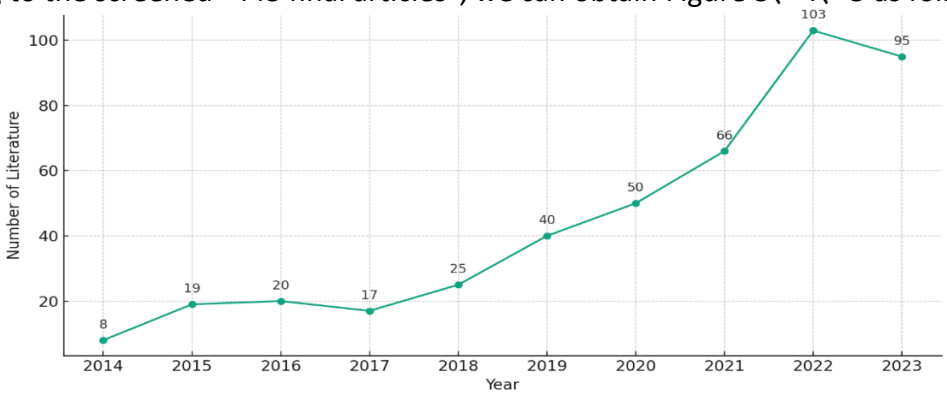

Figure 3. Trend Over Years with Smart Classroom Literature

The graph illustrates an ascending trend in the volume of literature on smart classrooms from 2014 to 2023. The number of articles started at 8 in 2014 and gradually increased with minor fluctuations observed in 2016 and 2017. Thereafter, the number of articles increased more sharply, reaching its peak of 103 articles in 2022. As of Nov.2023, 95 articles have been published so far this year. Overall, the graph indicates an increasing academic fascination with smart classroom technology in the past ten years.

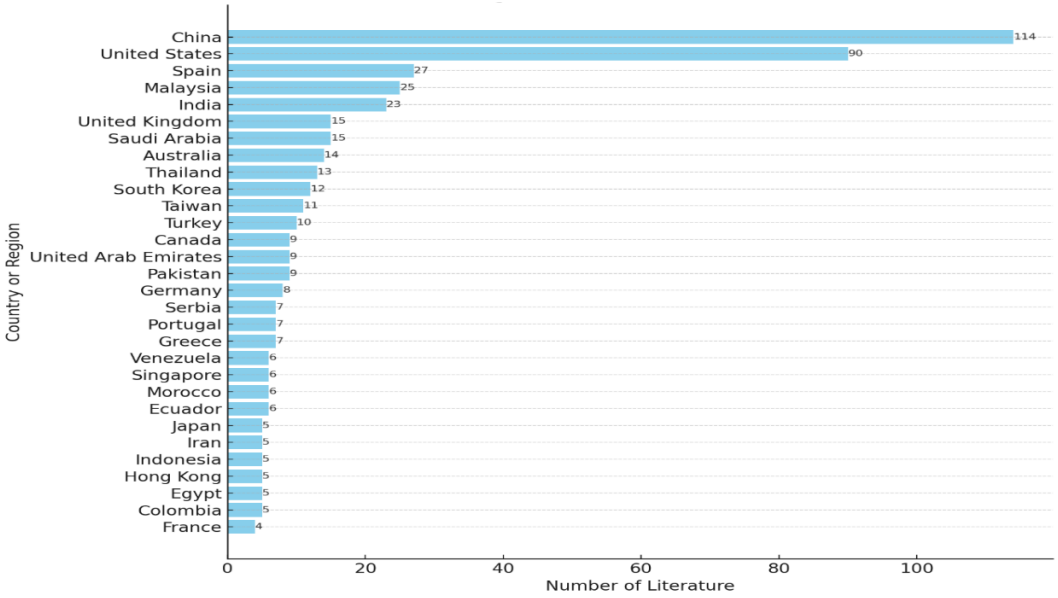

Figure 4. Countries or Regions of the Smart Classroom Literature

The bar chart depicts the number of literatures from the top 30 countries and regions, showing the distribution of smart classroom literature across different countries or regions. China has the highest number of publications with 114, followed by the United States with 90. The chart also highlights other countries, such as Spain, Malaysia, and India, which have contributed significantly with 27, 25, and 23 articles, respectively. The United Kingdom, Saudi Arabia, and Australia have made modest contributions, with each country ranging from 14 to 15 articles. There is a group of countries, including Turkey, Canada, and the United Arab Emirates, each contributing around 9 to 10 articles. Several countries, such as Serbia, Portugal, and Greece, have each contributed 7 articles. The chart shows that certain countries, such as Singapore, Morocco, and France, have contributed the least with only 4 to

6 publications each. This distribution demonstrates the global research interest and effort in the field of smart classrooms, with a noticeable concentration in specific regions.

It should be noted, however, the quantity of articles does not necessarily indicate the degree to which smart classrooms are utilized and advanced in this country or region.

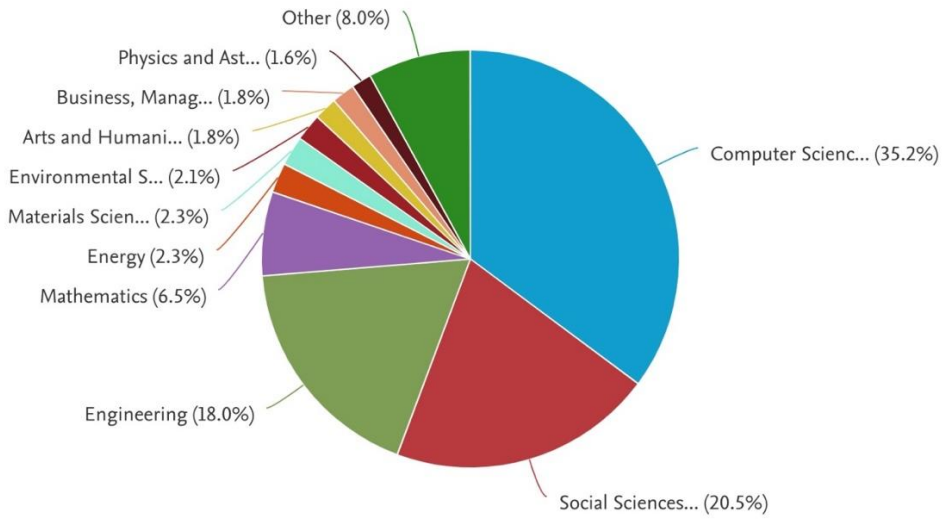

Figure 5. Distribution of Smart Classroom-Related Literature by Academic Category

The chart entitled "Smart Classroom-Related Literature Distribution by Academic Category" displays the proportionate distribution of academic disciplines throughout the body of literature related to smart classrooms. Computer Science is the dominating field, with 35.2% of the literature, demonstrating the significant role technology plays in smart classroom research. The Social Sciences account for a significant percentage at 20.5%, suggesting a keen focus on the influence of smart classrooms on both society and education. Engineering ranks second at 18.0%, potentially encompassing the development and deployment of smart classroom infrastructure. Mathematics only contributes minimally at 6.5%, possibly concentrated on statistical and analytical components, while Environmental Science, Materials Science, and Energy make up slightly over 2% each. The remaining categories, such as Physics and Astronomy, Business, Management, Arts, Humanities, and others, collectively make up less than 10% of the literature. The "Other" category, which probably includes various niche fields, accounts for 8.0%. This distribution underscores a multidisciplinary fascination with smart classrooms, with a strong focus on technological advancement and social implementation.

According to the screened "29 combined with online learning articles "and "44 combined with AI articles", we can obtain Figure 5、6、7 、8、9、10 as follows:

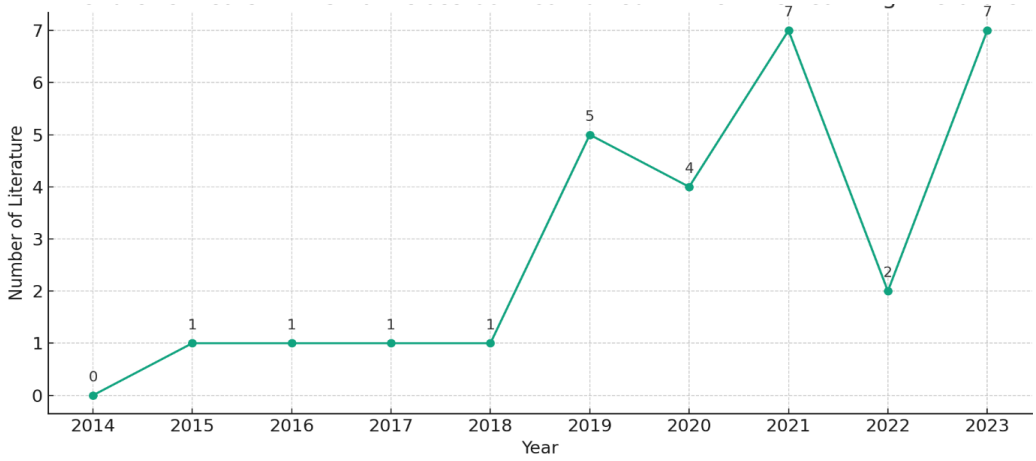

Figure 6. Trend Over Years with Smart Classroom combined with Online Learning Literature

Figure 6 illustrates the trend in literature pieces from 2014 to 2023 that incorporate smart classrooms and online learning. The trend began with a low count of one publication per year in 2014, which remained consistent until a surge in 2019 to five articles. In 2020, the count decreased slightly to four publications, perhaps suggesting a shift in research focus due to global events. However, there was a significant increase in 2021, with a peak of seven publications, indicating heightened interest in online learning due to the ongoing impact of the COVID-19 pandemic on education. The subsequent year, 2022, saw a notable dip to two publications, but the trend quickly bounced back to seven in 2023, indicating that there is no sustained interest in the integration of smart classroom technology and online learning models. This graph demonstrates the dynamic nature of research in educational technology and its responsiveness to external factors, such as COVID-19.

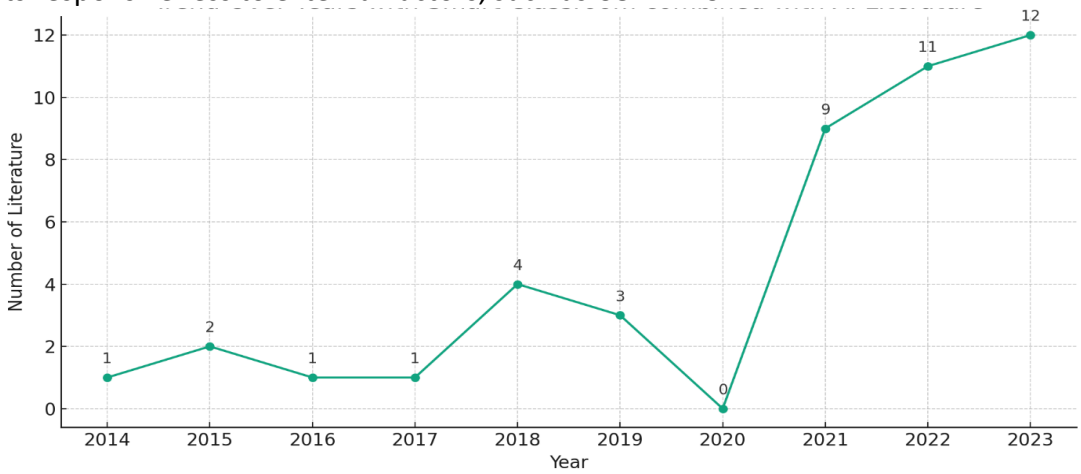

Figure 7. Trend Over Years with Smart Classroom Combined with AI Literature

Figure 7 illustrates the yearly trend in literature about smart classrooms and AI from 2014 to 2023. Initially, there was a scarcity of articles, with only one available in 2014 and subsequent years displaying erratic changes. However, 2019 saw a significant spike with a total of four articles. Beginning in 2020, there has been a substantial rise in academic articles related to AI applications in smart classrooms, with nonavoidable prior. The trend persists into 2021 with nine articles, highlighting significant advancement or increasing interest, albeit at a limited scale.

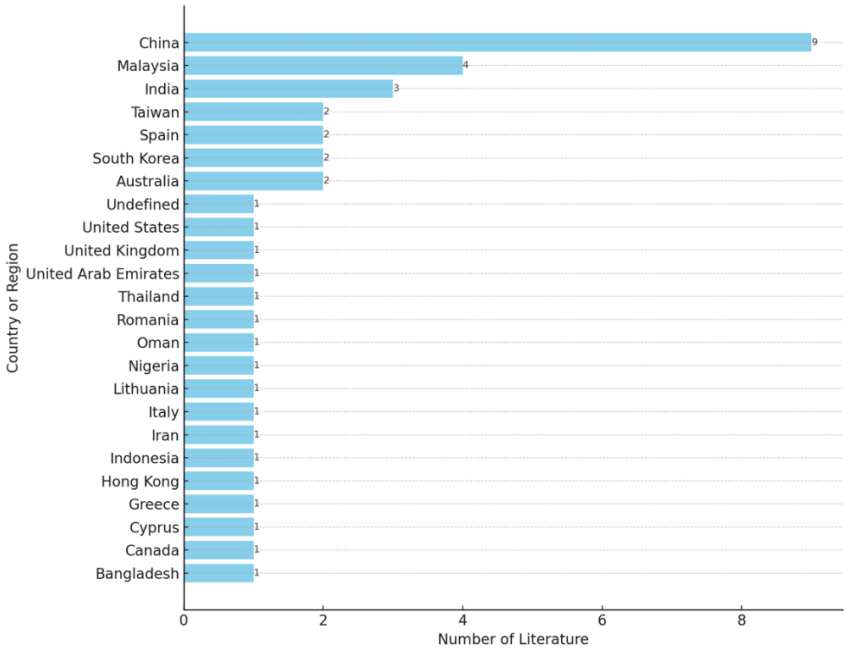

Figure 8. Countries or Regions of the Smart Classroom Combined with Online Learning Literature

Figure 8 shows China leading significantly with nine publications, followed by Malaysia with four, and India with three. Other countries like Taiwan, Spain, and South Korea each have two publications. A number of countries are represented with a single publication.

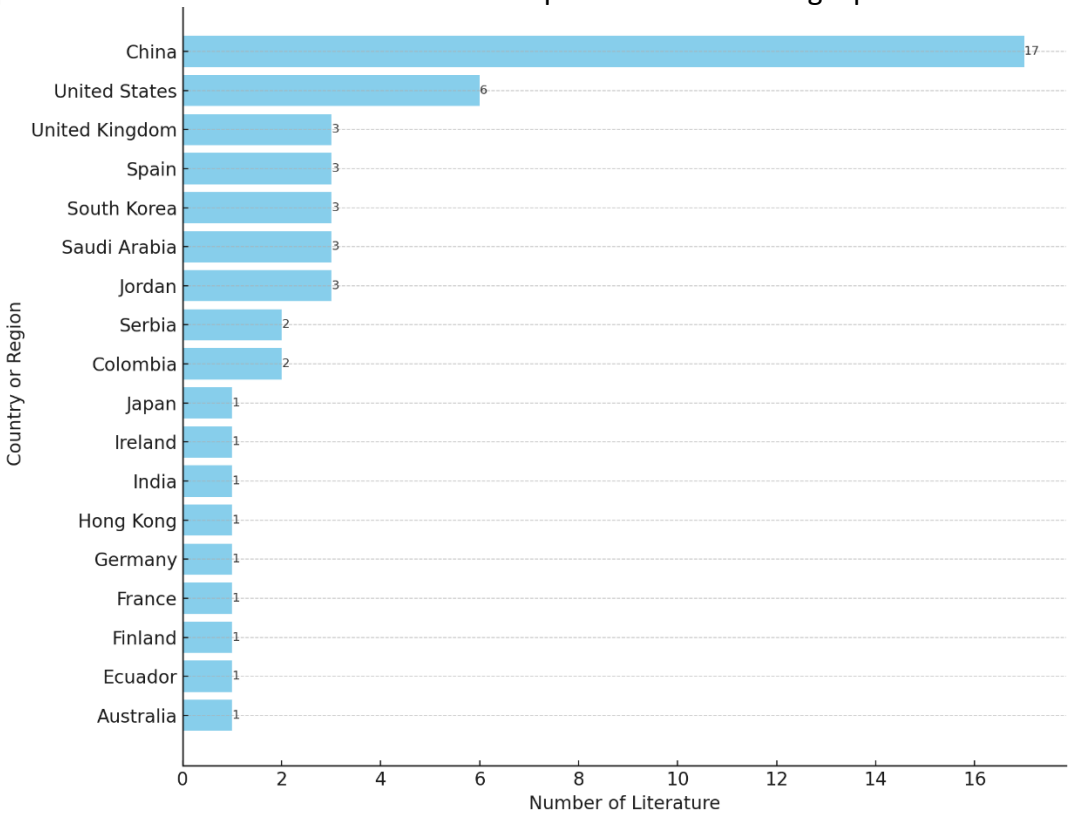

Figure 9. Countries or Regions of the Smart Classroom Combined with AI Literature

Figure 9 illustrates that China is again at the forefront with seventeen publications, followed by the United States with six. The United Kingdom, Spain, South Korea, and Saudi

Arabia, among other countries, contribute three articles each. A range of countries provide two or one articles. Combining insights from Figure 6, 7, 8, 9, it indicates that despite the ongoing COVID-19 pandemic and rapid advancements in AI, there has been insufficient consideration regarding the integration of online learning and AI technologies into smart classrooms. The exploration of smart classrooms may still be limited to the stage of augmented reality and imitating traditional classrooms, indicating a need for further development in this area.

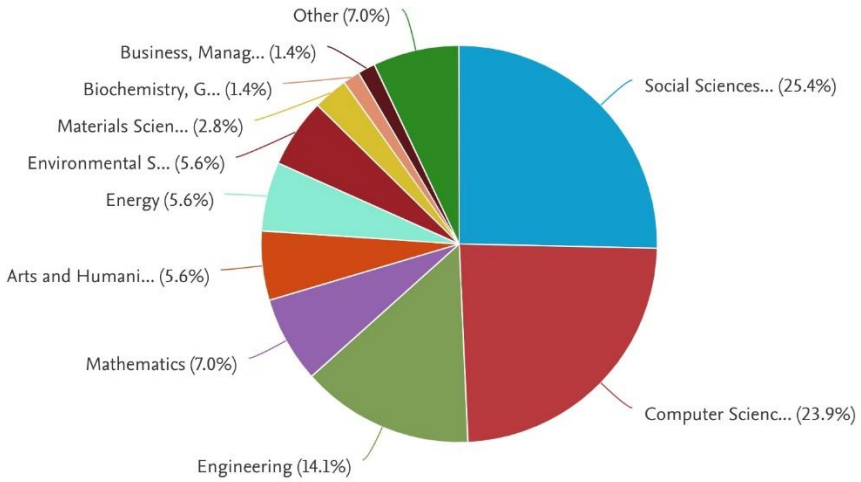

Figure 10. Distribution of Smart Classroom （combined with Online Learning） related literature by Academic Category

Figure 10 indicates that the distribution of fields is led by Social Sciences at 25.4%, followed by Computer Science at 23.9%, and Engineering at 14.1%. Mathematics and Arts and Humanities follow closely, each at 5.6%, while Environmental Science, Energy, Materials Science, and other fields have lower percentages. This distribution suggests a strong interdisciplinary interest in smart classrooms combined with online learning, with a focus on the societal impact and technological aspects.

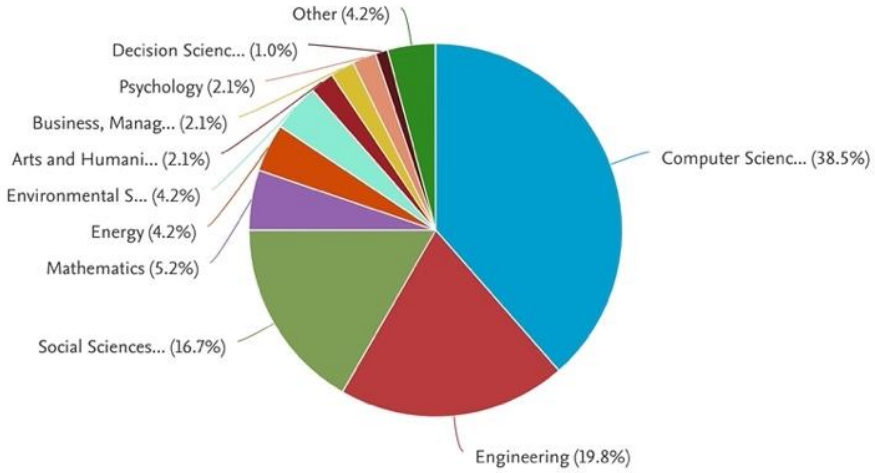

Figure 11. Distribution of Smart Classroom （combined with AI） related literature by Academic Category

Figure 11 displays that Computer Science is the predominant category, representing 38.5%, reflecting a greater emphasis on the technological advancement of smart classrooms when combined with AI. Engineering also represents a significant portion at 19.8%, followed by Social Sciences at 16.7%. On the other hand, Mathematics, Energy, and Arts and Humanities have smaller presence in comparison, and categories like Psychology and Decision Science appear with minor contributions.

Combining insights from Figure 10 and 11, it is apparent that smart classroom research predominantly focuses on Computer Science and Engineering, particularly when AI is involved, emphasizing the technological core of these studies. The presence of Social Sciences also highlights the significant social and educational impact of smart classrooms. Additionally, Figure 10 's broader distribution implies a more well-rounded interdisciplinary approach to online learning, while Figure 11's AI-related research heavily emphasizes technical and engineering aspects, with a significant emphasis on technological innovation. Overall, the 2 charts' reports demonstrate the multidisciplinary nature of research on smart classrooms, with different focuses depending on whether the integration involves online learning or AI.

By organizing data from the 443 final articles, Figure 11 provides information on the frequency with which the list of smart classroom equipment was addressed.

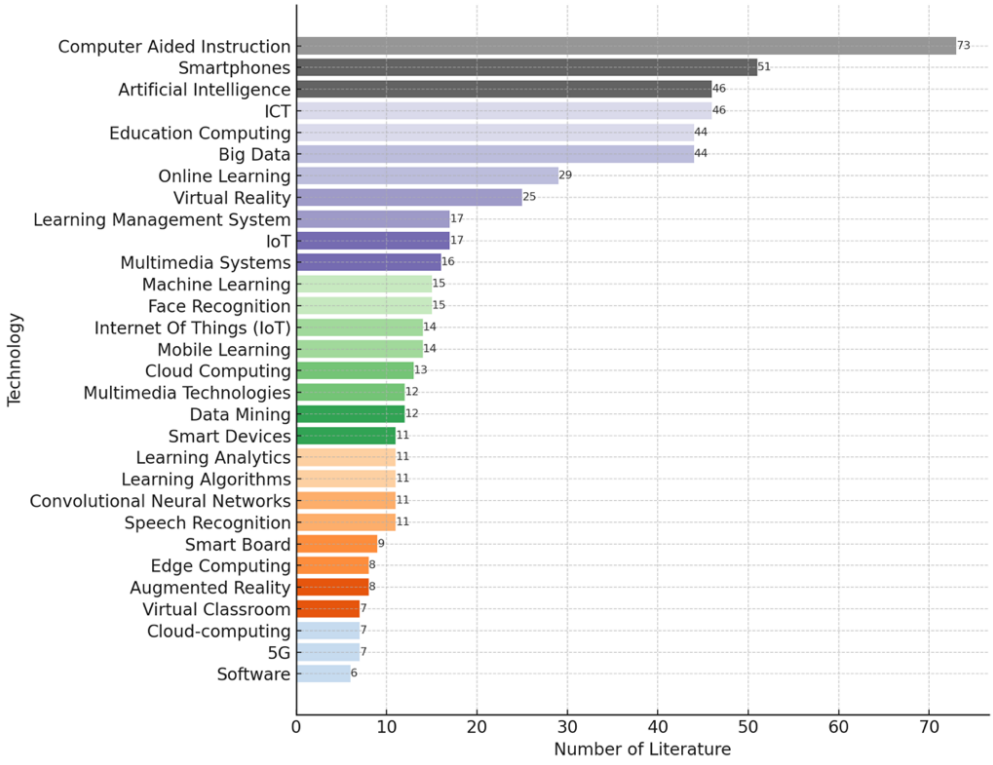

Figure 12. Distribution of Smart Classroom Literature by Technology

This chart offers a comprehensive comparison of the prevalence of various technology categories in literature on smart classroom, with "ICT" and "Computer Aided Instruction" standing out as significant, demonstrating their critical roles in the field (Choi-Lundberg et al., 2023). The chart enables easy cross-referencing of diverse technologies and their influence or emphasis in the smart classroom research panorama.

Discussion

Firstly, summarising all the data from Figure 3 to Figure 12 in the section above, it is easy to find that research on smart classrooms has been very enthusiastic and has involved many

disciplines around the world. We can also see notice the publication data reaches its peak in 2022, but there are not many articles involving Online Learning and Artificial Intelligence in smart classrooms. Secondly, in order to deal with these four research questions of the introduction, this study has strictly screened the literature in related fields and conducted a systematic review and analysis to reach the following conclusions.

How has the Theoretical Concept of the Smart Classroom Evolved in Recent Years?

The theoretical framework of smart classrooms has evolved to adopt a student-centred approach propelled by technological advancements (Li & Wong, 2021). Initially centred on the basic integration of digital tools, the framework now stresses individualized learning experiences enabled by AI and machine learning. The latest intelligent classroom theory comprises flexible learning environments (online learning) that promptly adjust to student requirements, enhancing involvement and catering to varied learning styles (Al Mamun et al., 2020).

How have Smart Classrooms Equipped with Educational Technology Evolved in Recent Years?

Smart classrooms have advanced from using basic digital tools to becoming complex ecosystems that combine technologies such as (Internet of Things) IoT, cloud computing, and immersive (Virtual Reality) VR/ (Augmented Reality) AR experiences. These classrooms have transcended the improvement of teaching to the transformation of learning, with AI offering individualized pathways and analytics informing decisions (Li & Gu, 2023). The transformation is indicated by a shift toward environments where technology is an active participant instead of solely a facilitator in the educational process.

What are the Practical Explorations of Smart Classrooms in Recent Years?

Smart classrooms have been implemented with a wide range of applications from virtual labs to AI-assisted language learning, demonstrating a trend towards experiential and culturally-enriching education (Guo et al., 2021). They are being examined for their potential to standardize and enhance educational delivery. Practical applications encompass ambient intelligence for tracking engagement, resource management systems tailored to learning styles, and standardized implementation of smart classroom models. These applications signify a strategic change towards data-informed, student-centred, and adaptable educational environments.

How to Redefine the Role of the Smart Classroom in the Landscape of Modern Educational Technologies as Cutting-Edge Technology Integrates?

As for the last question, we begin with a simulation diagram of smart classroom from HUAWEI Corporation as Figure 13:

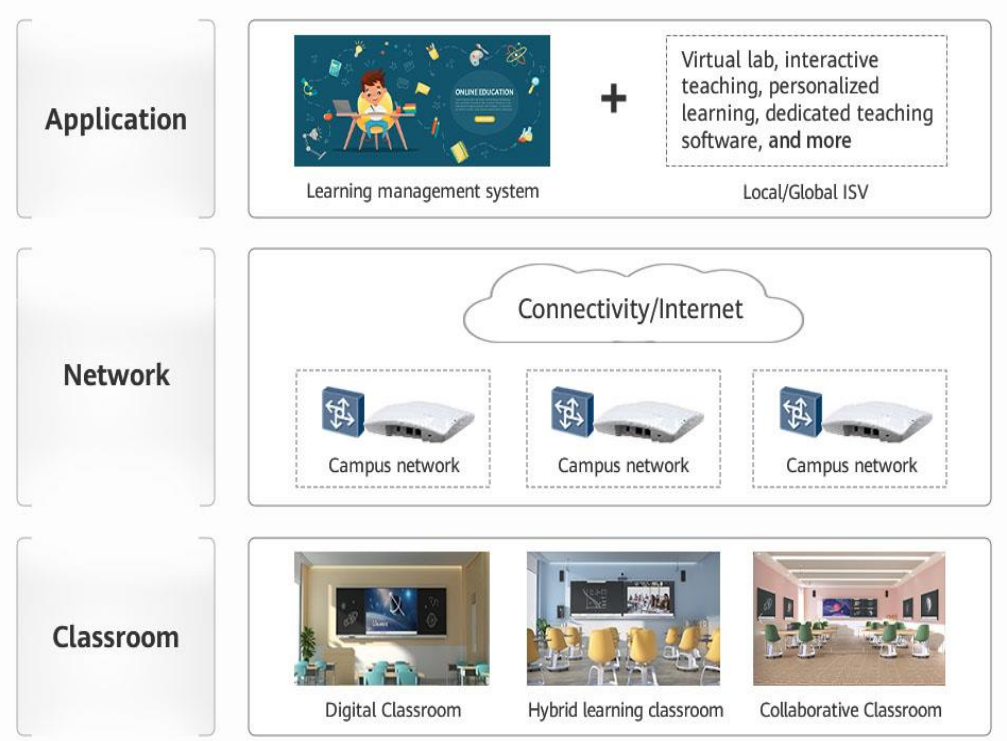

Figure 13. simulation diagram of smart classroom
(https://e.huawei.com/en/industries/education/basic-education/smart-classroom)

Based on Figure 13 provided by HUAWEI company and our previous discussions in this study, it reveals that the smart classroom environment is a multi-layered system that integrates different technologies to create an interactive , efficient, and personalized learning experience (Nai, 2022). However, this prevalent simulation diagram exactly reflects the limitations of our current thinking, because it weakens the role of online learning and disregards the importance of AI enhancements, specifically large language models will play in future smart classroom practices (Hu, 2023). If the advancement of smart classrooms can be divided into three stages: the imitation of traditional classroom stage, the remote online education stage, and the AI control stage (Cox, 2021). We will fail to get out of the first stage of imitation.

Previously, this paper has systematically analyzed 433 related articles since 2014 by PRISMA method. As the results and findings section, the exploration of smart classrooms involves multiple disciplines and the number is increasing year by year, distributed in various countries around the world, especially China is far ahead, but there are very few studies on smart classrooms combined with online learning and artificial intelligence, even though online learning and AI-enhanced learning have penetrated into various disciplines as well as interdisciplinary learning.

Finally, we need to revaluate how we position smart classrooms in the context of this new technological revolution. this study examined approaches to incorporate traditional, online, and AI-enhanced learning to redefine the role of the smart classroom as a hub in the landscape of modern educational technologies as Figure 14. This revised approach underscores technology's significance in meeting varying learning requirements and preparing learners for an interconnected global society. And this is my answer to the last

question: The smart classroom in the modern edtech landscape as a hub of innovation and personalization.

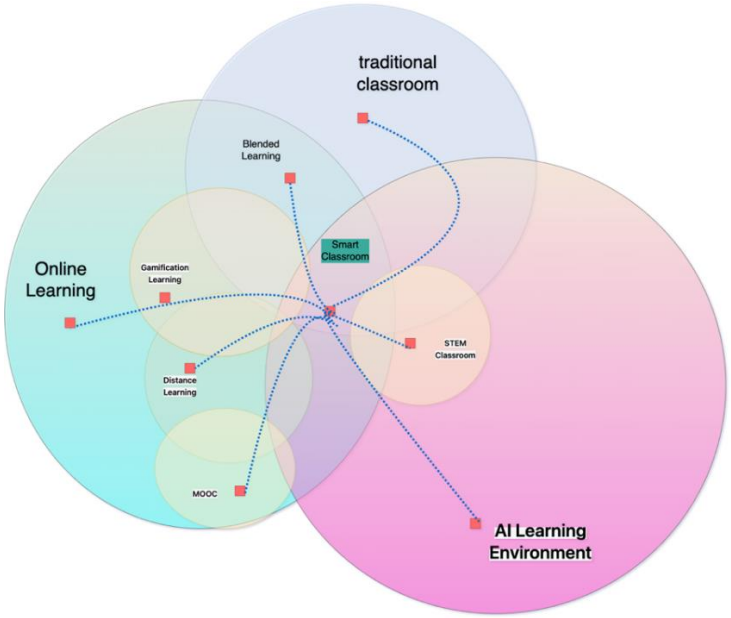

Figure 14. The Role of Smart Classroom in the Landscape of Modern Educational Technologies

Conclusion

The smart classroom is an innovative educational paradigm that reflects the evolution of traditional learning spaces into dynamic, technology-driven environments. These smart classrooms have been transformed by the integration of advanced technologies such as AI, online learning, virtual reality, and cloud computing, enabling personalized, interactive, and flexible learning experiences. The role of smart classrooms in modern educational technology landscapes is pivotal as they serve as a nexus for innovation, where learning is enhanced by adaptive technologies that cater to diverse educational needs and preferences. The shift towards these intelligent environments signifies a commitment to preparing students for a future where digital literacy and global interconnectedness are paramount. Smart classrooms stand at the forefront of this educational revolution, heralding an era where the boundaries of learning are expanded beyond the physical classroom and into the digital realm.

The COVID-19 pandemic since 2019 has accelerated the adoption of digital technologies in education, highlighting the need for improved online learning experiences for teaching and learning (Barthakur et al., 2022). In 2022, the emergence of ChatGPT has led to continuous transitions in the development of AI-Enhanced Learning environments. This paper attempts to analyse the status of research on smart classrooms that incorporate online learning and AI-enhanced learning in various nations and disciplines around the world, as well as the contemporary technological environment of smart classrooms by providing a systematic review of the current state of conceptual research and theoretical practice in the smart classroom. At the same time, we can see that research on smart classrooms has been very enthusiastic. It has involved many disciplines around the world. We also notice that there are not many articles on online learning and artificial intelligence in smart classrooms, although the publication data peak in 2022. Hence, the study uncovers that the smart classroom utilizes AI and online learning to furnish students with a collaborative learning environment that is adaptive and accessible in the landscape of modern educational technologies.

This research contributes significantly to the theoretical and contextual understanding of smart classrooms. Theoretically, it advances the conceptual framework of smart classrooms by integrating traditional, online, and AI-enhanced learning, offering new insights into their role in modern education. Contextually, the study provides a global perspective on the implementation of smart classrooms across various disciplines and regions, emphasizing the importance of adapting these technologies to diverse educational needs. This work not only fills existing research gaps but also serves as a guide for policymakers, educators, and researchers in leveraging smart classroom innovations to enhance learning outcomes in the AI-driven educational landscape.

Limitations and Recommendations for Future Work

Research on smart classrooms should address two aspects: teaching methods and technology. This paper solely focuses on the technical aspects. Nevertheless, to avoid falling into dilemmas, it is essential to consider the acceptance of teachers or students, despite the quality of the technology. Hence, exploring the issue of participation in contemporary smart classrooms is a potential area for future work in the development of smart classroom implementation.

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