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Systematic Review

Artificial Intelligence in Smart Classrooms: A Systematic Literature Review of Applications, Dimensions, and Teacher Roles

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Abstract

The integration of Artificial Intelligence (AI) into smart classrooms (SCs) has accelerated in recent years, fostering new forms of interaction, personalization, and data-driven educational decision-making. Despite this growing interest, the literature remains conceptually fragmented, particularly regarding how AI is integrated across the technological, pedagogical, and environmental dimensions of SCs. This systematic literature review aims to provide a structured synthesis of how AI is integrated into SC contexts, their main functions, their relation to these three dimensions, and the teacher's role in the system. Following PRISMA guidelines, peer-reviewed studies published between 2021 and 2026 were selected from Web of Science and Scopus, yielding a final corpus of 29 studies. The findings showed that AI integration is mostly concentrated in the technological dimension. The pedagogical dimension is linked to personalization, active learning, formative assessment, and instructional adaptation, while the environmental dimension is less developed. Teachers remain central actors who integrate technological tools, interpret the generated data, and mediate pedagogical decisions. Overall, AI-supported SCs are not only defined by technology but also by pedagogical use and teacher mediation.

Keywords: Smart Classroom; Smart Learning Environments; Artificial Intelligence; Artificial Intelligence in education; teacher role; learning analytics; Internet of Things; systematic literature review; PRISMA

1. Introduction

The rapid integration of AI into educational settings has prompted growing scholarly interest in how intelligent systems can transform teaching and learning processes. Among the most notable developments in this field is the emergence of SCs, which have been conceptualized as learning environments that integrate digital technologies to support interaction, adaptability, and the management of educational processes. Ref. [1] defines the "S.M.A.R.T." classroom (Showing, Manageable, Accessible, Real-time Interactive and Testing) as an environment equipped with technologies that facilitate real-time interaction and collective knowledge construction [2]. Similarly, Ref. [3] states that these environments promote greater connection and interaction between students and teachers while adapting to students' individual needs. Ref. [4] also emphasizes that intelligent learning environments should incorporate adaptive digital devices capable of adjusting to the environment and providing continuous feedback during learning. Ref. [5] defines the SC as a combination of advanced technologies used to optimize the learning experience for both students

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and teachers. Ref. [6] highlights the need to differentiate between a classroom equipped with technology and an SC, arguing that the latter requires a holistic integration that is not always achieved in practice. Ref. [7] proposes that smart learning environments strategically integrate technology to improve student learning and are structured around three dimensions: environmental, pedagogical, and technological. The environmental dimension includes architecture, furniture, and indoor environmental conditions; the pedagogical dimension involves teaching–learning processes and support systems; the technological dimension includes hardware, software, devices, and emerging technologies such as AI and the Internet of Things (IoT). In this review, following [8], SCs are understood as smart learning environments that collect and analyze data from students, teachers, the physical classroom, and learning management systems to provide timely and context-aware insights that support decision-making and enhance teaching and learning.

SCs do not manifest uniformly across educational contexts. In early childhood and primary settings, implementations tend to prioritize embodied interaction and physical engagement, foregrounding the environmental and pedagogical dimensions over complex analytics [9,10], whereas secondary and higher education contexts place greater weight on AI-driven personalization and learning analytics [2,5]. Diverse learning needs—including those of students with disabilities—further shape how the three dimensions must be configured to ensure accessibility and equity [11], while teacher experience conditions the degree to which AI-generated data can be translated into effective pedagogical decisions [6,12]. The COVID-19 pandemic further accelerated hybrid and remote configurations, exposing both the potential and the limitations of AI-supported SCs when environmental conditions fall outside institutional control [13,14]. Taken together, these variables confirm that SC should be understood as a dynamic and context-sensitive construct rather than a fixed technological configuration [3,7].

Despite the growing body of empirical work on AI in education, there are currently no systematic reviews that focus specifically on the context of SC. Most of the existing literature examines AI-based tools in isolation, without situating them within the broader architecture of smart educational environments or examining how their integration affects the multiple dimensions that characterize these spaces. Furthermore, the role of the teacher in AI-enhanced SCs has received comparatively little attention, despite being a critical factor in mediating the relationship between intelligent systems and learning outcomes.

Ref. [12] describes AI as a core element supporting the interactive and adaptive use of technologies in learning environments. Similarly, Ref. [11] conceptualizes AI as the central component responsible for processing information collected by sensors to improve the educational experience. In the context of Multimodal Learning Analytics (MMLA), Ref. [15] identifies AI as the most frequently exploited technology in the reviewed literature. Ref. [12] identifies fragmentation as a major challenge, noting that SC components are often disconnected and lack a common integrated framework.

The literature remains fragmented and uses different approaches and definitions. Ref. [16] highlighted the predominance of technological approaches and the need to pay greater attention to pedagogical and human dimensions of AI-supported education. A recent review examined AI technologies in SC, mainly focusing on AI techniques, technological maturity, and security or privacy challenges [13]. This review also considers AI applications and functions, but it focuses on their integration into SC from an educational perspective, with attention to the technological, pedagogical, and environmental dimensions and the role of teachers in these settings. This review focuses particular attention on the pedagogical dimension, not as a secondary aspect of SC but as the dimension that connects AI tools with teaching, learning, feedback, and instructional decision-making. From

this perspective, technologically advanced classrooms are not necessarily smart unless AI use is aligned with clear pedagogical purposes.

2. Materials and Methods

2.1. Data Collection and Search Strategy

This systematic literature review analyzed how AI is integrated into SC across technological, pedagogical, and environmental dimensions. The review followed the PRISMA guidelines [17]; the completed checklist is provided as Supplementary Materials (File S1).

The search covered studies published between 2021 and 2026 in English and Spanish. Web of Science (WoS) and Scopus were used as databases.

The search string included terms related to AI, learning analytics, AI-based systems, SC, and smart learning environments: ("artificial intelligence" OR "generative AI" OR "learning analytics" OR "AI-based systems") AND ("smart classroom*" OR "intelligent classroom*" OR "smart learning environment*" OR "intelligent learning environment*").

The search was conducted in mid-April 2026. Records were screened progressively through the title, abstract, and full articles for review.

2.2. Screening and Selection Process

This strategy yielded a total of 300 records, which are distributed as follows: 154 from WOS and 146 from Scopus. After removing 138 duplicate records, 162 unique records remained for initial screening, which proceeded across three successive stages. Title-based screening led to the exclusion of 79 records, followed by abstract screening, which eliminated a further 48. This left 35 studies to undergo full-text assessment.

Upon closer analysis, six of these were excluded for the following reasons: (1) two full texts were inaccessible, (2) two papers were purely theoretical and lacked empirical data, (3) one study focused exclusively on online learning environments rather than SC, and (4) one did not employ AI-based systems. Consequently, 29 empirical studies were retained for inclusion in the final synthesis, as shown in Figure 1.

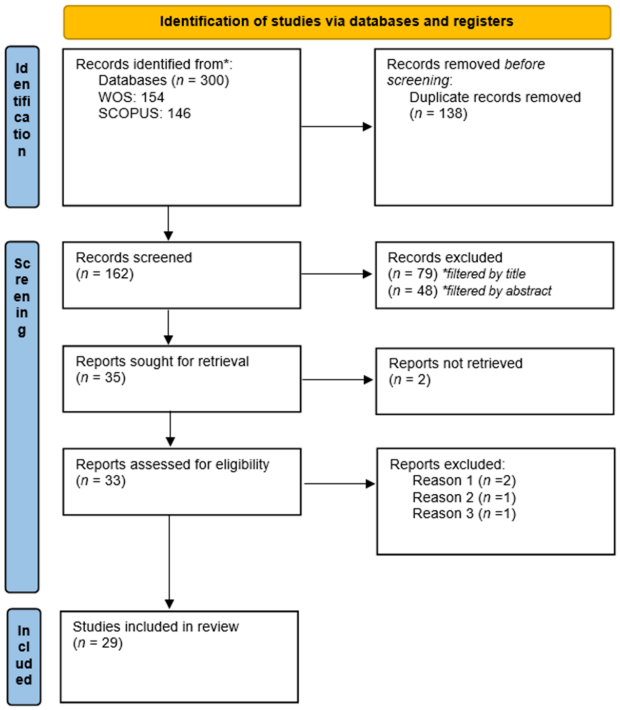


Figure 1. PRISMA diagram. * WoS and Scopus.

2.3. Research Questions

The review was guided by the following general research question: "How is Artificial Intelligence integrated into a Smart Classroom across technological, pedagogical, and environmental dimensions?" To address this question, three specific research questions were formulated, focusing on AI applications; their relationship with the technological, pedagogical, and environmental dimensions of SC; and the role of teachers in these settings (Table 1).

Table 1. List of research questions.

Number	Research Questions *
1	What AI applications are used in SC contexts, and for what purposes?
2	How do these applications relate to the technological, pedagogical, and environmental dimensions of SC?
3	What is the role of the teacher in SC integrating AI?

* According to the three dimensions.

To structure the analysis, the three dimensions proposed in [7] were used as analytical categories and adapted to the focus of this review. First, the technological dimension corresponds to Educational Technology (ET) and includes hardware, software, platforms, sensors, connectivity systems, and emerging technologies such as AI, Big Data, IoT, and cloud computing, as well as system attributes such as real-time feedback and adaptivity. Second, the pedagogical dimension corresponds to Performed Processes (PPs) and includes learning content, personalization, feedback, assessment, active learning, collaboration, motivation, autonomy, and system-aided monitoring or automation. Third, the environmental dimension corresponds to Physical Ambient Conditions (ACs) and includes classroom architecture, furniture, layout, lighting, temperature, humidity, air quality, and other indoor environmental conditions. These dimensions were used to analyze how AI is integrated into SC across the selected studies.

3. Results

This section presents the main characteristics of the selected studies (n = 29), focusing on their general features.

The geographical distribution is concentrated in Asia, particularly in China (e.g., Guangzhou, Hangzhou, Jilin). Additional contributions come from Europe (e.g., Spain, Norway) and regions such as the Middle East and North Africa (e.g., Iraq, Palestine, Morocco), as well as other Asian contexts (e.g., Malaysia, Taiwan).

Table 2 presents the 29 studies included in the review, including authors, year, country, sample size, educational level, and study design.

Table 2. List of 29 selected articles with essential information.

Reference	Country	Sample	Educational Level	Study Design
[9]	China	104	Primary education (4th grade in a mathematics course)	Quasi-experimental research
[10]	Spain	71 (under-graduated students in preschool education)	Higher education	A qualitative single-case study
[11]	China	17 (undergraduate students)	Special education college	Educational design research
[14]	Spain	45	Primary education	Pre-test/post-test design

Table 2. *Cont.*

Reference	Country	Sample	Educational Level	Study Design
[18]	China	2440	Higher education	A quantitative design
[19]	China	90 (two classes of 45 each)	Secondary education	A quantitative comparative experiment
[20]	-	30	Higher education	Quasi-experimental pilot study
[21]	China	100 (20 female and 80 male)	Higher education (English classes)	Experimental and comparative research study
[22]	China	677	Higher vocational education	Quantitative empirical study
[23]	China	613	Higher education	Mixed-methods empirical study
[24]	Malaysia	200 (100 students and 100 teachers)	Higher education	Empirical and experimental study
[25]	China	60 college students	Higher education	Experimental and comparative study using mixed methods
[26]	Palestine	92	Lower secondary education (8th grade)	Mixed methods
[27]	India	-	-	Multimodal AI systems
[28]	China	40	Vocational education specializing in dance	Experimental testing
[29]	China	40	Vocational education	Quasi-experimental pretest-posttest control group design
[30]	China	28 teaching videos from 28 different classes	Higher education	Data-driven research
[31]	China	421	Higher education	Non-experimental, quantitative, survey-based design
[32]	China	-	Higher education	Theoretical/design-based study
[33]	China	3 students and 1 teacher	Higher education	Experimental and technical research
[34]	China	613	Higher education	A mixed-method empirical study
[35]	Taiwan	50 (35 male, 15 female)	Higher education (first year)	Quantitative empirical research
[36]	Iraq	31 students and 1 lecturer	Higher education (College of Science students)	Technical implementation and experimental testing
[37]	Norway	44	Equivalent to lower secondary education (8th grade)	Design thinking process; mixed-method research design
[38]	Morocco	-	-	Experimental testing
[39]	China	60	Secondary education	Controlled designed experiment
[40]	China	100	Higher education	Experimental and evaluative study
[41]	China	-	Higher education	Experimental and technical research
[42]	China	197	Higher education	Compares an experimental group against a control group

Note: List ordered by reference number.

Regarding educational level, most studies were conducted in higher education contexts. Secondary education was less frequently represented, including both general and vocational settings. Primary education appeared only in a limited number of cases (e.g., [9]), while early childhood education was represented in only one study (e.g., [10]). Additionally, some studies involved mixed educational levels (e.g., K–12) or specialized contexts such as special education (e.g., [43]).

Regarding study design, most studies adopted empirical approaches, with a predominance of experimental and quasi-experimental designs, often involving control groups or pre–post-tests. These approaches were primarily used to assess the impact of AI-based interventions in real classroom settings. In addition, several studies employed quantitative empirical methods and mixed-method designs, combining quantitative and qualitative data. Qualitative approaches were less frequent and were mainly represented by case studies focusing on specific contexts or teacher-related aspects (e.g., [10]. A small number of studies adopted design-oriented or technical approaches, sometimes with limited classroom-based validation (e.g., [32]).

The number of participants varied considerably, ranging from very small samples (e.g., [32]) to large-scale samples (e.g., [33]). Several studies also involved relatively large cohorts (e.g., [18,22]), and most studies included medium-sized samples numbering between 30 and 200 participants. In some cases, both students and teachers were involved (e.g., [43]).

Table 3 complements Table 2 by summarizing the main AI technologies or applications used in each study and the SC dimensions primarily addressed. As shown, the technological dimension (T) is present across virtually all studies, while the pedagogical dimension (P) appears in the majority of cases, often in combination with T. The environmental dimension (E) is less frequent and tends to co-occur with sensor-based or IoT-integrated applications. This distribution reflects the uneven development of the three dimensions in the current literature on AI in SC.

Table 3. AI technologies/applications used and SC dimensions addressed for the 29 selected studies.

Reference	AI Technologies/Applications Used	SC Dimensions
[9]	AI classroom platform; personalized resource delivery; deep learning for convergent environments	T, P
[10]	Smart learning environment; data collection; student modeling; adaptive response (sense–analyze–react cycle)	T, P
[11]	Intelligent learning environment; AI-assisted accessibility tools for hearing-impaired students; design-based research	T, P, E
[14]	AIoT; energy monitoring; environmental quality sensors (lighting, temperature, and air quality); sustainability analytics	T, E
[18]	Intelligent teaching platform; data analytics; civic education management system	T, P, E
[19]	AI-optimized teaching strategies; data-driven instructional adaptation	T, P
[20]	AI and augmented reality (AR); experiential learning systems for photographic arts education	T, P, E
[21]	AI and data science integration; digital transformation tools for college English	T, P

Table 3. *Cont.*

Reference	AI Technologies/Applications Used	SC Dimensions
[22]	Smart environment platforms; teacher-technology collaboration tools; learning analytics	T, P
[23]	Deep learning-based AI teaching model; automated instructional support	T, P
[24]	AI anxiety sentiment evaluation; NLP; adaptive feedback systems for English audio-visual learning	T, P
[25]	Smart classroom HCI systems; cognitive load monitoring; academic emotion detection	T, P
[26]	AI learning environment for algebra; academic emotion support; adaptive mathematics instruction	T, P
[27]	Psychologically responsive AI; multimodal AI systems; cognitive/emotional/motivational monitoring	T, P
[28]	Motion capture system; interactive learning platform; performance analysis for dance education	T, P
[29]	AI-assisted dance skill evaluation; visual feedback systems; motion analysis; automated performance assessment	T, P
[30]	IoT devices; learning analytics; data-driven English language teaching; visual analysis tools	T, P, E
[31]	Smart classroom academic analytics; moderated-mediation model; survey-based AI integration assessment	T, P
[32]	AI classroom design; automated assessment; recommendation systems; NLP for English language and literature	T, P
[33]	Deep learning emotion recognition architectures; smart classroom emotional support systems	T, P
[34]	AI English literature smart classroom; NLP; recommendation systems; LLMs integrated with ICT	T, P
[35]	Precision education platform; learning analytics; adaptive content delivery; real-time feedback	T, P
[36]	Facial recognition technology; automated attendance management system	T, E
[37]	Multi-modal learning analytics (MMLA) dashboard; multimodal sensors; K-12 orchestration tools	T, P, E
[38]	IoT sensors; convolutional neural networks (CNNs); real-time learner attention detection	T, E
[39]	Blockchain; wireless sensor networks (WSNs); real-time health and physiological monitoring; personalized learning	T, E
[40]	AI-based mobile information system; Smart Classroom Platform 2.0; English language teaching model	T, P
[41]	AI-based art design classroom; visual analytics; automated evaluation of creative productions	T, P
[42]	HMM; NLP; adaptive learning; dynamic difficulty adjustment (DDA); virtual tutor; automated feedback	T, P

Note: T = Technological dimension; P = pedagogical dimension; E = environmental dimension.

3.1. Research Question 1: Applications and Purposes

To address RQ1, "What AI applications are used in SC contexts, and for what purposes?", the studies were analyzed according to two criteria: the dominant type of AI application or technology described and the main function attributed to it within the SC context. The identified patterns are not mutually exclusive, as different technologies are often combined within the same systems. Overall, eight patterns were identified.

A first pattern includes studies describing integrated intelligent systems or broad SC platforms, where AI is part of a complex architecture rather than an isolated tool. This pattern appears in SCARLETT, where [10] combines data collection, student modeling, and personalized response through the sense–analyze–react cycle. It also appears in [42], which describes an ecosystem combining Hidden Markov Models (HMMs), Natural Language Processing (NLP), adaptive learning, Dynamic Difficulty Adjustment (DDA), a virtual tutor, and automated feedback. Refs. [9,18,31,32,40] also describe environments integrating multiple intelligent technologies into teaching, assessment, interaction, or management platforms. The main function of this pattern is to organize classroom processes through data collection, analysis, and educational response.

A second pattern is related to learning analytics, Big Data, data mining, and data-driven decision support. In these studies, AI transforms learning, behavioral, or interaction data into information for monitoring, diagnosis, or decision-making. Ref. [35] combines behavioral recognition, dashboards, and chatbots to support reflection and precision education. Ref. [30] uses learning analytics to track progress, knowledge mastery, and effectiveness. Ref. [41] analyzes data from IoT devices to detect difficulties and personalize teaching. Refs. [31,32,34,40,41] also use analytics, data mining, or clustering to support personalization, assessment, or efficiency. The main characteristic of this group is the transformation of classroom data into operational information.

A third pattern is linked to personalization, adaptation, and recommendation. AI is used to adjust resources, learning pathways, difficulty levels, content, or feedback. Ref. [10] personalize tasks, quizzes, and geolocated recommendations. Ref. [42] uses Bayesian knowledge tracing, collaborative filtering, and DDA. Ref. [9] implements personalized resource pushing, while [21] provides adaptive content and individualized feedback. Ref. [26] implemented the CK-12 Flexi system, which provides adaptive pacing, immediate feedback, and on-demand hints and examples based on student performance. Refs. [23,32,34,40,41] also connect classification or data analysis with personalized plans or pathways. This pattern frequently appears together with learning analytics and behavioral tracking.

A fourth pattern includes applications for detecting, recognizing, and monitoring student states. These include computer vision, emotion recognition, affective computing, multimodal analytics, and sensing techniques. Ref. [19] uses multimodal emotion recognition through Support Vector Machine (SVM). Ref. [35] recognizes behaviors with Convolutional Neural Networks (CNNs). Ref. [24] uses Deep Belief Networks (DBNs) to detect anxiety, while Ref. [38] detects attention through CNN and IoT. Ref. [37] monitors engagement, affect, and self-regulation through Multi-Modal Learning Analytics (MMLA). Ref. [27] describes Psychologically Responsive AI (PRAI) systems for cognitive, emotional, and motivational states, and Ref. [33] focuses on emotion recognition using advanced deep learning architectures. The main functions are to monitor students' states, provide real-time information, and support instructional adjustments, feedback, or regulation.

A fifth pattern includes AI applications for language learning, communication, and conversational support. Several studies apply AI to English learning, translation, or literature through NLP, learning analytics, automated assessment, recommendation systems, speech recognition, and robot translation. Ref. [42] applies HMM, NLP, virtual tutoring, and automated feedback to translation. Ref. [40] incorporates Natural Language Un-

derstanding (NLU), Question and Answer (Q&A) systems, pattern recognition, learning analysis, and adaptive recommendation in English learning. Ref. [32] applies learning analytics, automated assessment, and recommendation systems to English language and literature. Ref. [41] uses IoT and analytics in English classes, while Ref. [34] mentions NLP, speech recognition, and robot translation. Conversational tools also appear as support for interaction, tutoring, and communicative practice. Ref. [21] uses chatbots for speaking practice and anxiety reduction, and Ref. [30] mentions Large Language Models (LLMs) integrated with Information and Communication Technology (ICT). Refs. [21,35,40,42] also describe chatbots, virtual tutors, or Q&A systems. Overall, the functions in this pattern include language practice, automated feedback, assessment, personalization, tutoring, and communicative support.

A sixth pattern includes AI applications for classroom management, automation, and administration. Ref. [36] provides the clearest example, using facial recognition for automated attendance. Ref. [21] also includes attendance automation, question banks, exams, and behavior monitoring. Ref. [18] mentions robots and platforms designed to reduce teachers' routine tasks. In this pattern, the goal is not necessarily to intervene in learning but to automate or facilitate classroom management processes.

A seventh pattern appears in applications integrating IoT, AIoT, sensors, and environmental or physiological data. Ref. [14] applies AIoT to monitor energy, lighting, temperature, and air quality. Ref. [39] combines Wireless Sensor Networks (WSNs), AI, and blockchain to collect physiological and behavioral data related to health and well-being. Ref. [38] uses cameras and connected sensors for attention detection. Ref. [37] uses sensor and interaction data in MMLA, while Ref. [27] includes sensing modalities in PRAI ecosystems. These studies show how AI is used to interpret physical, physiological, or contextual data and relate them to comfort, well-being, attention, engagement, or adaptation.

The final pattern includes AI applications in artistic, visual, and bodily domains. Ref. [20] combines Deep Recurrent Neural Networks (DRNNs), image filtering, and Augmented Reality (AR) in photography. Ref. [28] uses motion capture and interactive learning in dance, while Ref. [29] applies motion analysis, automated evaluation, and visual feedback. Ref. [41] uses learning analytics, visual analysis, and interactive design tools in art design. The main functions are visual feedback, performance assessment, support for creativity, analysis of productions or movements, and development of specific skills.

3.2. Research Question 2: Dimensions

To address RQ2, "How do these applications relate to the technological, pedagogical, and environmental dimensions of SC?", the reviewed studies were analyzed through the three-dimensional framework proposed in [7]. It is important to note at the outset that these three dimensions are not equally represented in the literature, nor do they operate in isolation. Across the 29 selected studies, the technological dimension is the most consistently addressed, functioning as the enabling infrastructure through which AI applications are deployed. The pedagogical dimension appears with significant frequency, particularly in studies focused on personalization, formative assessment, and active learning, though it is often framed as a consequence or application of technology rather than as an independent design priority. The environmental dimension is the least systematically explored, appearing in partial or diffuse ways in many studies, which reflects a broader gap in the SC literature regarding the physical conditions of learning spaces. The sections below analyze each dimension in turn, attending to its distinct characteristics and their interconnections.

3.2.1. Technological Dimension

The technological dimension appears as the material and digital foundation that enables SC to function. In the reviewed studies, this dimension is configured through the integration of devices, platforms, sensors, connectivity systems, and data analysis mechanisms. Several studies describe architectures combining hardware and software, including interactive whiteboards, smart desks, recording systems, tablets, smartphones, cameras, IP cameras, laptops, smartboards, motion capture technologies, and mobile devices, together with digital platforms, cloud services, Moodle, mobile information systems, the Precision Education Platform (uses student data to customize learning experiences), Smart Classroom Platform 2.0 (transforms a traditional classroom into a more interactive, connected, and data-driven learning space), and teacher dashboards [10,19,20,28,29,33–36]. A recurring presence of IoT, Big Data, sensors, data analytics platforms, and real-time visualization or feedback systems is also observed. This shows that the technological dimension is not limited to equipment but also structures the collection, processing, and use of classroom data [15,21,23,25,30,37–39,41].

The technological dimension is generally organized around connected infrastructure, intelligent platforms, and analysis or feedback systems. Some studies emphasize advanced technical architectures, including programming stacks based on Python or PyTorch, Deep Belief Networks, Convolutional Neural Networks (CNNs), Transformers, Vision Transformer, blockchain, Artificial Intelligence of Things (AIoT), or AI-based data fusion [14,24,33,36,38,42]. Other studies present technology as support for interaction, accessibility, personalization, or learning monitoring through real-time feedback systems, adaptive digital platforms, speech recognition, captioning, visual representations, or intelligent learning management systems [9,11,26,31,32,40,41].

3.2.2. Pedagogical Dimension

The pedagogical dimension appears in relation to the transformation of teaching and learning toward more personalized, active, and student-centered approaches. In several studies, AI is linked to the adaptation of content, learning pathways, or feedback based on student data, supporting personalized, self-regulated, or progress-based learning models [23,24,32,34,35,39–41]. This orientation also appears in studies connecting technology with formative assessment, immediate feedback, learning monitoring, and the adjustment of teaching according to students' cognitive, emotional, or behavioral needs [24,29,33,37].

A second pattern is the presence of active, collaborative, experiential, or contextualized pedagogical approaches. Some studies situate AI within models such as Problem-Based Learning, Group Investigation, flipped classroom, blended learning, project-based learning, experiential learning, or ubiquitous learning, aimed at promoting participation, collaboration, reflection, critical thinking, or transfer to real situations [9,10,18–21,26,30,31,35]. In other cases, the pedagogical dimension appears in specific subject areas such as photography, dance, art design, mathematics, English, or inclusive education, where AI supports specialized skills, visual feedback, embodied learning, creative development, or equitable participation [11,20,28,41].

Finally, some studies represent the pedagogical dimension more indirectly, where AI supports learning through the reduction in administrative workload, improvement of learning conditions, increased engagement, or reduction in barriers to participation [11,14,36].

3.2.3. Environmental Dimension

The environmental dimension appears in heterogeneous ways across the articles. Some studies relate it to physical classroom conditions or their intelligent control. These studies mention elements such as functional space design, smart desks, digital sensing, intelligent

lighting, and air conditioning systems used to adjust the internal environment [18]. Other studies refer to the control of temperature, humidity, and air quality [21], the adjustment of lighting, temperature, and humidity [25], and energy or environmental monitoring through AIoT to reduce consumption, improve sustainability, and optimize conditions such as lighting, temperature, and air quality [14]. More specific references also appear, such as lighting and student distance in classrooms using facial recognition [36], or flexible furniture, including movable tables and chairs, to support discussion layouts [40].

In other studies, the environmental dimension appears in a broader or more diffuse way through the configuration of connected, intelligent, interactive, accessible, or responsive learning environments. This appears in studies describing the integration of physical space and digital systems to respond to learning states, interaction, or well-being [31,38,39,41]. It also appears in studies focused on embodied learning, accessibility, or creativity, where the classroom is described as an interactive, inclusive, or experimental space [11,28,29,41]. Some studies use the concept of "environment" in a more pedagogical or digital sense, referring to safe, participatory, flexible, or immersive spaces without addressing physical environmental conditions in depth [26,32,37].

3.3. Research Question 3: Teacher Role

To address RQ3, teacher roles were analyzed as overlapping functions rather than fixed categories. As a result, six teacher roles have been identified. One recurring role is the teacher as an instructional or learning designer who organizes, redesigns, or adapts AI-supported learning experiences. This role appears when teachers create data-driven lesson plans, design pre-study resources, adjust teaching strategies, or align technology use with pedagogical goals. Ref. [42] describes teachers as adaptive instructional designers who adjust teaching progress, content, and strategies based on real-time diagnostics. Ref. [21] presents teachers as creating data-driven lesson plans from student data. In non-higher education contexts, Ref. [9] describes primary teachers developing pre-study resources and adjusting lesson plans based on platform data, while Ref. [26] describes an eighth-grade teacher redesigning a teaching unit according to the SAMR model and deciding when to introduce the AI tool.

The second role is the teacher as a data-informed decision-maker and adaptive monitor. Teachers use AI-generated data to observe progress, identify needs, and adjust instruction. This role appears when teachers use dashboards, real-time diagnostics, behavioral data, or AI feedback to modify teaching pace, content, or support strategies [10,24,31,35]. Other studies focus on attention, engagement, health, or learning states. Ref. [26] describes dashboard data used to identify students needing help. Ref. [37] presents teachers interpreting AI insights to guide pedagogical decisions. Ref. [38] refers to attention data, and Ref. [39] refers to health and learning insights. Ref. [33] extends this role to emotion recognition, where teachers use information about psychological states and classroom atmosphere to adjust teaching strategies.

A third role is the teacher as a facilitator, guide, or mentor of learning processes. This role becomes more precise when linked to actions such as guiding discussions, supporting inquiry, promoting active learning, scaffolding practice, or encouraging creativity. Ref. [35] describes the teacher as a guide in the PBL process. Ref. [9] presents the teacher as promoting active inquiry and collaborative exploration. Refs. [23,34] describe a shift from the teacher as a knowledge authority to a more flexible facilitator or mentor role supported by AI-generated data. In artistic and vocational contexts, Ref. [20] links the teacher to artistic meaning-making and visual storytelling, while Refs. [28,29,41] emphasize pedagogical guidance, motivation, confidence, creative evaluation, and human feedback.

A fourth role is the teacher as a supervisor who exercises professional judgment. AI is a support system, while the teacher remains responsible for interpreting outputs, contextualizing data, and deciding when and how to intervene. This role is clear in [10], where the teacher required greater control over the AI-supported process through a dashboard. It also appears when teachers interpret AI-generated insights or attention data while retaining responsibility for pedagogical decisions and ethical data use [37,38]. Other studies describe this role more broadly through teacher agency, human oversight, pedagogical responsibility, informed use, or non-replacement [11,14,27,39].

A less frequent role is the teacher as an emotional and well-being supporter. Teachers use AI-generated information to support confidence, motivation, anxiety regulation, self-esteem, stress management, or classroom atmosphere. Ref. [24] describes the teacher as an emotional counselor who helps students overcome oral practice anxiety. Ref. [26] presents the teacher as protecting students' self-esteem and confidence when technical problems arise. Ref. [40] describes the teacher as providing timely help and encouragement based on AI-identified learning states. Ref. [33] extends this role to monitoring stress, emotional atmosphere, and students' psychological states. In vocational dance contexts, Refs. [28,29] also refer to teachers supporting motivation and confidence through AI-supported feedback.

Finally, some studies describe the teacher as an orchestrator or manager of AI-mediated classroom processes. This role includes coordinating activities, managing digital resources, controlling AI-mediated interactions, supervising check-ins or roll calls, and synthesizing AI-supported discussions. It is especially visible in [25], where the teacher initiates the lesson, controls AI-mediated discussion content, manages check-ins and roll calls, and synthesizes AI-led discussions. Ref. [26] also describes the teacher as a designer and orchestrator who supervises class progress, handles technical issues, and guides mini presentations. Ref. [40] refers to the teacher as an analyst and manager who monitors learning behaviors, facilitates discussions, and manages digital resources. A more peripheral version appears when AI supports administrative processes. Ref. [36] describes the teacher as reclaiming instructional time by delegating roll call to the AI system, while Ref. [21] managing digital examination and resource systems.

3.4. Comprehensive Synthesis Matrix

The findings from the three research questions are brought together in Table 4, which presents a comprehensive synthesis matrix cross-referencing the eight AI application patterns identified in RQ1, the three SC dimensions addressed in RQ2, and the six teacher roles identified in RQ3. Each row specifies the primary function served and representative study citations.

Table 4. Comprehensive synthesis matrix: AI application patterns, SC dimensions, and teacher roles.

AI Application Pattern (RQ1)	SC Dimensions (RQ2)	Primary Function	Teacher Roles Activated (RQ3)	Representative Studies	Educational Level Context
1. Integrated SC Platforms	T (primary), P	Orchestrate classroom processes; data collection, analysis, and educational response	Instructional designer; orchestrator/manager	[9,10,18,42]	Higher Ed, Primary, Secondary
2. Learning Analytics and Data-Driven Decision Support	T (primary), P	Transform classroom data into operational information; monitoring, diagnosis, decision support	Data-informed decision-maker; adaptive monitor	[22,35,37,41]	Higher Ed, Vocational

Table 4. *Cont.*

AI Application Pattern (RQ1)	SC Dimensions (RQ2)	Primary Function	Teacher Roles Activated (RQ3)	Representative Studies	Educational Level Context
3. Personalization, Adaptation, and Recommendation	T, P (both central)	Adjust resources, learning pathways, difficulty, content, and feedback based on student data	Instructional designer; facilitator/guide	[9,10,21,26,42]	Higher Ed, Secondary, Primary
4. Student State Detection and Recognition	T (primary), P, E	Monitor student cognitive, emotional, and behavioral states; support real-time instructional adjustments	Adaptive monitor; emotional well-being supporter; professional supervisor	[24,27,33,37,38]	Higher Ed, Secondary, K-12
5. Language Learning and Conversational Support	T, P (both central)	Language practice, automated feedback, personalized assessment, conversational tutoring support	Facilitator/guide; emotional well-being supporter	[21,24,32,34,42]	Higher Ed, Secondary
6. Classroom Management and Automation	T (primary), E	Automate administrative tasks (attendance, exam management); free instructional time	Orchestrator/manager; professional supervisor	[18,21,36]	Higher Ed, Secondary
7. IoT, AIoT, and Environmental Sensing	T, E (both central)	Interpret physical, physiological, and environmental data; optimize comfort, well-being, and engagement	Professional supervisor; adaptive monitor	[14,27,30–33]	Primary, K-12, Higher Ed
8. Artistic, Visual, and Bodily Domains	T, P (both central), E	Visual feedback, performance assessment, creativity support, embodied skill development	Facilitator/guide; Emotional well-being supporter; instructional designer	[20,28,29,41]	Higher Ed, Vocational

SC Dimensions: T = technological; P = pedagogical; E = environmental. Teacher Roles: (1) instructional/learning designer; (2) data-informed decision-maker and adaptive monitor; (3) facilitator, guide, or mentor; (4) professional supervisor; (5) emotional and well-being supporter; (6) orchestrator/manager of AI-mediated processes.

4. Conclusions and Prospects

This review examined how AI is integrated into SC across technological, pedagogical, and environmental dimensions. Overall, the findings show that AI is integrated mainly through data-driven and adaptive systems, but its educational value depends on how these systems are connected to pedagogical aims, classroom conditions, and teacher mediation.

Regarding RQ1, the most common AI applications identified in the reviewed studies include learning analytics, adaptive systems, conversational tools, automation, and sensor-based or IoT/AIoT systems. These applications are mainly used to monitor learning, analyze data, personalize instruction, provide feedback, support interaction, and assist classroom management.

Regarding RQ2, the integration of AI across the three SC dimensions is uneven. The findings support previous definitions of SC as environments that use digital technologies to foster interaction, adaptability, and the management of educational processes [1,3,5]. However, when the results are analyzed through the framework proposed by [7], which distinguishes technological, pedagogical, and environmental dimensions, the technological

dimension is the most developed. This dimension appears mainly through platforms, sensors, analytics, dashboards, and real-time feedback systems. The pedagogical dimension is also important, but it appears mainly through specific uses of AI, such as personalization, active learning, formative assessment, feedback, instructional adaptation, and teacher decision-making. The environmental dimension is the least clearly developed. Some studies address physical classroom conditions, such as lighting, temperature, air quality, furniture, or spatial organization, while others use "environment" in a broader digital or pedagogical sense.

This reveals a tension, because SCs are defined as integrated environments, but the studies often treat them as technology-driven systems. This supports the distinction between classrooms that simply use technology and SCs understood as more integrated educational environments [6,8]. AI can support the development of SC, but the presence of advanced technology is not enough. These systems become educationally meaningful when they are connected to teaching, learning, space, and context.

Regarding RQ3, AI changes the teacher's role in SCs. Across the reviewed studies, teachers appear as instructional designers, data-informed monitors, facilitators, supervisors, emotional supporters, and orchestrators of AI-mediated activity. Teacher agency remains essential for interpreting AI-generated data, making contextual decisions, and connecting technological possibilities with meaningful teaching and learning processes.

4.1. Limitations

The main limitations of this review are related to the composition and scope of the corpus. The geographical concentration in China and the overrepresentation of higher education may limit the transferability of the findings to other educational contexts and levels. In addition, the conceptual heterogeneity of the field and the different levels of detail across studies affect the comparison between cases. Therefore, the results provide a structured view, but they should not be understood as a representation of all possible forms of AI integration in SC.

4.2. Future Research

Future research should address the limitations identified in this review and also address some lines that emerge from the analysis:

- Explore how environmental conditions are integrated in AI-supported SC, particularly the environmental factors and how they are related to teaching and learning processes.
- Analyze how teachers experience their changing role in relation to data management, pedagogical decision-making, and the new demands of SC.
- Analyze how teachers are being trained to address the pedagogical and technical demands of using AI in education.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/encyclopedia6060138/s1, File S1: PRISMA 2020 Checklist. Reference [17] is cited in the Supplementary Material.

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Abbreviations

The following abbreviations are used in this manuscript:

SC	Smart Classroom;
IoT	Internet of Things;
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses;
AI	Artificial Intelligence;
AIoT	Artificial Intelligence of Things;
RQ	Research Question;
CNNs	Convolutional Neural Networks;
AR	Augmented Reality
ICT	Information and Communication Technology;
LLM	Large Language Models;
WSNs	Wireless Sensor Networks;
MMLA	Multi-Modal Learning Analytics;
DRNN	Deep Recurrent Neural Network;
SVM	Support Vector Machine;
DBN	Deep Belief Networks;
PRAI	Psychologically Responsive AI;
NLP	Natural Language Processing;
NLU	Natural Language Understanding;
DDA	Dynamic Difficulty Adjustment;
HMMs	Hidden Markov Models.

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