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SMART CLASSROOM: TAXONOMY OF FEATURES, EXISTING TECHNIQUES, CHALLENGES AND RESEARCH OPPORTUNITIES

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Abstract

Recent years have seen the publication of a sizable quantity of research on smart classrooms. The aftermath of COVID 19 experience has introduced diverse smart classroom platforms with students, instructors, and administrators more engaged and empowered. However, the introduction of smart classrooms still lacks the necessary technological elements and characteristics to compete with the conventional face-to-face teaching methods. Piecemeal adoption will not create the ideal smart classroom environment. This paper, therefore, looked at the taxonomy of features/components that make up an ideal smart classroom environment. A thematic analysis of various existing literatures was used to understand and enumerate the essential tools needed for an ideal smart classroom, present existing works on smart classroom implementation and identify challenges and research opportunities for an ideal smart classroom environment. Findings from this study showed that more robust smart classrooms with a variety of pedagogical methods and adaptive learning are required to fulfil the unique requirements of students; formative assessment will be a useful strategy, helping students transition from being passive to being active learners; the smart learning environment must integrate formal and informal learning to create an autonomous learning environment that supports individual learners; more so from a technological than a pedagogical standpoint, emphasis should be placed on the applications of analytics to teaching and learning.

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1.0 INTRODUCTION

A flexible and dynamic educational approach that can adapt to changing educational needs is essential in the times we live in. We must envision a classroom that anticipates emerging trends in higher education and reflects how new Information and Communication Technologies (ICTs) can help students to assimilate knowledge and skills more quickly and effectively. Many individuals find the term “smart education” ambiguous, despite the current worldwide push towards the use of digital technologies as a significant teaching method in contemporary education [1]. According to [2], the term "smart" is increasingly often used in educational

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research to designate new language such as "smart learning", "smart universities", and "smart classrooms". [3] defined a smart classroom as an educational environment equipped with various technological tools like audio, video, and advanced multimedia devices to help students improve in learning, and for teachers to effectively manage and teach students. [4] described the smart classroom as an environment that is intelligent and efficient for teaching and learning through the integration of "internet +" and other advanced technologies. [5] definition of a smart classroom is similar to that of [4]. The authors added that these enhanced IoTs, cloud, and intelligent technologies will provide learners with interactive and engaging educational experiences that can lead to efficient learning outcomes.

A smart classroom, therefore, utilizes cutting-edge technology to integrate efficient teaching strategies into the classroom. It is an improved space that uses multimedia, animations, music, video, and other learning tools to improve teaching and learning. It is becoming increasingly obvious that technology is integral to every part of our lives; therefore, the way that students obtain education is crucial to this progress. According to [6], smart systems are creative systems where ICT tools enhance city life to accommodate changing societal requirements, as well as economic and environmental issues in the future. Students range in their degrees of intelligence, their appreciation of technology, their levels and abilities of understanding, their level of discipline, which is crucial for motivation and focus, and their level of learning preparedness. Universities are working in a highly dynamic and very viable environment today to match the special abilities of students to the requirements of the courses they provide in a technology world as complicated as ours.

Understanding what the ideal future will look like may be difficult for educators. The fundamental foundation of the smart city idea is among its most important features. Since there is a dearth of information and data related to the study of smart cities and the concepts of smart education, the dynamic nature of contemporary education is now frequently described. Advances in ICTs will have a significant impact on the delivery of essential education and other human services. Education will ride the wave to ensure a better life for its residents. This study, therefore, aimed at presenting essential components that will bring about the ideal education needed for a better life. The objectives of this study are to investigate the essential tools for an ideal smart classroom, review existing literature on the implementation of smart classrooms, compare smart classroom essential learning tools implemented by existing works and suggest future direction for the implementation of a robust smart classroom

2.0 TAXONOMY OF ESSENTIAL LEARNING TOOLS IN A SMART CLASSROOM ENVIRONMENT

The proliferation of smart learning environments is being fueled by the rapid development of computer and communication technology. The past ten years have witnessed widespread use of mobile devices (such as smartphones, tablets, and laptops), Internet of Things (IoTs), and wireless communication networks, which have greatly facilitated and driven the need for the creation of intelligent learning environments [7]. These technical capabilities enable the learning systems to recognize and gather information about learners' interactions with smart learning tools in real-world learning environments. Various features/components are therefore needed to enhance an intelligent learning environment. Just like a good classroom teacher, a smart classroom must be equipped with tools that can effectively manage a classroom for knowledge delivery. This section examined the essential tools needed for an ideal smart classroom environment.

2.1 Methodology

A thematic analysis of existing literature was conducted to understand and identify the essential tools required for an ideal smart classroom. Four basic search phrases (as described in Table 1) with several alternate search terms utilized to arrive at the taxonomy of essential tools for the smart classroom. English-language papers, classroom-related papers, and full-text publications were the criteria used for inclusion in this study. Fifty-two (52) articles were selected for this study. Table 2 described database sources of this article.

Table 1: Search phrases to investigate tools for an ideal smart classroom

RQ1	What are the essential infrastructure devices required for an effective smart classroom?
RQ2	What are the key features of a smart classroom that facilitate effective learning outcomes?
RQ3	What are the most effective assistive tools for a smart classroom environment?

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RQ4	What are the concerns of the smart classroom environment on the learning outcomes of students?

Table 2: Database sources for the thematic analysis

Database Sources	**Articles**
Springerlink	[22], [33], [49]
MDPI	[29], [30]
Elsevier/ScienceDirect	[25], [27], [34], [42], [45], [48], [51]
ACM Digital Library	[4], [7], [10], [11]
IEE Xplore	[5], [9], [14], [19], [24], [32], [36], [37]
Wiey/Hindawi	[17], [26]
Taylor & Francis	[35]
UNESCO	[1], [13]
Researchgate	[40], [41], [46], [50]
Scopus/Other Indexed Journals	[3], [6], [15], [16], [18], [20], [21], [23], [28], [31], [38], [39], [43], [47], [52]
Other Conference Proceedings	[2], [8], [12], [44]

Results from this thematic analysis of existing works on tools in a smart classroom were categorized into two: functional requirements and non-functional requirements, as described in Figure 1.

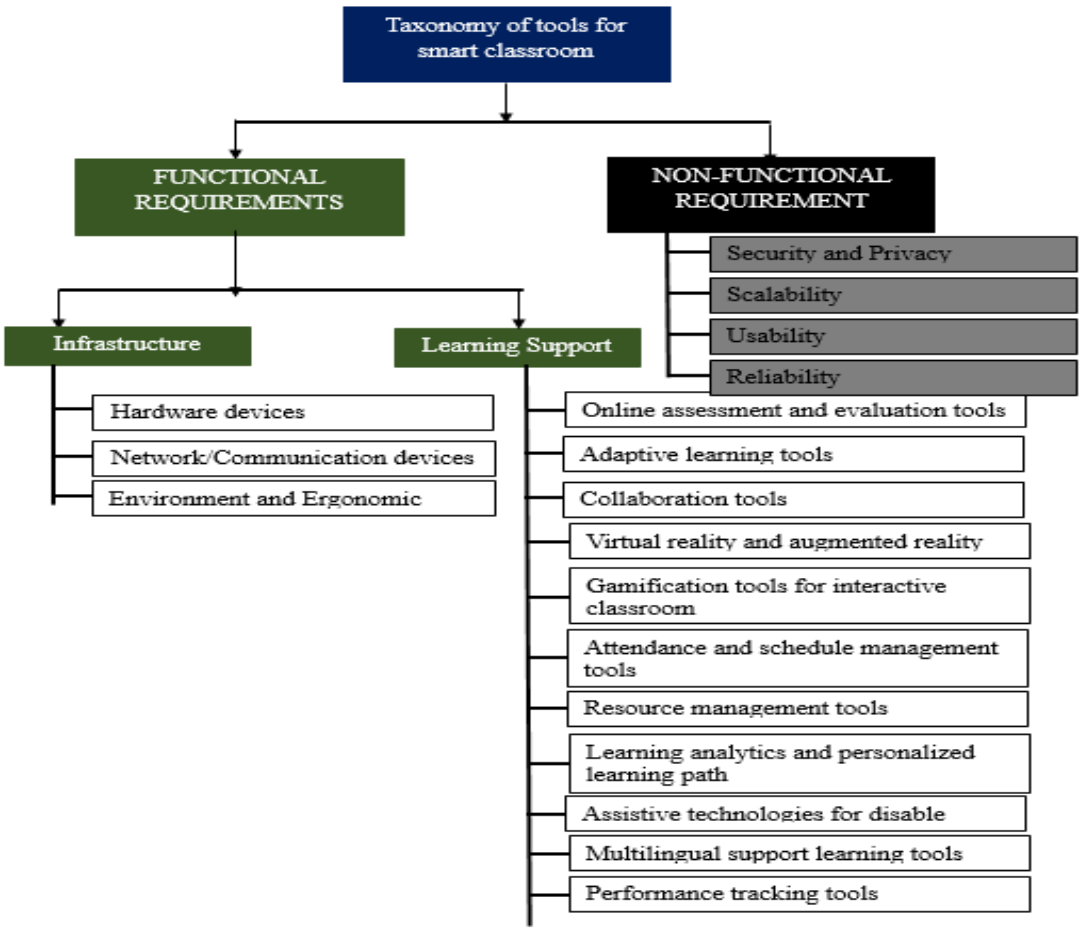

Figure 1: Taxonomy of essential tools for a smart classroom environment

Figure 1 proposes various essential tools/components that must work together to accelerate the global revolution of teaching and learning methods in a classroom. The perfect digital classroom can be

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created using these powerful digital technologies and features, which will revolutionize education and improve information delivery. Therefore, the numerous components listed in Figure 1 will be needed to build an ideal smart classroom.

2.1.1 Functional requirements

These requirements describe what functions are expected of any smart classroom that can help improve the learning outcomes of the students. They are the required operations/functions, tools, and technologies expected in an ideal smart classroom.

a. Infrastructure: The infrastructure for smart education includes both the physical and digital elements required to facilitate the integration of technology in educational settings, enabling smooth and efficient learning experiences. Infrastructure for smart education has advanced significantly in recent years. The accessibility of high-speed internet connectivity, dependable hardware, and strong network infrastructure has increased, making it possible to integrate different instructional tools. A reliable internet connection is necessary for accessing educational information, interacting with peers, and participating in real-time contact with students and instructors, given the growing dependence on digital resources and online platforms. Smart education infrastructure also comprises the supply of appropriate hardware devices in addition to internet access. Laptops, tablets, interactive whiteboards, and other digital technologies that promote learning and participation are among them. To fully reap the rewards of smart education, it is essential to ensure that these gadgets are accessible to both instructors and students. A safe and scalable network environment should also be supported by the infrastructure to secure sensitive student data and security requirements; this includes a solid network design, firewalls, and data protection tools. It includes a number of elements and frameworks that make use of technology to enhance accessibility, participation, effectiveness, and educational results.

According to [8], smart systems are creative systems where ICTs enable users to fulfil the demands of future generations, as well as economic and environmental issues. Frameworks include network connectivity, hardware, and software that support effective education. Studies by [9-11] addressed diverse infrastructural needs for an effective classroom.

Connectivity and communication via a strong, dependable internet connection are also essential components of smart education because they let students and teachers access online materials, work together, and take part in smart classrooms. Collaborative work is involved with this technology. With effective connectivity and communication, project management systems, Microsoft Office 365, Google Docs, and other tools become efficient for teachers and students to collaborate and communicate effectively. Widespread use of communication technology will ensure continuous access to learning management systems, video conferences, and other online resources that enable fast data transfer rates, low latency, and secure connections. To provide freedom and mobility within the learning environment, wireless connectivity is essential in this educational setting. Both students and instructors should be able to connect their devices to the internet without a cable.

In addition to using communication devices like smartphones, tablets, or laptops for students and teachers to interact and exchange information, the development of smart learning environments has been greatly facilitated and made necessary by sensing technologies (RFID, GPS, and QR codes). These sensing technologies, together with good communication and collaborative tools, are essential to continually improve the learning environment [12].

IoT is an effective method for smart classroom communication [13]. With IoT, users can control all classroom components from any place in the world. [14-19] all contributed to the use of IoT for effective teaching and learning in a smart classroom. This is only possible if there is good connectivity.

Environment and ergonomics in a smart classroom can impact the cognitive and health of any learner. Ergonomic design in a smart classroom can help learners to engage more and has a direct influence on their physical well-being. Lighting, air quality,

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and sound coordination have a significant impact on a smart classroom. [20] suggested the use of adjustable furniture and optimized spatial layout as essential ergonomics tools for effective learning. Tools light lighting, temperature, and acoustics are special components that can stimulate learners and also allow them to have a versatile and comfortable learning environment. Non-compliance to the issue of environment and ergonomics can lead to musculoskeletal pain and metabolic disorders [21].

b. **Learning supports**: Learning tools use publicly-accessible and fee-based online educational resources, which allow users access to digital textbooks and e-books with interactive features including multimedia content, integrated quizzes, and links to other resources. Compared to traditional textbooks, these digital materials offer a more dynamic and interesting learning experience [2], [5-6]. A variety of these online platforms and courses provide instructional information needed for a good learning environment. These platforms give users access to interactive exercises, quizzes, and discussion forums as well as video lectures. Students often work at their own pace while interacting with the teacher and other students. Numerous educational apps are available that offer gamified exercises, simulations, and quizzes as interactive learning experiences. Learning is now more accessible thanks to educational applications. Students may explore realistic simulations and virtual worlds using virtual and augmented reality, which improves their comprehension of difficult ideas. Digital material is superimposed over the physical world in augmented reality, creating a hands-on, interactive learning environment. As would a human instructor or tutor, a smart learning environment must respond correctly and autonomously to various learning scenarios and conditions; this includes having the capacity to assist students in becoming more organized and conscious of their own learning objectives, procedures, and outcomes [22-23].

In the setting of today's technologically driven classrooms, there must be efficient and effective class management processes [24]. The introduction of technology has completely changed the face of education, causing classroom management to become a popular kind of tool in an online learning environment. To guarantee the best learning results, it is necessary to handle the special problems presented by classroom management in a learning environment. A smart classroom environment emphasizes the need to create clear expectations, rules, and norms, and penalties for noncompliance in order to maximize students' learning opportunities. To create a positive and stimulating environment for smart learning, it is crucial to have a welcoming, inclusive classroom culture that values cooperation and respect. This environment should also be flexible, adaptable, and open to changes as needed. The works of [25-26] attempted to solve the issue of attendance when it comes to class management in a smart classroom.

A robust smart classroom can lead to personalized learning paths using data analytics, where the content and pace of training are tailored to the needs of each learner. With the help of artificial intelligence, the instructor may utilize the huge amount of data to keep tabs on the student's development, spot potential growth areas, and offer personalized guidance. The data gathered for various delivery methods may differ depending on technology, background, institutional features, and instructional practices. By using this information to create personalized learning paths tailored to each student's needs, educators can identify areas where more support is needed and offer challenging materials to those students who excel [27]. This guarantees that each student has a unique learning experience, which supports the creation of adaptive learning platforms that modify the activities and content based on the development and performance of the students.

Students are appropriately challenged and receive targeted help, when necessary, with the use of algorithms to evaluate these huge amounts of data. As a result, teachers can spot early learning gaps or areas where students are having trouble, quickly intervene, and offer focused solutions by assessing student performance data. Students are better able to get the assistance they need to achieve because of this proactive approach. Additionally, data analytics

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enables teachers to keep an eye on pupils' development in real time. In order to make well-informed decisions regarding instructional tactics and interventions, educators can uncover trends and patterns by examining data on student performance, engagement, and involvement. Teachers may assess student development and modify their teaching strategies as necessary with the use of continuous monitoring. This helps with individualized evaluation and feedback. Additionally, teachers may provide students with focused feedback that identifies both their areas of strength and need for development. Students can enhance their performance in class by acting appropriately after receiving feedback that helps them comprehend their progress. Performance tracking by [28] and learning analytics by [29-31] are some effective solutions that can be implemented in a smart classroom.

A smart classroom must also be inclusive and accessible to ensure that all students, regardless of their skills, backgrounds, or circumstances, have equal access to and benefit from educational opportunities. For students with impairments, the smart classroom must provide accessible technology features and aids, including screen readers with captioning. To serve a variety of student demographics, adaptive input devices also enable multilingualism by providing language translation and localization options. This method will work well for students who choose to study in their mother tongue since it offers translated versions of the course materials and makes use of language translation software to make participation and comprehension easier.
By prioritizing accessibility in the design and implementation of a smart classroom, educational institutions can create an environment that supports the learning needs of all students, regardless of their abilities or backgrounds. [32] proposed a human voice artificial intelligence in education. The proposed model can be improved to ensure that presentations can be translated into diverse languages to satisfy learners' needs. Works proposed by [33-35] are all tailored towards providing an assistive technology for students with various forms of disabilities.

2.1.2 Non-functional requirements

These are functions that have no direct impact on the operations/functions in a smart classroom, but can impact the capabilities and constraints in the use of smart classrooms.

Due to the quick adoption of smart classrooms, security and privacy are now crucial considerations for protecting students' and teachers' privacy and fostering a safe learning environment. Utilizing connected devices often leads to potential vulnerabilities that must be addressed to guarantee the confidentiality, integrity, and availability of crucial data; as a result, taking steps to ensure data privacy, availability, and security from unauthorized access is crucial. [36] carried out a systematic survey on e-learning security. Their work showed that many e-learning platforms are vulnerable to attack. This goes to show that smart classrooms must be equipped with features/components that will prevent access to students' and tutors' privacy.

Regular software updates and security patches are necessary to address vulnerabilities and protect against emerging threats. It is also crucial to secure data transmission between devices and networks to prevent eavesdropping and data interception by unauthorized parties. These measures to protect user' personal information and ensure their privacy include encryption, secure data storage, and strict access controls to prevent unauthorized access to personal data.

Usability and reliability significantly enhance learning outcomes in any smart classroom. Teachers' ability to use essential tools in teaching, students' ability to navigate through the smart classroom platform seamlessly, and the reliability of the classroom environment can facilitate better cognitive development, learners' engagement behaviour, and their ability to manage information and structure their learning processes [37].

The scalability of a smart classroom can help in robust educational delivery and also allow for broader student engagement. A smart classroom should be able to use open architectures that support different human-computer interfaces for better communication, processing of heterogeneous data, intercultural and intercontinental engagements, and above all, the ability to accommodate more learners, instructional/learning tools, and still maintain its optimal performance.

3.0 REVIEW OF EXISTING TECHNIQUES FOR SMART CLASSROOMS

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Many academics in computer science and education have set out to make learning systems intelligent. Smart classrooms that use artificial intelligence approaches in educational applications are developed by researchers every day. By customizing learning interfaces or content to meet each student's needs, smart classroom developers want to help individual students in their approach to learning. Within the past ten years, a lot of learning systems have been put into place in addition to the growing use of computer networks and the World Wide Web. This section, therefore, offers several existing works linked to creating an effective and efficient smart classroom environment for students.

In order to create a smart learning system for a team-based presentation class, [38] created a peer-assessment system that connected an online and in-person smart classroom. This kind of collaboration-based learning is team-based presentation learning, which aims to evaluate students' learning processes while improving students' metacognitive skills. The two components of the system are a mobile application for students and instructors, and a web-based tool for teachers. The instructors' tool facilitates the registration of team data and assessment items, the evaluation of each team's presentation, and feedback on the outcomes of their presentations. Presenters may quickly view their evaluation results following the presentation. The mobile application evaluates peers' presentations in real-time. In order to facilitate student assessments, the system also guarantees that students will have access to tutor feedback as soon as the tutor's remarks become available. The App Inventor from MIT used a programming tool for creating Android applications with a simulator and MYSQL as the database technology for the implementation. Using an Apache 2 web server and PHP (Hyper-Text Preprocessor), the Web version of the smart classroom was integrated. A crowdsourcing-based approach for a smart learning environment was presented by [39]. The idea focused on using the IoT to build intelligent environments. Prior to building and executing the services required, [39] suggested crowdsourcing model ensures that information from students is gathered. The intended audience for the work consisted of University of Belgrade business students. The work gathered information on a number of factors related to students' requirements, skills, preferences, and knowledge in order to enhance the teaching and learning process. Based on the factual and subjective demands of the students, these parameters were set. The information that is subjective was gathered via a survey form and is relevant to education. The objective parameters represent some physical measurements from the physical environments, such as temperature, pressure, voltage, and so on. Based on the subjective and objective data they evaluated, [39] created two smart classrooms employing various techniques. Students' subjective parameters are used in one classroom, while objective parameters are used in the other. A smart corridor with information boards to further improve the learning and teaching process was integrated in the system. Students can connect their smartphones or tablets to the corridor using wireless technologies like Near-Field Communication (NFC) or Bluetooth to access the most recent information about their studies, classes, and exams. Finally, a learning management system data center was connected to the information gathered, both objectively and subjectively, where it is analyzed and feedback-provided.

The study by [40] created a smart classroom that uses a comprehensive strategy to instill the context of a technologically enhanced learning environment (Figure 2). Given the enormous influence of ICT on the modern educational system, the [40] strategy for creating a smart classroom essentially entails the methodical integration of ICT tools as a teaching-learning practices platform for school management. Creating desktop and mobile applications is a key component of their smart classroom strategy. While tutors and teachers access the classroom using a desktop program connected to the network, students use their individual mobile devices to connect to the smart classroom through wireless network technology. The system modules mimic intelligence by replacing the traditional chalkboard with an interactive smart whiteboard that functions as a computer monitor and allows users to interact with the screen using a keyboard, stylus pen, or even their finger. Other modules include a multimedia control center that limits student noise during the use of the smart classroom, a module for recording smart lectures, and a classroom management module that gives the tutor complete control over the smart classroom's components. Additionally, [40] included a module in the form of an electronic library that is updated and modified frequently and is packed with programs appropriate for different educational levels. The primary contribution was the integration of the smart board. Several educational goals were intended to be met by the interactive smartboard in order to provide a dynamic, engaging, and distinctive learning environment. Additionally, it was created to enhance the abilities of tutors and students as well as pedagogical tools and techniques, all of which have a good impact on the learning process as a whole.

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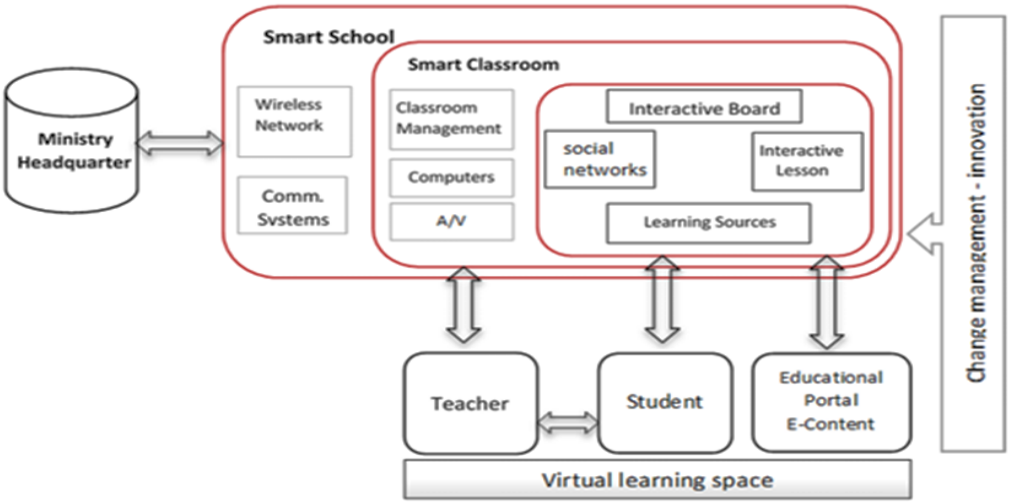

Figure 2: Smart classroom architecture [40]

While [38-40] have similar contributions to the development of smart classrooms, [39] utilized the environmental feature of smart classrooms in their learning management. The study by [41] implemented a smartphone-based smart classroom as shown in Figure 3. Taking into account that kids might easily become distracted by mobile devices, [41] equipped the smart classroom with software that blocks elements that divert pupils from their studies. The features use the device's ability to be turned into a learning tool by allowing access to sites like Wikipedia, Moodle, and other instructional materials, while also blocking programs that have been blacklisted, such as games and social networking apps.

By auditing students' past data in the university data center, tutors may keep an eye on the list of applications open on each student's device, thanks to capabilities provided by the smart classroom. The approach, moreover, gives appropriate authorities the capacity to add new instructional materials to their whitelist. Using Facebook Deep Face and Google Face Detection Technology, the mobile selfie module pre-configured in the device allowed the smart classroom to further provide a face recognition mechanism for collecting attendance during lecture times. An attempt made by [41] solved the issue of resource and attendance management. With the integration of face detection technology, security is also enhanced. Knowledge-aware learning analytics for intelligent learning was proposed by [42]. Realizing that knowledge awareness, a crucial element of smart learning, is lacking in present learning systems, [36] created a framework for knowledge-aware learning analytics for smart learning (Figure 4), drawing on research from learning analytics methodologies and processes.

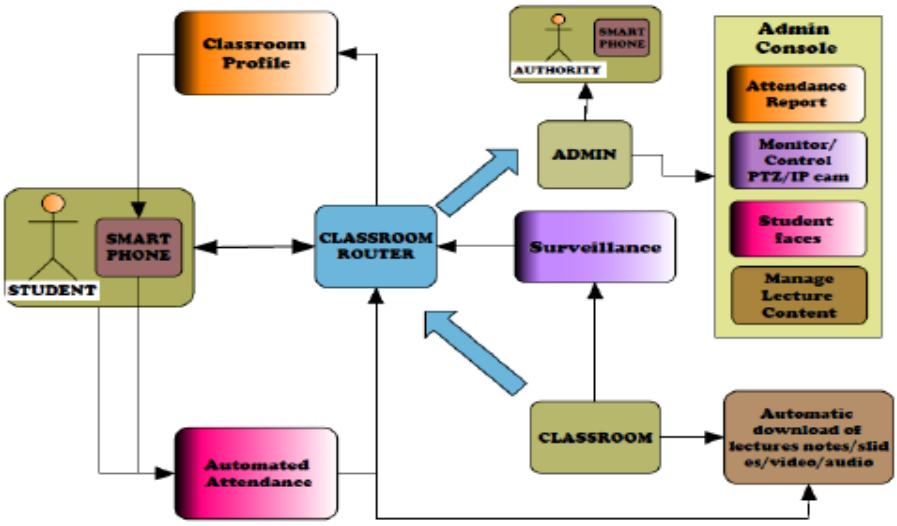

Figure 3: Smartphone-based smart classroom [41]

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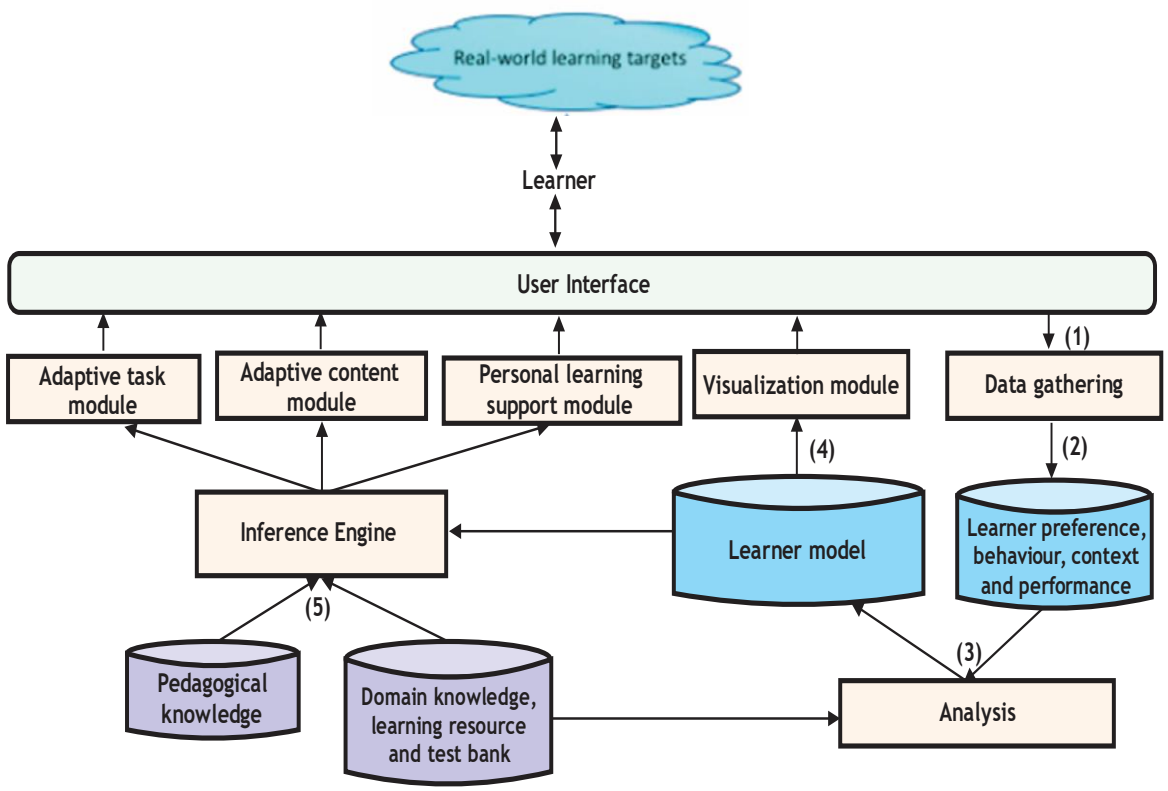

Figure 4: A framework of a knowledge-aware LA for smart learning [42]

In order to conduct this study, learning analytics from learners' interaction data was collected, examined, and provided to stakeholders in an understandable manner. Following their thorough literature evaluation, six research objectives for data-driven analytics in education were determined. These goals include modelling behaviour on the part of students and instructors, predicting performance, increasing students' and teachers' self-reflection and self-awareness, predicting dropout and retention, improving feedback and assessment services, and making resource recommendations. To offer adaptive learning support, three categories of knowledge were employed: learner knowledge, pedagogical knowledge, and domain knowledge. [42] concluded that to attain genuine adaptively, domain knowledge and pedagogical knowledge must be taken into account. Further study is required on the use of this knowledge for learning analytics in smart learning environments. Furthermore, stakeholders may get a greater grasp of learning, chances for improved decision-making, and an awareness of the decisions' consequences by incorporating knowledge into today's data-driven techniques. Most of the learning support tools for an ideal smart classroom were considered in this study, except for gamification, assistive technologies, and multilingual support learning tools. Improvement on this study, considering Figure 1, will make the study of [42] a more robust and efficient smart classroom.

In a study by [43], architecture for creating and managing context-aware smart classrooms was proposed. The proposed architecture was divided into three parts: a model for technology integration, a prototype for a context-aware smart classroom, and supporting measures for the operation of smart classrooms. Based on the study's findings and a smart classroom project at Ming Chuan University (MCU), the classroom prototype was created. In order to make it easier to create context-aware smart classroom apps, the integration architecture was tiered and employed a Raspberry Pi in the bottom layer to integrate underlying technologies and give application interfaces to the higher-layer applications. Consequently, a context-aware, energy-saving smart classroom application was developed based on the suggested classroom prototype and the implemented web application interface. The study's findings demonstrated that it is technically possible to construct context-aware smart classrooms on smart campuses using the suggested design. Research on blockchain technology to support smart learning and inclusion was conducted by [44]. This study assessed the opinions of educational stakeholders, including blockchain developers and pre-service teachers, on the viability of using blockchain technology to close many of the gaps in the smart learning environment. The Smart Ecosystem for Learning and Inclusion (SELI) international initiative served as the inspiration for the design of this study. Three

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blockchain developers and 491 pre-service teachers from various nations took part in the study. The questionnaire and interview methods were utilized to gather the data for this investigation. On the gathered data, content analysis and descriptive statistics were run. The study's findings showed that there is little awareness of and little implementation of blockchain technology in the sector of education. Most of the pre-service teachers who responded to the study had no idea how useful blockchain technology is in the classroom. According to blockchain developers, resources for education-based applications are extremely rare—those that exist are rarely open-source—and blockchain is still relatively new to many individuals.

A self-optimizable smart lighting system based on learning context in the classroom was developed by [45]. The researchers found that lighting conditions had a substantial influence on students' performance. The researchers created a smart lighting system that can evolve continuously; it could dynamically modify the luminance distribution, Correlated Colour Temperature (CCT), and brightness based on the unique learning environment. This technology integrates with school timetables to enable both manual and automated scene change. Ten lighting settings were offered for different classroom circumstances, all of which were included within the comfortable zone of the Kruithof curve (a region of illuminance levels and colour temperatures often viewed as comfortable to an observer), based on the current knowledge regarding lighting preferences. A system for gathering and analysing learning context, lighting conditions, environmental data, and student performance data was also introduced for the classroom environment data-processing framework. [45] concluded that this approach can assist researchers in examining the relationship between environmental factors and student performance. The feature introduced by [45] solved the ergonomic component for an ideal smart classroom. [46] created a ubiquitous computing-based smart classroom that incorporates connecting gateways. The study concluded that modern internet technologies are ubiquitous. The ability to embed processors and sensors into a variety of physical items to create a network and exchange data is made possible by the pervasiveness of digital technologies. Thus, the study reasoned that by establishing a smart learning environment, using ubiquitous computing can support collaborative learning. According to the researchers' notion, a ubiquitous classroom is a smart classroom that facilitates communication between various devices connected to a gateway via wireless networks. The researchers created a smart classroom that functions as an application execution platform, controls classroom equipment, and links the participants. When a candidate is connected to the network, the gateway further confirms their attendance. This allows users to be verified at the moment of class entry, facilitating smooth classroom management for students. The information system, the embedded gateway, and the smart devices are the three main parts of the system. The database server and administrative tools are part of the information system. The information system module has remote security management, remote classroom management, and user management. The second part, the embedded gateway, facilitates data interchange with smart devices, remote access, and classroom bridging. The third and final element consists of smart gadgets and sensors that facilitate communication between students and tutors through hardware, software, and video and audio devices. The Raspberry Pi (credit card-sized single-board computer) and the Open Service Gateway Initiative (OSGi) framework were used by the researchers to construct the gateway for the ubiquitous smart classroom. A Radio Frequency Identification (RFID) reader and a smart video projector are the smart gadgets that are being employed. A comprehensive and dynamic component mode for the Java programming language is implemented by OSGi, a modular system and service platform. Arduino was utilized to carry out the implementation.

Table 3 shows a description of the category of tools provided as possible solutions by the selected works in this study. The description is based on the taxonomy of tools presented in Figure 1.

Table 3 shows that the state-of-the-art solutions for smart classroom environments are piecemeal. Each smart classroom system provides specific solutions or a range of solutions, but lacks a complete solution for an ideal smart classroom environment. It is therefore necessary to begin to think of a solution that is all-encompassing. Considering the diverse cultural and multilingual nature of the world, smart classrooms should adapt to the standard learning culture and the native language of specific learners. Not much is done in the area of gamification for the smart classroom. More assistive technologies for persons with disabilities are needed for a robust smart classroom. Scalability in terms of physical components may not be an issue in a smart classroom; software scalability is, however, necessary for an ideal smart classroom. Any smart classroom should be able to accommodate more learners with diverse interests.

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Table 3: Comparison of existing smart classroom systems in relation to features/components needed for an ideal smart classroom environment.

Functional requirements	Infrastructure	Hardware devices	[9-11], [38 – 52]
		Network communication devices	[14-19], [39], [46]
		Environment and Ergonomic devices	[21], [38], [45]
	Leaning Support	Online assessment and evaluation tools	[38]
		Adaptive learning tools	[42]
		Collaboration tools	[38], [46]
		Virtual reality and augmented reality	
		Gamification tools for interactive classroom	
		Attendance and schedule management tools	[25-26], [41], [46]
		Resource management tools	[39-41], [46]
		Learning analytics	[29-31], [42], [45]
		Personalized learning path	[42]
		Assistive technologies for disable students	[33-35]
		Multilingual support learning tools	
		Performance tracking tools	[28], [38]
Non-functional requirement	Security and Privacy		[41], [46]
	Scalability		
	Usability		[37]
	Reliability		[37]

4.0 CHALLENGES AND FUTURE DIRECTION

The smart learning environment now faces significant hurdles due to technological advancements. This section proposes a few of these hurdles along with their projected resolution.

4.1 Pedagogical Approaches:

Diverse integrations of intelligent learning environments and individualized learning have been made possible by advancements in education [47]. A fundamental shift from the one-size-fits-all, centralized, static, top-down, and knowledge-push models of traditional learning solutions to a more personalized, social, open, dynamic, emergent, and knowledge-pull model is required because learning is personal, social, distributed, universal, flexible, dynamic, and complex. In order to promote student learning and effectiveness in smart classrooms, new pedagogical techniques are needed for the successful implementation of integrating technology into the curriculum. More robust smart classrooms with a variety of pedagogical methods are required to fulfil the unique requirements of students, as curricula from different institutions throughout the world project distinct pedagogical approaches and make the integration of smart learning systems challenging.

4.2 Personalized Adaptive Learning:

In a sophisticated learning setting, pupils' unique requirements have received increased consideration. A smart learning environment is thought of as a learning system for enabling effective individualized learning [48]. This suggests that individualized learning is supported methodologically and technically by adaptive learning. With personalized adaptive learning, pupils' unique growth is supported by adaptive modifications made in accordance with their unique qualities. Students can benefit from individualized learning and adaptive learning through the use of smart devices and intelligent technology in smart learning environments. According to [49], there is significant potential for the smart learning environment to successfully support the growth of customized and adaptive learning. For this reason, most academics now find it difficult to create learning ecosystems that use smart systems to customize self-regulated learning. Adapting teaching tactics and keeping an eye on learners' unique features, performance, and personal growth are some of the procedures involved in addressing the adaptive smart learning challenge [49].

4.3 Assessment Method:

Over the last few decades, educational institutions' assessment techniques have remained mostly

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unchanged, despite advancements in psychological research and educational technology. In light of the smart classroom setting, accurate evaluation becomes even more important than it has in the past, necessitating the development of new assessment techniques in order to gauge the smart classroom's efficacy. Formative assessment might be a useful strategy. It can help students transition from being passive to being active learners, able to identify learning gaps, assess their own strengths and limitations, and come up with solutions.

4.4 Integration of Formal and Informal Learning:

For many years, formal education in schools and universities served as the primary avenue for students to gain knowledge. However, with the development of internet technology, students now have easy access to and use informal learning techniques. According to [50], this outcome offers a formal learning time allocation of 50% to the student's study time. Nonetheless, the smart learning environment must integrate formal and informal learning to create an autonomous learning environment that supports individual learners, given the blurring of the lines between formal and informal learning and the growing emphasis on informal learning.

4.6 Learning Data

To plan, run, and instruct, educational technology makes use of data (such as behavioral and demographic data); smart technology presents new chances to expand the "data gaze" [51]. A lot of behavioral data on learners is produced in a smart classroom. It is crucial to remember that the information gathered for various delivery methods may differ based on instructional approaches, technology, background, and institutional features [27]. Thus, a major problem is figuring out how to incorporate data into various situations, create data-centric smart education, and give students a seamless learning environment and individualized, tailored services [52]. The collection and use of this learning data while adhering to pertinent data protection norms and standards presents another difficulty. Processing learning data, tracking student progress, and giving the system, teachers, and students feedback are all possible uses for learning analysis. However, it is discovered that researchers in the fields of computer science and data science are mostly responsible for the present studies on the design and use of learning analytics, as documented in this study. More so from a technological than a pedagogical standpoint, the emphasis is on the applications of analytics to teaching and learning.

CONCLUSION

The idea of "smart classroom" which characterizes education in the digital era, is becoming more and more popular. Smart classroom environments, in their broadest sense, are a new generation of educational systems that combine technology and pedagogy in an efficient and effective way to improve learning outcomes. This strategy delivers educational resources as a service, making them easily available to learners worldwide. From this vantage point, we may anticipate significant changes to the organizational structures and instructional methodologies of education. With the availability of educational content, an instructor other than the one in charge of the course may provide some of the lectures. Tests can also be administered separately, with an outside entity administering the exams in place of the course instructor. Services, therefore, need to take the perspective and learning path of the learners into account. In an intelligent learning environment, students should have access to a variety of services during various learning phases, delivered by various physical and virtual learning institutions. To create smart classroom environments that are more successful, researchers must get greater insight by developing a system with the perceptions and learning outcomes of their students in mind. A variety of factors, including learning accomplishment, problem-solving skills, self-efficacy, and self-regulation, should be used in an evaluation. Meanwhile, it is worthwhile to look at how smart classrooms affect students with various learning styles, cognitive styles, or other personal traits in terms of how well they learn and how they perceive the environment. Researchers and educators will find it crucial to have a thorough grasp of learners' behaviours and learning patterns to provide learning resources and tactics that are more successful.

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