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AI- and IoT-Assisted Sustainable Education Systems during Pandemics, such as COVID-19, for Smart Cities

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Abstract: The integration of AI and the IoT in education has the potential to revolutionize the way we learn. Personalized learning, real-time feedback and support, and immersive learning experiences are some of the benefits that AI and the IoT can bring to the education system. In this regard, this research paper aims to investigate how AI and the IoT can be integrated into sustainable education in order to provide students with personalized and immersive learning experiences during pandemics, such as COVID-19, for smart cities. The study's key findings report that AI can be employed in sustainable education through personalized learning. AI-powered algorithms can be used to analyze student data and create personalized learning experiences for each student. This includes providing students with tailored content, assessments, and feedback that align with their unique learning style and pace. Additionally, AI can be used to communicate with students in a more natural and human-like way, making the learning experience more engaging and interactive. Another key aspect of the integration of AI and the IoT in education obtained from this research is the ability to provide real-time feedback and support. IoT-enabled devices, such as smart cameras and microphones, can be used to monitor student engagement and provide real-time feedback. AI algorithms can then use these data to adapt the learning experience in real time. IoT-enabled devices, such as tablets and laptops, can be used to collect and process student work, allowing for the automatic grading of assignments and assessments. Additionally, IoT technology can facilitate remote monitoring and grading of student work, which would be particularly useful for students who cannot attend traditional classroom settings. Furthermore, AI and the IoT can also be used to create intelligent personal learning environments (PLEs) that provide students with personalized, adaptive, and engaging learning experiences. IoT-enabled devices, such as smart cameras and microphones, combined with AI-powered algorithms, can provide real-time feedback and support, allowing the PLE to adapt to the student's needs and preferences. It is concluded that integrating AI and the IoT in sustainable education can revolutionize the way people learn, providing students with personalized, real-time feedback and support and opening up new opportunities for remote and disadvantaged students. However, it will be important to ensure that the use of AI and the IoT in education is ethical and responsible to ensure that all students have equal access to the benefits of these technologies.

Keywords: AI; IoT; sustainable education systems; smart cities

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1. Introduction

The emulation of human intelligence processes by computer systems is known as artificial intelligence (AI). The development of intelligent machines that function and respond much like people is the focus of this area of computer science [1]. Machine learning, computer vision, and natural language processing are all examples of AI technology. These tools may be used to build systems with intelligence that can reason, analyze, and gain knowledge from data. On the other hand, the Internet of Things (IoT) is a network of real physical items, such as gadgets and appliances, that are integrated with sensors, software, and connections to allow for data collection and exchange. IoT devices have the ability to connect to the Internet and other devices, enabling data sharing and communication [2]. This makes it possible to develop smart homes, cities, and other applications that may use the information gathered from these gadgets to raise productivity and quality of life. Smart cities refer to cities that use technology and data analysis to improve the quality of life of their citizens, enhance sustainability, and streamline urban services. The implementation of IoT devices and sensors plays a significant role in this, as the data collected can be used to make informed decisions about how to manage the city more efficiently. For example, in a smart city, sensors could be used to monitor traffic flow and optimize traffic lights to reduce congestion or to monitor air quality and adjust it accordingly. In this way, the IoT and smart cities are interrelated and work together to create more connected and livable urban environments.

During a pandemic, such as COVID-19, AI and the IoT in sustainable education can be utilized to enhance students' learning opportunities. For instance, chatbots powered by AI may be used to answer inquiries from students and offer them individualized learning experiences [3]. IoT tools may be utilized to track students' development and give teachers feedback. Additionally, students with special needs and impairments can benefit from the employment of AI-powered virtual assistants. Industrial IoT and AI capabilities can also be utilized to provide students and patients with individualized feedback and guidance [4]. A similar system was used in healthcare during the pandemic of COVID-19, and thus, the same can be replicated to enhance education. Figure 1 shows an IoT-based education system that connects teachers and students through a cloud-based teaching system, allowing the students to learn remotely using their IDs based on RFID and mobile devices. This enables teachers to easily track learners and the process remotely.

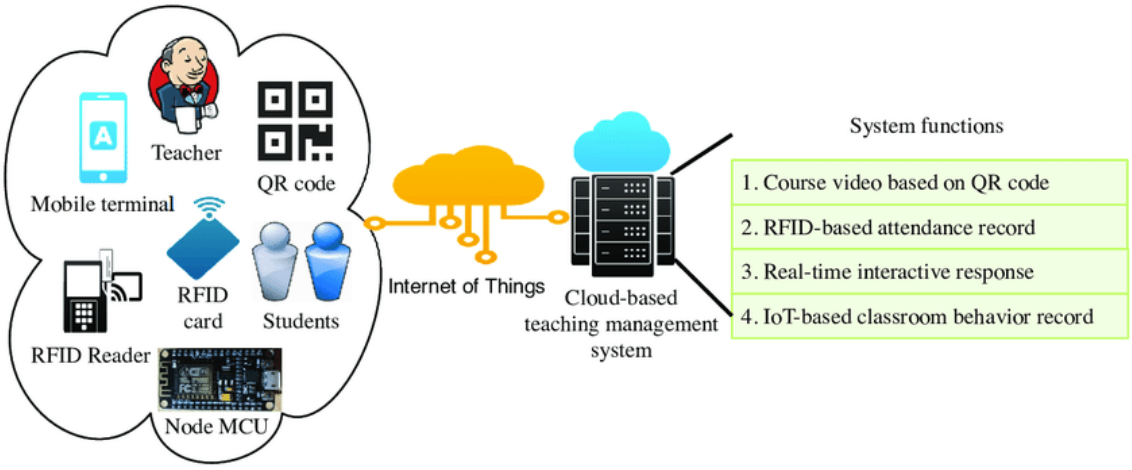

Figure 1. An IoT-based education system.

Furthermore, IoT-enabled devices are capable of being utilized to track students' attendance, engagement, and progress, as well as offer real-time data to teachers and administrators in order to optimize the student learning experience. Overall, AI and the IoT have the potential to play a critical role in facilitating distant learning and preserving students' educational continuity during an epidemic. Despite the potential benefits of

AI and the IoT in education, there are a number of issues that must be addressed [5]. One of the key challenges is the lack of standardization in developing and implementing these technologies. This can make it difficult for educators to effectively integrate these technologies into their teaching practices. Additionally, there are also concerns about the potential for these technologies to perpetuate existing inequalities in education, as not all students may have access to the same resources and opportunities. This study aims to examine further how these technologies can be used in education systems during pandemics, such as COVID-19.

Related Works

Various scholars have worked to examine the application of AI- and IoT-assisted sustainable education systems during the pandemic. The use of artificial intelligence (AI) and the Internet of Things (IoT) in education has grown in popularity in recent years, with potential benefits, such as personalized learning and improved student engagement. However, the global COVID-19 pandemic accelerated the need for remote and online learning, leading to an increased interest in the use of AI and the IoT in educational systems for smart cities. One study explored the potential of AI-assisted education in smart cities during the COVID-19 pandemic [6]. The authors found that AI-assisted education can provide personalized and adaptive learning and support for remote and online learning. They also discussed the importance of data privacy and security in the implementation of AI-assisted education systems. Another study investigated the use of the IoT in educational systems for smart cities during the COVID-19 pandemic [7]. The authors found that IoT-assisted education can provide real-time monitoring and data collection and support for remote and online learning. They also discussed the challenges of implementing the IoT in education, such as cost and privacy concerns.

Moreover, Chakraborty and Abougreen [8] examined the use of AI and the IoT in a smart campus system during the COVID-19 pandemic. The authors found that a smart campus system can provide a range of benefits, such as real-time monitoring of students' attendance and learning progress and support for remote and online learning. They also discussed the potential challenges of implementing such a system, such as data privacy and security. In a systematic review, ref. [9] analyzed the existing literature on the use of AI and the IoT in education during the COVID-19 pandemic. The authors found that AI- and IoT-assisted education can provide a range of benefits, such as personalized and adaptive learning, real-time monitoring and data collection, and support for remote and online learning. Another study also supported the claim regarding the potential challenges, such as data privacy and security, and the importance of further research to address these challenges in a smart city [10,11].

In terms of education, the study [11] states that AI and IoT technologies have been used to enable remote learning and online education. This includes the use of virtual and augmented reality, online tutoring, and e-learning platforms. The authors also note that AI and IoT technologies have been used to improve the accessibility of online education for students with disabilities. Additionally, the paper suggests that AI and IoT technologies have the potential to improve the efficiency and effectiveness of online education by providing personalized learning experiences and real-time feedback to students and teachers. However, the authors also note that there are still challenges to be addressed, such as the need for more robust and secure systems and the need for more research on the long-term effects of using these technologies in education. Succinctly, research on AI- and IoT-assisted education systems during pandemics, such as COVID-19, for smart cities indicates that these technologies can provide a range of benefits, such as personalized and adaptive learning, real-time monitoring and data collection, and support for remote and online learning. However, there are also potential challenges, such as data privacy and security, that need to be addressed in the implementation of these systems.

2. Background and Motivation

AI has been greatly studied in studies from the past decade, increasing the interest in future applications in smart cities, as the data collected by integrating the software systems can be used to organize capital, resources, and energy more efficiently. While entering into a digitalized era, a notable increase in the application of AI and the IoT can be observed. Numerous applications of AI in smart city operations have been implemented so far, such as advanced computing, neural networks, fraud detection, sensing technology, speech recognition, and human–computer interface software [10]. In addition to these general applications of AI and the IoT, specific applications were greatly influenced due to the COVID-19 pandemic [12]. As per the studies [10,11], the pandemic impacted video-conferencing in the education system, where students can access platforms for e-learning. In the software tools for video conferencing, the video lectures were recorded, unlike traditional lecture-conveying methods. Figure 2 demonstrates the primary features of a smart classroom [11]. It explains how smart classrooms are now enabling students and teachers to become involved in the digital world and benefit from Internet tools for various functions, such as self-assessments, e-learning, and consistent monitoring.

Figure 2. The primary features of a smart classroom.

The characteristics demonstrated in Figure 2 are necessary to comply with a smart classroom environment. In addition, lectures may be delivered in the native language rather than English, which makes it difficult for the students to follow. However, the implementation of AI technology and speech recognition algorithms could be used to translate the lectures using subtitles [11]. The integration of language translation-based subtitles along with video transcription and knowledge graphs in terms of video clips facilitated students' comprehensive understanding. The education system domain is not untouched by IoT technology, and it has been playing a significant role in improving students' engagement in the classroom. Moreover, the study [13] also states that the system of learning a foreign language has become easier in smart cities due to access to Internet technology, which uses multicriteria analysis. The figure below shows an effective interaction system led by AI and IoT smart systems in a smart classroom.

Real-time feedback can be attained freely, and the system can be facilitated by the IoT, which provides a simulation environment for student monitoring and progress evaluation. AI, ML, and IoT technology, in this regard, automate time-consuming activities, such as grading and attendance. Educational software adopts aids in students' smart learning,

even in the pandemic environments, via e-learning software technologies. The main issue that arises in the education system provided to students in a smart city is education in wireless environments [14]. In this regard, the attention of researchers and practitioners needs to be gained so that a smart city's education system can be facilitated by innovative learning techniques and ideas, leading to the application of AI and the IoT to reach the maximum heights of sustainability in smart cities' education systems. Figure 3 represents a smart interaction in an e-learning environment [14]. It demonstrates the significance of smart interaction in an e-learning environment with the help of the use of technology and strategies to facilitate communication, collaboration, and engagement among students and between students and the teacher. Key concrete examples displayed in the figure include video lectures, lecture slides, and e-learning material.

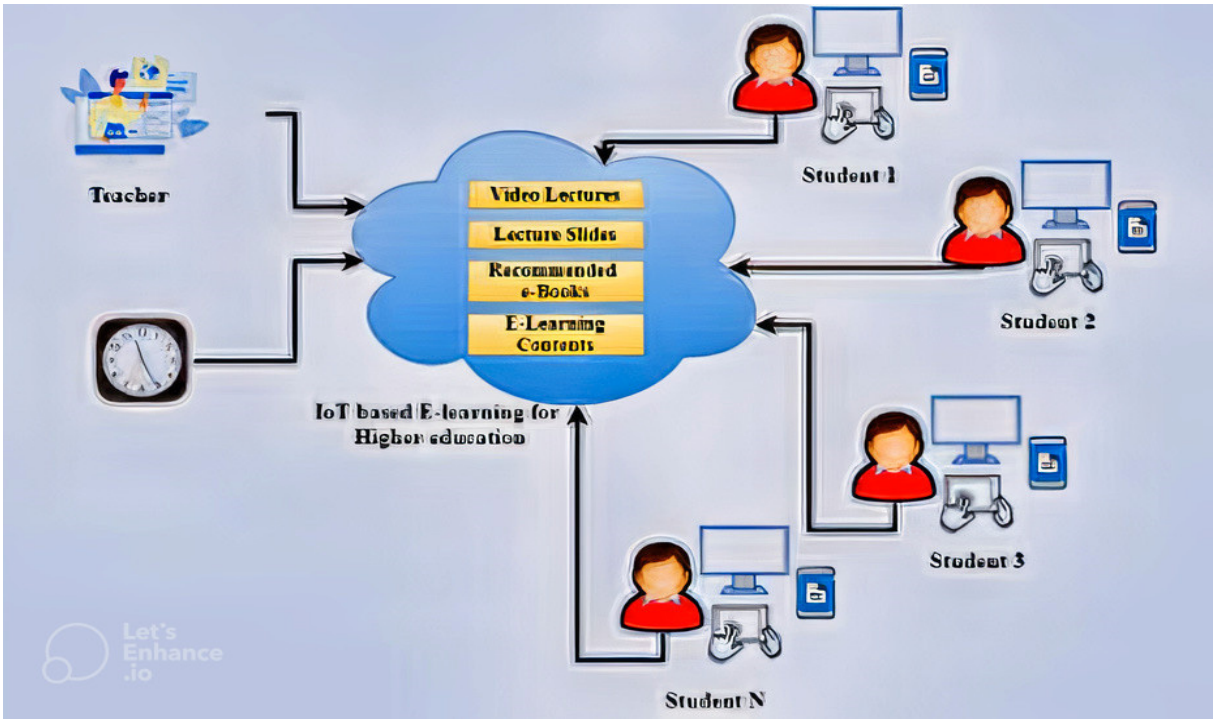

Figure 3. A smart interaction in an e-learning environment.

Further, the study [15] reflects that remote-based learning systems have become necessary, specifically during the pandemic age when cities are leaning towards adopting smart city standards. Individual and adaptive education systems shall minimize the consequences of distance learning so that higher levels of accomplishments can be made. AI technology and data mining through IoT technology aid in transforming the education systems of smart cities. This could also facilitate personalized learning and enable tailoring the content as per individual needs among students' needs. Education systems have not been directed towards personalization to meet students' cognitive requirements and facilitate them when physical and classroom learning is unavailable.

To address the above-mentioned concern, the motivation of the study is to provide AI- and IoT-assisted educational settings in smart cities where AI-powered robots, algorithms, and the IoT would be employed, and they would enable the instructors and students to perform their educational tasks more effectively and rapidly. Technological advances, such as AI and the IoT, will simplify education for instructors and students [16].

Moreover, considering the above-mentioned motivation, we also emphasize the AI- and IoT-based virtual and physical learning settings. AI- and IoT-based technology provide a new educational environment combining components from virtual and physical learning environments during pandemics, such as COVID-19, for smart cities. This involves the use

of technology, such as virtual and augmented reality, smart devices, and Internet-connected devices, to facilitate remote learning and communication between students, teachers, and administrators. This system could also utilize data analytics and machine learning to personalize learning experiences and provide real-time feedback to both students and teachers. Additionally, the system could integrate with smart city infrastructure to provide a seamless and efficient learning experience, such as using smart traffic signals to adjust commute times for students and teachers and utilizing smart buildings to optimize energy usage and classroom conditions [17].

A study also explained that in smart cities, AI- and IoT-assisted technology allows pupils to access the learning world by using wearable technology to interact without being limited by time or place [18]. It helps them engage with various objects in real time using their online identities, such as avatars, intelligent NPCs, or digital educational sources. Moreover, they will be able to feel engaged as if they are in an educational environment of the real world as a consequence. From this vantage, it is obvious that integrating the metaverse into schools may open up a wide range of amazing learning opportunities for students. Therefore, considering these motivations, the aim of the study is to provide significant details regarding AI- and IoT-assisted education in smart cities during pandemics, such as COVID-19, to enhance the quality of the educational system.

3. Future Vision of AI- and IoT-Assisted Education System

Artificial intelligence (AI) and the Internet of Things (IoT) have the potential to revolutionize the field of education by enhancing the learning experience and personalizing instruction [19]. The integration of these technologies into the education system can provide a more interactive, efficient, and engaging learning environment. One of the main ways AI can assist in education is through intelligent tutoring systems (ITSs) [20]. The future of AI and ITSs looks promising, as these technologies have the potential to revolutionize the way people learn. ITSs can use AI-powered algorithms to analyze student data and create personalized learning experiences for each student. This includes providing students with tailored content, assessments, and feedback that align with their unique learning style and pace. Additionally, ITSs can use natural language processing (NLP) and machine learning (ML) techniques to communicate with students in a more natural and human-like way, making the learning experience more engaging and interactive. These systems use AI techniques, such as natural language processing and machine learning, to adapt to each student's individual needs and abilities. For example, the Carnegie Learning Cognitive Tutor uses AI to provide personalized feedback and instruction to students, resulting in improved performance and motivation [20].

Another area in which AI can assist in education is through the use of natural language processing and machine learning to automatically grade student work. This can save educators significant time and allow for a more efficient and accurate assessment of student learning [21]. This technology can potentially change how student work is automatically graded in the future. It can enhance the automated grading process through the use of smart cameras and microphones. IoT-enabled devices, such as smart cameras and microphones, can be used to assess student work in real time, providing instant feedback on their performance. For example, a smart camera could be used to monitor a student's writing during an exam, providing instant feedback on their grammar and spelling. A microphone could be used to assess a student's pronunciation in a language class and give instant feedback on specific sounds or words. IoT technology can also be used to facilitate remote monitoring and grading of student work [22]. For example, students can use IoT-enabled devices, such as laptops and tablets, to participate in remote classes, and teachers can use these devices to monitor and grade student work. This would be particularly useful for students who are not able to attend traditional classroom settings, such as those who are physically disabled or live in remote areas. IoT technology can also play a role in education by providing students with access to a wide range of digital resources and enabling collaboration and communication among students and teachers.

For example, the use of IoT-enabled devices, such as smartphones, tablets, and smartboards, can allow for the creation of interactive and engaging learning experiences.

Furthermore, the IoT can be used to track and monitor student progress, providing teachers with real-time data on student engagement, performance, and learning outcomes. It can be used to track and monitor student progress by integrating smart devices into the classroom [23]. These devices can collect student engagement, performance, and behavior data, providing teachers and administrators with valuable insights into student progress. For example, IoT-enabled devices, such as smart cameras and microphones, can be used to track student engagement during class, providing teachers with real-time feedback on student participation and attention levels. IoT-enabled devices, such as tablets and laptops, can be used to track student performance on assessments and homework assignments, providing teachers with a complete picture of student progress. This can be used to personalize instruction, identify areas of difficulty, and adjust teaching methods as needed [23]. Succinctly, the integration of AI and the IoT in the education system has the potential to provide a more personalized, interactive, and efficient learning experience. However, it is important to consider the ethical and privacy concerns associated with using these technologies, as well as the need for proper training for educators to fully realize their potential.

One of the main ways AI can assist in education during pandemics is through virtual and remote learning systems. AI-powered virtual learning environments (VLEs) can provide students with personalized, self-paced instruction and adapt to the individual needs of each student [24]. Additionally, AI-powered virtual assistants can provide students with real-time support and guidance, helping to mitigate the lack of face-to-face interaction with teachers [25]. IoT technology can also play a role in education during pandemics by providing students with access to a wide range of digital resources and enabling remote collaboration and communication among students and teachers. IoT-enabled devices, such as smartphones, tablets, and smartboards, can be used to create interactive and engaging learning experiences, even in a remote setting. IoT-enabled monitoring of students' activity and progress can also provide teachers with real-time data on student engagement, performance, and learning outcomes. This can be used to personalize instruction, identify areas of difficulty, and adjust teaching methods as needed.

AI and the IoT can also be used to create intelligent personal learning environments (PLEs) that can adapt to each student's unique needs and preferences and provide real-time feedback and guidance, helping to improve student engagement and learning outcomes [26]. A PLE is a personalized and adaptive learning environment that uses AI and the IoT to provide students with a tailored learning experience. The two most prominent anticipated future visions of incorporating AI and IoT technologies based on PLEs include providing personalized content and adaptive learning. AI can be used to analyze student data and create personalized content that aligns with their unique learning style and pace. For example, an AI-powered learning management system (LMS) could provide students with tailored content based on their performance on assessments and homework assignments. IoT-enabled devices, such as smart cameras and microphones, can be used to monitor student engagement and provide real-time feedback. AI algorithms can then use these data to adapt the learning experience in real time. For example, if a student is struggling with a particular concept, the PLE can provide them with additional resources or support to help them better understand the material. Furthermore, AI-powered virtual and augmented reality technologies can also create immersive and interactive learning experiences, even in a remote setting [27].

In conclusion, AI and the IoT have the potential to transform education in the context of pandemics by providing a more flexible and adaptable learning environment. The integration of these technologies can provide students with personalized instruction, real-time support and guidance, and access to a wide range of digital resources. However, it is important to consider the ethical and privacy concerns associated with using these technologies, as well as the need for proper training for educators to fully real-

ize their potential. The Table 1 below shows the future vision of AI- and IoT-assisted education systems.

Table 1. AI and IoT for Smart Education.

Feature	Key Benefits	Technologies Used	Impact on Teachers	Impact on Students
Personalized Learning	Tailored curriculum and lesson plans for individual students based on their learning styles and abilities.	Machine learning, natural language processing, cognitive computing.	Increased efficiency and effectiveness in teaching.	Increased engagement and motivation for learning, improved academic performance.
Intelligent Tutoring Systems	Real-time feedback and guidance for students as they work through problem-solving tasks and assessments.	Artificial intelligence, natural language processing, computer vision.	Reduced workload for teachers, increased ability to monitor student progress.	Increased self-directed learning, improved problem-solving skills.
Virtual and Augmented Reality	Immersive and interactive learning experiences for students, allowing them to visualize and explore complex concepts.	Virtual reality, augmented reality, computer vision.	Increased ability to deliver engaging and interactive lessons.	Increased engagement and motivation for learning, improved understanding of complex concepts.
Smart Classrooms	Automated and connected classrooms, with smart devices and sensors for monitoring student engagement and progress.	Internet of Things, sensors, cloud computing.	Increased ability to monitor and analyze student data, improved ability to make data-driven decisions.	Increased engagement and motivation for learning, improved ability to collaborate and communicate with classmates.
Adaptive Learning Platforms	Platforms that adapt to the learning pace and style of individual students, providing personalized feedback and support.	Machine learning, natural language processing, big data.	Increased efficiency and effectiveness in teaching, improved ability to monitor student progress.	Increased engagement and motivation for learning, improved academic performance.
Feature	Key benefits	Technologies used	Impact on teachers	Impact on students

4. AI and IoT Roles at the Application and Infrastructure Levels

In this section, the focus will be on the AI and IoT roles at the application and infrastructure levels with respect to smart cities' educational systems. As shown in Figure 4, AI can be used for personalized learning, adaptive testing, and intelligent tutoring systems at the application level. For example, an AI-powered system can analyze student data to identify areas of weakness and then provide customized learning content to help students improve [28]. Devices of the IoT, including tablets and smartboards, can also be utilized to enhance the experience of the classroom, providing students with collaborative, multimedia-rich content and allowing teachers to easily assess student understanding [29]. While at the infrastructure level, AI and the IoT can be used to improve the management and maintenance of school buildings and grounds. For example, IoT sensors can be used to monitor the energy consumption of school buildings, allowing administrators to identify areas where energy efficiency can be improved [30]. AI-powered systems can also be used to predict and prevent equipment failures, reducing downtime and maintenance costs. AI and the IoT can influence smart cities' education systems, providing students with more personalized and effective learning experiences and making it easier for administrators to manage and maintain the school infrastructure in a smart city context [31]. Figure 4 illustrates AI and the IoT for the education systems in smart cities at the application and infrastructure levels [28]. The integration of artificial intelligence (AI) and Internet of Things (IoT) technologies in education systems brings significant benefits to smart cities by improving both the application and infrastructure levels, resulting in a more efficient and effective learning experience for students.

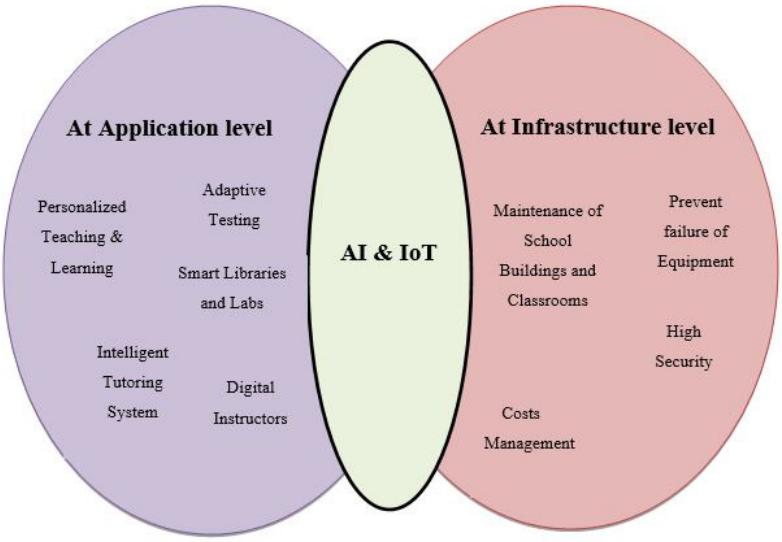

Figure 4. AI and IoT for the education systems in smart cities at the application and infrastructure levels.

AI and the IoT play a vital role in optimizing and automating the education system at the application and infrastructure levels in smart cities. Home health monitoring and remote personalized learning are two roles of AI and the IoT that can be applied in smart cities' sustainable education systems at the application level. IoT devices, such as laptops, tablets, and smartphones, provide remote learning and communication between students, teachers, and administrators. Moreover, machine learning algorithms are utilized to analyze data on student work and tailor instruction to individual student's needs. For example, an AI system may be able to identify patterns in a student's performance data, such as areas where the student struggles or excels, and adjust the instruction accordingly. Another approach is to use natural language processing to provide personalized feedback to students on their written work. Additionally, AI can be used to personalize learning through the application of adaptive learning systems, which calibrate the pace and challenge of instruction depending on how a student performs [32].

Moreover, AI-powered intelligent tutoring systems can be used to provide individualized instruction to students depending on their learning demands, skills, emotions, and aptitude. AI can also be used to create immersive and interactive virtual and augmented reality experiences for students in smart classrooms to enhance the learning experience. Intelligent tutoring systems (ITSs) typically consist of a student model, which keeps track of the student's knowledge, skills, and progress, and an instructional model, which determines the appropriate content and teaching strategies to use. Some ITSs also include a dialogue module that allows students to interact with the system using natural language, which can make the instruction more engaging and personalized [33]. The IoT has been found to be effective in improving student learning outcomes, particularly in areas, such as math, science, and language learning. However, it is important to note that ITSs alone cannot replace human teachers, and it is always recommended to supplement human instruction [34].

Likewise, AI algorithms can be used to create adaptive tests that adjust to the student's performance level, providing a clearer assessment of their knowledge and skills. Adaptive testing is a method of assessment in which the difficulty of the test questions is adjusted based on the student's performance. By using AI algorithms, adaptive tests can be tailored to the individual student's knowledge, skill level, and learning style. One common approach to creating adaptive tests using AI is using machine learning algorithms to analyze student performance data and determine the appropriate difficulty level for the next test question. For example, if a pupil responds to a question properly, it is followed by a more difficult question, while if they answer incorrectly, the next question will be easier. Another approach is to use natural language processing to understand the student's

response and adjust the question difficulty accordingly [35]. AI-powered adaptive tests can be used in both formative and summative assessment scenarios, providing instant feedback and identifying the student's strengths and weaknesses. Additionally, adaptive testing can also help reduce test anxiety and increase the engagement of students. AI is also utilized in automatically grading assignments, quizzes, and exams, reducing the workload of teachers and allowing them to focus more on instruction and mentoring [36]. Table 2 demonstrates the summarized insights into how AI and IoT play a significant role at the application and infrastructure levels to strengthen the education system.

Table 2. Demonstrates the summarized insights into how AI and IoT play a significant role at the application and infrastructure levels to strengthen the education system.

Application Infrastructure	Role of AI	Role of IoT
Remote Learning	AI algorithms can be used to personalize and optimize remote learning experiences, such as adaptive learning systems and intelligent tutoring systems, to improve student engagement and performance.	IoT devices can be used to provide access to remote learning resources, such as online libraries and educational apps, and to monitor student participation and progress.
Classroom Management	AI algorithms can be used to monitor and manage student behavior in real time, providing feedback and support to teachers to help maintain classroom discipline and student engagement.	IoT devices can be used to monitor classroom conditions, such as temperature and air quality, and to provide data-driven insights that can be used to improve the learning environment.
Student Health and Safety	AI algorithms can be used to monitor student health and safety, such as identifying symptoms of illness, tracking potential exposure to COVID-19, and providing early warning of potential health risks.	IoT devices can be used to monitor student health and safety, such as tracking movement and interactions with others, and to provide data-driven insights that can be used to improve safety protocols.
Campus Management	AI algorithms can be used to optimize campus operations, such as scheduling and resource allocation, to ensure efficient use of resources and reduce costs.	IoT devices can be used to monitor and control access to campus facilities, such as classrooms and labs, and to provide data-driven insights that can be used to improve campus safety and security.
Parent–Teacher Communication	AI algorithms can be used to facilitate communication between parents and teachers, such as chatbots and virtual assistants, to improve parent engagement and support student learning.	IoT devices can be used to provide real-time updates on student progress and activities, such as homework completion and attendance, and to facilitate communication between parents and teachers.
Learning Analytics	AI algorithms can be used to analyze data on student performance and behavior, providing insights that can be used to improve teaching and learning strategies.	IoT devices can be used to collect data on student behavior and engagement, such as tracking student interactions with learning resources and identifying patterns in student participation.

At the infrastructure level, AI and the IoT also play a significant role. For example, in a smart classroom environment, IoT sensors can be used to monitor and control lighting, temperature, and other environmental factors in classrooms to optimize the learning environment. In attendance tracking, IoT devices, such as RFID or NFC tags, can be used to track student attendance and location, helping to improve the safety and security of the students and school staff. In smart cities, students also benefit from AI- and IoT-assisted smart libraries and labs, which enhance the services and resources available in libraries and research labs. IoT devices can be utilized to track the usage of books and other library resources, helping to optimize inventory and reduce costs [37].

AI can also be used to improve the search and discovery of resources, such as books, articles, and multimedia. AI-powered search algorithms and robots enhance the context and intent of a user's search query and return more relevant results. AI analyzes library usage data and provides personalized recommendations to users [37]. In research labs, AI can be used to assist with data analysis, experimentation, and modeling. In this case, AI algorithms analyze large data sets, identify patterns and correlations, and make predictions. Additionally, AI can be used to optimize and automate laboratory processes, such as sample preparation, analysis, and data collection. Smart libraries and labs can also be used to improve accessibility, security, and energy efficiency [38]. Therefore, AI and the IoT at the application and infrastructure levels in the education systems of smart cities can help to automate and optimize various systems and processes, resulting in an intelligent campus where IoT devices are employed to track students' and teachers' movements on campus, to improve security, and to optimize the usage of the infrastructure as well as improved efficiency, productivity, and cost savings, and an enhanced quality of education for students [39].

5. Case Study—I: Digital Classroom at Application and Infrastructure Levels

5.1. Al/IoT Server-Centric

In an AI/IoT server-centric digital classroom, the AI and IoT devices are connected to a central server for data processing and decision-making, as stated in Table 3 above. This approach allows for the centralization of data and resources, which can make it easier to manage and maintain the system. The server runs the AI algorithms and manages the communication between the devices and the AI system [40]. One potential application of this approach in a digital classroom could be the use of IoT sensors to monitor student engagement and behavior and AI algorithms to analyze the data and provide real-time feedback to teachers. The AI/IoT server-centric approach also allows for the use of advanced analytics to monitor student performance and track progress over time, using different approaches to personalize instruction and improve student outcomes. One of the approaches is biosignals, which can represent scientific data from tests, such as electrophysiology, brain imaging, and monitoring of blood pressure. The majority of biosignals are well-studied in physiology and/or technology. However, how these indicators change throughout interaction is uncertain [41].

Table 3. AI/IoT server-centric and user-centric approaches at the application and infrastructure levels of digital classrooms.

AI/IoT	Server-Centric	User-Centric
AI/IoT-Powered Digital Classroom	The AI/IoT server-centric approach also allows for the use of advanced analytics to monitor student performance and track progress over time using different approaches to personalize instruction and improve student outcomes.	One potential application of this approach in a digital classroom could be the use of AI-powered personal learning assistants that are integrated into the student's device, such as a tablet or laptop. These assistants can use the data collected by IoT sensors to provide personalized feedback and learning resources to the student in real time.
AI/IoT-Powered Virtual Assistants and Smart Books	They provide personalized learning experiences for students based on their individual needs and progress. The use of AI-powered virtual assistants can also help to improve communication and collaboration among students and teachers.	The AI/IoT user-centric virtual assistants and smart books allow students to have more autonomy and control over their learning experience, which can lead to increased engagement and motivation.

Another application could be the use of AI-powered virtual assistants to provide personalized learning experiences for students based on their individual needs and progress.

AI-powered virtual assistants can also help improve communication and collaboration among students and teachers [42]. However, the AI/IoT server-centric approach also has some limitations. It requires a robust and reliable network and infrastructure to support it, which can be costly to implement and maintain. Additionally, it may have higher latency than more distributed architectures and may not be as well-suited for real-time or low-latency applications. The use of an AI/IoT server-centric approach in the digital classroom can enhance the teaching and learning experience, providing personalized and interactive learning opportunities, real-time feedback, and data analytics to improve student outcomes, as shown in Table 3. However, it requires significant investments in terms of technology, infrastructure, and training and support [43].

5.2. AI/IoT User-Centric

In an AI/IoT user-centric digital classroom, the focus is on providing an experience tailored to the student's individual needs and preferences rather than being controlled by a central server, as described in Table 3. This approach utilizes AI and IoT devices distributed throughout the classroom and directly connected to the student rather than relying on a central server for processing and decision-making. One potential application of this approach in a digital classroom could be the use of AI-powered personal learning assistants that are integrated into the student's device, such as a tablet or laptop. These assistants can use the data collected by IoT sensors to provide personalized feedback and learning resources to the student in real time, such as interactive AI chatbot applications. The AI chatbot plays a crucial role in helping students to connect with academic staff and resolve their questions. It aids in obtaining an academic performance history. Additionally, it will impart social and economic education, which is crucial for children to comprehend [44].

Another application could be the use of IoT-enabled "smart" textbooks that include embedded sensors that track student interactions with the content and provide personalized feedback and learning resources to the student. The AI/IoT user-centric approach also gives students more autonomy and control over their learning experience, leading to increased engagement and motivation [45]. However, the AI/IoT user-centric approach also has some limitations. It can be more difficult to manage and maintain a large number of distributed devices, and the security and privacy of student data can be more difficult to control. Additionally, the level of personalization may not be as high as with the AI/IoT server-centric approach, as the personalization is based on the device's capabilities and the student's preferences. The use of an AI/IoT user-centric approach in the digital classroom can provide students with a personalized, interactive, and autonomous learning experience, as illustrated in Table 3. However, it requires an investment in terms of technology, infrastructure, and support, as well as a well-designed security and privacy system [46].

6. Case Study—II: Intelligent Tutoring System (ITS) at the Application and Infrastructure Levels

6.1. Al/IoT Server-Centric

An AI/IoT server-centric intelligent tutoring system (ITS) is a type of educational technology that uses artificial intelligence and the Internet of Things to provide personalized and adaptive instruction to students. This type of ITS is typically built on a centralized server, which is responsible for managing and processing the data generated by the system. The system uses devices of the IoT, including cameras and sensors, to collect information on students' engagement, behavior, and performance in real time. AI algorithms then analyze these data to determine the student's needs and provide personalized feedback and instruction [47]. For example, if a student is struggling with a particular concept, the system may recommend additional resources or provide extra support to help them understand it better. An AI/IoT server-centric ITS can be delivered via a web-based platform or a mobile application, allowing students to access the system anytime. It can also be integrated with other educational tools, such as learning management systems and

assessment systems, to provide a more comprehensive and seamless learning experience. This type of ITS can also assist educators in monitoring and analyzing student performance and engagement and can provide valuable insights into how to improve the learning experience for each student [48].

However, AI/IoT server-centric intelligent tutoring systems (ITSs) have several limitations. These include limited scalability issues, as an ITS relies on centralized servers that can have difficulty scaling to large numbers of users or handling high volumes of data [49]. There is also a lack of personalization, as ITSs that rely on centralized servers may not be able to provide personalized instruction to each student because the instruction is typically based on the average student's performance. Likewise, there is also a difficulty in adapting to changes in curriculum or student needs, which can limit their effectiveness over time. Therefore, it is important to ensure that the system is designed by considering the above-mentioned challenges [50].

6.2. AI/IoT User-Centric

At the user level, an AI/IoT-centric intelligent tutoring system (ITS) provides personalized instruction to users. As illustrated in Figure 5, the system uses data collected from IoT devices to gather information about the user's learning style and preferences and then uses AI algorithms to adapt the instruction to best suit the user. This approach allows the system to provide the user with a more personalized and effective learning experience. The system may be used in a variety of settings, such as in academia, training, or professional development. AI/IoT can be used in schools and universities of smart cities to provide personalized instruction to students tailored to their individual learning styles and needs. The system can also provide remote training and education to individuals in remote or underserved communities and assist in providing self-directed learning opportunities for users looking to acquire new skills or knowledge on their own, which assists in professional development [51,52]. It can be utilized in language learning, where the system provides users with personalized language instruction. The IoT devices collect data on the user's speech patterns and language usage. However, device dependency, limited data sharing, security issues, limited control over the user environment, and limited offline capabilities are some of the limitations of AI/IoT user-centric intelligent tutoring systems (ITSs) [53,54]. Figure 5 visualizes the generalized description of the intelligent tutoring system (ITS) [55]. An intelligent tutoring systems (ITS) is a computer-based instructional system that provides personalized learning experiences to students. This system incorporates a menu of visualizations, including dynamic graphic visualizations and HoloLens, to enhance the learning experience. The program utilizes artificial intelligence and machine learning algorithms to assess student performance and adapt the curriculum accordingly. An ITS can be used to teach a variety of subjects and can be customized to meet the needs of individual students.

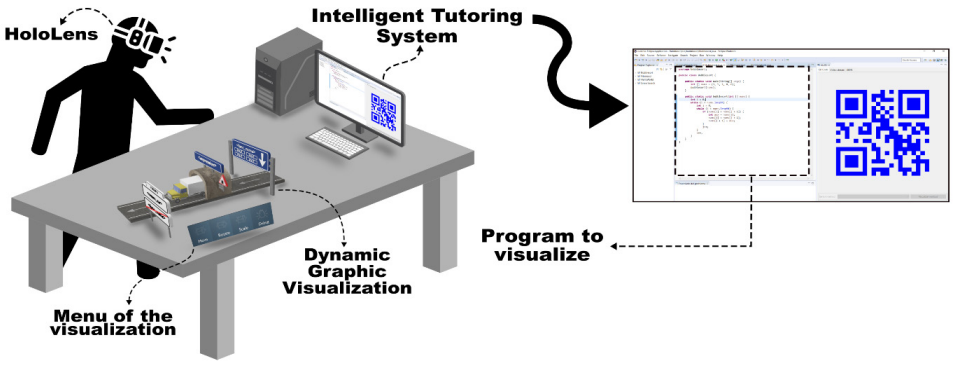

Figure 5. The Generalized Description of the Intelligent Tutoring System (ITS).

7. Conclusions

In this research article, the authors discussed artificial intelligence (AI)- and Internet of Things (IoT)-based applications by emphasizing their uses in sustainable educational systems to improve the learning experience and academic performance of students during a pandemic era, such as COVID-19. For instance, first, the authors described AI-powered chatbots, which play a crucial role in helping students in connecting with academic staff and resolve their questions. They aid in obtaining an academic performance history. Similarly, IoT devices can be used to monitor students' progress and provide real-time feedback to teachers. Moreover, the authors also illustrated the future vision of AI- and IoT-assisted sustainable educational technologies in the current research paper, which have revolutionized this sector. Integrating innovative technologies into an education system can provide students with a more interactive, efficient, and engaging learning environment. The study also assisted with various ways in which AI can assist in education. One of them is intelligent tutoring systems (ITSs) that use AI techniques, such as natural language processing and machine learning, to adapt to each student's individual needs and abilities. The second one is the application of machine learning and natural language processing to automatically grade student work. Lastly, IoT devices provide students with access to a wide range of digital resources and enable collaboration and communication among students and teachers. During the pandemic, AI and IoT technology played a very important role in the upheaval of the education sector. AI allows education through virtual and remote learning systems at the application and infrastructure levels, providing virtual instructors with real-time support and guidance, digital textbooks, libraries, and labs, and helping to mitigate the lack of face-to-face interaction with teachers and students. IoT technology also played a significant role, both at the application and infrastructure levels, in education during the pandemic by providing access to pupils to a large number of digital resources and enabling collaboration and communication among students and teachers remotely. The authors also discussed IoT-enabled devices, such as smartphones, tablets, and smartboards. These devices can be used to create interactive and engaging learning experiences, even in a remote setting and provide students with interactive, multimedia-rich content, and allow teachers to easily assess student understanding. AI and the IoT together, both at the server and user levels, transformed students' learning experience during the pandemic and created intelligent personal learning environments (PLEs) for students. These PLEs can adapt to each student's unique needs and preferences, providing real-time feedback and guidance and helping them to improve student engagement and learning outcomes. However, some challenges need to be considered for future research, such as privacy, security issues, lack of scalability, personalization, and limited data sharing, which may create problems for better AI/IoT technologies' implementation in sustainable education systems in smart cities.

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Abbreviations

AI	Artificial intelligence
IoT	Internet of Things
ITS	Intelligent tutoring system
RFID	Radio frequency identification
NFC	Near-field communication
COVID	Coronavirus disease of 2019

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