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Technological Advancements and Their Influence on Academic Performance

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Abstract

Background/purpose. Traditional online learning platforms exhibit limitations relative to face-to-face education, as students tend to prefer and achieve superior performance outcomes in conventional classroom environments. This study aimed to examine comparative experiences across various learning modalities and to identify opportunities to improve virtual education platforms, specifically through the incorporation of Augmented Reality (AR) technology as a transformative educational tool.

Materials/methods. The study employed a comprehensive review of contemporary literature examining various learning modes (face-to-face, online, and immersive virtual learning) and analyzed instances of AR integration in educational settings to assess their impact on teaching and learning outcomes.

Results. The results indicated a distinct preference for in-person learning and improved performance outcomes compared to online platforms. The study identified several effective instances of augmented reality (AR) integration in educational settings, demonstrating positive effects on learning experiences and underscoring AR's potential to enhance educational outcomes in virtual learning environments.

Conclusion. Face-to-face learning offers clear advantages over existing online platforms; however, augmented reality technology holds substantial potential to create impactful, engaging virtual learning experiences that can effectively rival traditional educational methods. The strategic implementation of augmented reality in virtual education can significantly enhance student engagement and academic achievement.

1. Introduction

A smart classroom is a learning environment that integrates digital tools and resources with tangible materials to enhance in-person interaction among students and to document their collective knowledge (Huang et al., 2019). This classroom model incorporates various advanced technologies, such as video projectors, sensors, automated communication systems, cameras, mobile devices, facial recognition software, and environmental monitoring tools to enhance the learning experience for educators and students (Mircea et al., 2021). A smart classroom seeks to improve students' performance, creativity, and critical thinking by integrating technology with pedagogical paradigms such as social learning, mobile learning, and ubiquitous learning (N. S. Chen et al., 2016; Palanisamy et al., 2020). This study primarily concentrates on the technology components of a smart classroom, despite its inclusion of several elements.

The advent of Artificial Intelligence (AI) and the advancement of interactive, remote, and mobile computing technologies in both physical and virtual environments have shaped the establishment of smart classrooms. Many technologies employed in these environments are predominantly reliant on AI, enhancing learning by making it more engaging, adaptive, and intelligent (ten Have & Patrão Neves, 2021). This study defines a smart classroom, as depicted in Figure 1, as a physical or virtual learning environment that incorporates modern technology and artificial intelligence to improve the educational experience. In 1956, John McCarthy coined the phrase "Artificial Intelligence" to denote computer systems capable of tasks usually requiring human ability, including learning and reasoning (Sadiku et al., 2022). Since the 1970s, the domain of Artificial Intelligence in Education (AIED) has shaped the application of technology in pedagogy, to enhance student achievement and the overall educational experience. The objective of AIED is to create AI-driven systems—such as robots, intelligent tutoring systems, and virtual pedagogical agents—that facilitate personalized and adaptive learning while automating regular educational duties, such as feedback and assessment (AlFarsi et al., 2021).

Recent advancements in deep learning have considerably enhanced AI technologies (Sejnowski, 2020), facilitating their efficient use in complex machine learning tasks and promoting the growing adoption of AI-driven applications in educational settings.

Sensors (2024) defines "smart classrooms" as technology-enhanced, enclosed settings that incorporate sensors and AI to monitor real-time learning interactions. Nevertheless, "the research on sensor technology in smart classrooms is also inadequate," indicating a lack of robust empirical evidence regarding their educational effects (Sensors, 2024).

Smart Learning Environments (2023) stated that "AIED aims to establish AI-powered systems which allow flexible, engaging, and personalised learning," but highlighted the absence of "a critical analytical framework for evaluating these emerging technologies" in current literature (Smart Learning Environments, 2023).

A review in the Journal of Computers in Education (2024) emphasized that "little is known about how AI should be taught and applied effectively in real educational settings," urging further research on "how AI tools can enhance measurable learning outcomes" (Journal of Computers in Education, 2024).

Moreover, the investigation into smart classroom technology and the implementation of AI in education (AIEd) is fragmented and devoid of systematic review and structure (Sensors, 2024).

This study investigates the impact of technological improvements, namely AI-driven smart classroom systems, on students' academic achievement. Although current research has examined the structure and design of smart classrooms, there has been insufficient focus on the direct correlation between technological innovation and academic performance.

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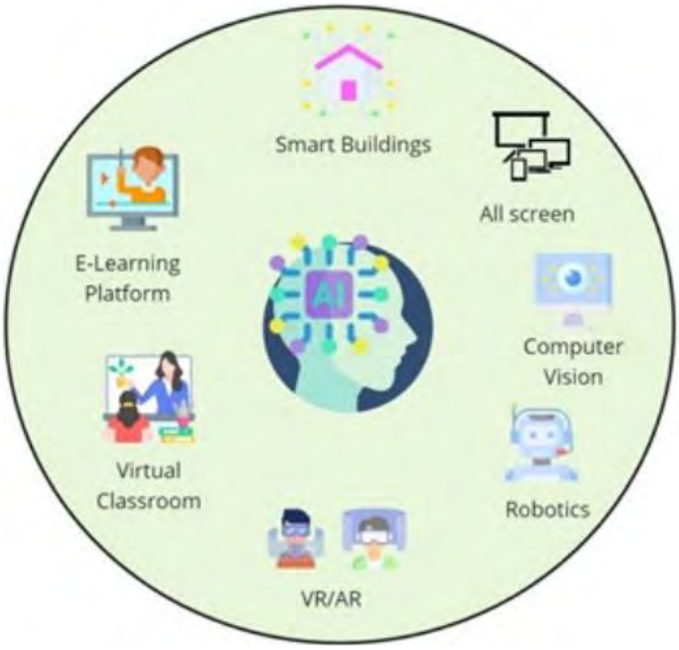

Figure 1. Principal Technological Tools Used in A Smart Classroom.

2. Literature Review

A multitude of studies on intelligent classes have been published in the literature. In their 2019 evaluation of smart technologies for physical environments, student engagement, assessment, and content generation and dissemination, researchers Saini and Goel provided recommendations for future research directions. While their strategy resembles ours, we prioritize integrating advanced technologies, including artificial intelligence, into intelligent courses and demonstrate a broader range of smart technologies. Researchers in (L. Chen et al., 2020) focused on the application of AI in education, discussing advantages and disadvantages and conducting a SWOT analysis. They showcased a range of educational innovations, including software applications, humanoid robots, internet-based avatars, and digital platforms. Authors in (X. Chen et al., 2022) examined the advantages of AI in education, including the application of educational robots, intelligent training systems for personalized instruction, natural language processing, performance forecasting, conversation analysis, and instructor evaluation. Whereas Dimitriadou and Lanitis (2022) provided a succinct summary of AI applications in smart classrooms, our work offers a comprehensive analysis of the advantages and disadvantages of AI use in such environments, accompanied by an extensive examination of relevant technologies.

3. Methodology Technology Learning

The term "classroom management" refers to the techniques or strategies a teacher utilizes to maintain order and regulate the classroom environment. Within this framework, management endeavors to maintain a comfortable and safe learning environment that facilitates successful class delivery. This survey focuses on computer vision-based surveillance and security, as well as smart environments related to class administration technology.

Table 1 demonstrates the incorporation of many technological instruments and approaches in classroom administration, instructional aids, and performance evaluation. The table emphasizes the application of computer vision-based surveillance, robotics, and intelligent surroundings in classroom management. These technologies are designed to establish a supportive and safe educational environment. The table includes the use of virtual, augmented, and mixed reality, e-learning platforms, and all-screen technology as teaching aids. These tools are crucial in augmenting the educational process by offering immersive and interactive learning experiences. Finally, the performance evaluation table demonstrates how technology is used to measure the performance of both students and teachers. This is essential for tracking progress and verifying the efficacy of the educational process. The table provides a thorough review of contemporary technology and methodologies that can be utilized to enhance classroom management, instruction, and evaluation.

"The research on the technology of smart classrooms and the application of AI technology in education (AIEd) … is scattered and lacks systematic review and organization."

"Classroom Behavior Recognition Using Computer Vision" (Liu et al., 2025) stated that computer vision in education "has primarily targeted physical actions, learning engagement, attention, and emotion in classroom settings, yet many behavioral categorizations lack correlation with instructional content and events." (Sensors, 2025)

"Artificial Intelligence in Classroom Management" (Fütterer, 2025) reviewed 104 studies published between 2000 and 2022. It concluded that "AI can play a key technical and pedagogical role in managing classroom environments, improving safety, and personalizing instruction."

Table 1. Technology Learning

Management of Classroom 1	Aids of Teaching	Assessment of Performance
Computer Vision-based Surveillance/Security	Robotics	Student performance assessment
Smart Environment	Virtual/Augmented/Mixed Reality	Teacher performance assessment
Smart Environment	E-learning Platforms	Teacher performance assessment
Smart Environment	All Screen	Teacher performance assessment

3.1. Electronic Monitoring Using Computer Vision

Computer vision techniques are commonly employed in smart classrooms for tasks such as behavior recognition and attendance tracking.

3.2. Recognition of Attendance

To save effort in maintaining student attendance records, many schools have implemented automated attendance detection using facial recognition technologies. According to Chowdhury et al. (2020), one such technology is a Convolutional Neural Network (CNN)-based facial recognition system that can identify pupils in real-time video streams captured by stationary cameras. Other variations on this strategy include systems that employ images from moving cameras (Mery et al., 2019), cameras affixed to a classroom's entryway, or spinning cameras (Gupta et al., 2018).

3.3. Smart Environment

The phrase "smart buildings" refers to entire edifices that use contemporary technological advancements and artificial intelligence to create a secure, efficient, and user-centric environment that optimizes resource utilization economically (Dryjanski et al., 2020). The Internet of Things (IoT), mobile applications, external telecommunications, and sensor technology (Wu et al., 2021) are commonly employed to enhance advanced technologies in smart schools (Kong & Fu, 2022).

Teaching Aids

To enhance student engagement and connectivity, several electronic tools are used to facilitate instruction in contemporary smart classrooms. This section provides an overview of these tools.

3.4. Behavior Recognition

An entire action performed by an individual in a video sequence can be identified using a computer vision-based technique known as "human action identification" (Parambil et al., 2022). In a smart classroom, the ability to identify students' behavior and emotions is highly beneficial for identifying unpleasant circumstances, such as high anxiety or diminished focus. In smart schools, advanced AI-powered monitoring systems can detect students who are not engaged in the classroom and notify the instructor (Li et al., 2019).

Additionally, authors in Wang et al. (2021) developed an AI-based model that accurately categorizes the level of student engagement in a smart classroom using multimodal data, such as facial expressions, body posture, and speech signals. The model can identify when students are confused or disinterested and provide the instructor with immediate feedback to enhance the learning environment. Similar to this, (TS & Guddeti, 2020) proposed an attention-aware learning system that uses eye-tracking technology to measure students' attention levels during lectures and provides personalized learning materials to keep them engaged. These studies show the potential of AI-driven systems to increase student engagement and improve classroom teaching efficiency.

In their research, Rashmi et al. (2021) demonstrated that a hybrid CNN could assess students' body movements, facial expressions, and other cues to determine their level of engagement. The three levels of pupil involvement studied in the research were neutral, involved, and bored. Similar to this, authors in Dimitriadou & Lanitis (2022) proposed an automatic system that tracked a variety of student actions, including eating, napping, using phones, participating in conversations, and paying attention. The primary goal of their research was to identify and localize various pupil activities within an image frame.

Prior research centered on tracking student behavior in technologically advanced classes. The authors of (Wang et al., 2021) suggested a brand-new collection of random student actions, which featured 15 distinct student behaviors. The smart classroom used in this research had four fixed cameras on the wall (front and rear of the classroom) to capture students' activities from different angles. It also had round desks for the students. More recently, researchers suggested an action recognition system that recognizes seven actions carried out by students enrolled in online classes (Dimitriadou & Lanitis, 2022; Shiomi et al., 2015). The images were recorded, and the action detection procedure was performed on each student's personal computer, making it suitable for remote educational activities. This was accomplished using CNN architectures.

3.5. Robotics

Educational robots can be physical objects (Kollia & Siolas, 2016; Weibel et al., 2020) or they can be avatars that are software entities (Johal et al., 2018; Pereira, 2016).

Actual Robots

An actual robot is a device capable of performing tasks usually done by people. Since the first robot was presented in 1980 (Mubin et al., 2013), several instructional robots resembling animals or people have been developed to accommodate various educational levels. A subgroup of instructional technology known as educational robots helps students learn more effectively, perform better academically, and actively participate in problem-solving activities (Timms, 2016). The primary motivation for integrating machines into the educational process is to develop platforms that encourage more social contact and promote learning (Okita et al., 2009). Table 2 lists some instances of instructional machines employed over time.

Table 2. A Selection of Robots and Their Main Abilities

Year	Robot Name	Appearance	Main Abilities	References
2000	Asimo	Humanoid (HUM)	Walk, converse, and observe	(Ishiguro et al., 2001)
2001	Robovie	HUM	See, hear, and speak	(Loos, 2015)
2004	Nao	HUM	Walk, perform, speak, and watch	(Kennedy et al., 2015; Osada et al., 2006)
2006	PaPeRo	Semi-HUM	Talk, see, and move	(Han & Kim, 2009)
2007	Tiro	HUM	Walk, chat, watch, and perform	(Hashimoto et al., 2011)
2009	Saya	Semi-HUM	Talk, see	(Woo et al., 2021)
2020	AV1	Human-like	Talk, see	(Jones & Castellano, 2018)
2020	ZenoBot	Human-like	Talk, see	(Werner-Seidler et al., 2017)

Table 2 presents the progression of robots over time, emphasizing their design and primary functionalities. The table covers the period from 2000 to 2020, illustrating the evolution of robots over two decades. Robot categorization is based on their introduction year, nomenclature, physical characteristics, primary functions, and sources of additional information. The robots predominantly exhibit humanoid characteristics, with certain models being semi-humanoid or resembling humans. These robots possess fundamental capabilities, including locomotion, verbal communication, visual perception, and auditory reception, with certain models capable of executing more intricate tasks. The table illustrates the progress in robotics technology over time, emphasizing the growing complexity and human-like characteristics of robots. This progression indicates ongoing efforts in robotics to develop more versatile and interactive robots capable of performing various functions. Initially, routine tasks were performed by robots without artificial intelligence. The demand for intelligent robots capable of performing complex tasks led to the integration of various sensors that gather environmental data, coupled with AI systems for assessment and decision-making based on this data (Brady et al., 2012; West, 2018). Robotics commonly employs instruments such as motion detectors, Time-of-Flight (ToF) optical sensors, and microphones in conjunction with AI systems to perceive the environment (Ben-Ari & Mondada, 2018; Poppinga & Laue, 2019). CCD cameras and infrared depth cameras can enhance the performance of time-of-flight cameras in vehicles. Robots are generally trained to execute tasks effectively, utilizing data gathered by instruments to develop neural network models that enable them to understand users and respond appropriately (Vega & Cañas, 2019). Robots currently possess a range of integrated AI capabilities, such as speech recognition, intelligent agent technology, movement control, object manipulation, motion control, computer vision, and natural language processing.

Children with autism have found success using social robots to help them understand concepts such as emotional closeness and personal limits, as well as to develop their autonomous learning abilities (Bourguet & others, 2020). Robots can learn about each student's unique requirements and react in a way that is individualized, giving input and support (Chocarro et al., 2021). Robots' capacity to capture students' facial expressions and mood swings is another crucial feature that enables the assessment of students' behavior and mental states. This can assist in identifying and treating any possible emotional disturbances, like tension or despondency (Colace et al., 2018). For instance, MIT researchers created a computer dubbed "Teacher bot" that can recognize and respond to students' feelings to offer tailored feedback and support (Tian et al., 2021).

Chatbots

The term "chatbot" is derived from the combination of "chat," meaning conversation, and "bot," an abbreviation for "robot" (Morrissey & Kirakowski, 2013). Chatbots are computer programs designed to simulate interactions with human users through instant messaging systems. Chatbots hold significant potential as educational tools for remote students, offering personalized support, instructional materials, and tutoring assistance to enhance the learning experience (Morrissey & Kirakowski, 2013; Pereira, 2016). Several instructional chatbots have been developed and utilized over time, with select examples presented in Table 3.

Table 3. A Selection of Chatbots and Their Main Abilities

Year	Chatbot Name	Main Abilities	REF
2011	StuddyBuddy	Respond to inquiries and conduct lessons	(Pereira, 2016)
2013	IBM Watson	Respond to inquiries and disseminate information	(Singh et al., 2019)
2016	Dawebot	Create a quiz, reply to questions	(Pakanati et al., 2020)
2016	Botsify	Respond to inquiries, join	(Karri & Kumar, 2020)
2017	Nerdy Bot	Respond to inquiries	(Górski et al., 2016)
2019	Amazon QnABot	Answering concerns	(Billinghurst et al., 2015)
2020	Google Assistant	Answer queries, watch videos, and participate in games	(Kasapakis et al., 2019)

Table 3 illustrates the development of chatbots from 2011 to 2020. It categorizes chatbots based on the year they were introduced, their names, main abilities, and references for further information. The main abilities of these chatbots primarily involve responding to inquiries, but over time they have evolved to perform more diverse functions. For instance, some chatbots can conduct lessons, create quizzes, disseminate information, and even participate in games. The table reflects the advancements in chatbot technology over the years, highlighting the increasing complexity and versatility of chatbots. This progression signifies continuous innovation in chatbot technology, creating more intelligent and interactive chatbots capable of serving a wide range of functions and applications.

3.6. Augmented/Virtual/Mixed Reality

Virtual, augmented, and mixed reality technologies are frequently used in smart classrooms to provide students with fully engaging learning experiences. The use of 3D simulations of actual or hypothetical environments that users can perceive, investigate, and engage with is known as VR (Mystakidis, 2022). The use of AR allows students to engage with both virtual and real materials by adding virtual information to their physical environment (Kye et al., 2021). According to Dincelli and

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Yayla (2022), mixed reality (MR) is the coexistence of real-world and virtual/digital elements (see Fig. 2). Because of the immersive and participatory learning experience this technology can offer, it provides students with a unique and engaging way to learn that is not feasible with conventional teaching techniques.

The concept of the metaverse has recently gained more attention and is expected to enter our world in the coming decades. The idea of the metaverse has been around since the 1990s, but it has gained new life as VR/AR technologies become more commonplace. An alternate digital realm known as the metaverse enables multiple users to submerge themselves in settings that blend the physical and digital worlds (Marini et al., 2022). By enabling a seamless merging of the real and digital worlds, this technology has the potential to completely transform how people engage with one another and the environment. As the metaverse continues to grow, it is likely to have a significant influence on education and how students learn, offering fresh and thrilling possibilities for immersive and interactive learning experiences.

As these technologies enable complex connections with virtual items and multisensory interactions, the metaverse leverages them to foster absorption. These technologies include VR, AR, and blockchain. The metaverse has been a topic of discussion among many scholars and educators in education, so it is not a novel idea. The metaverse can provide a virtual space for people to connect and engage in social interaction for instructional purposes. By using VR and other immersive technologies to create more dynamic and engaging experiences, it has the potential to completely transform how students learn and engage with instructional material. This can enhance comprehension and recall.

The use of the metaverse in schooling is not without its difficulties, though (Bown et al., 2017). Concerns about data protection, technology adoption, expense, inefficiency, lack of standardization, and possible addiction to these immersive settings are just a few of these difficulties. When implementing metaverse technologies in educational environments, it is crucial for educators and lawmakers to carefully consider these challenges (Shahab et al., 2021). The metaverse can be an effective tool for improving students' learning experiences by overcoming these difficulties (Krasonikolakis et al., 2018).

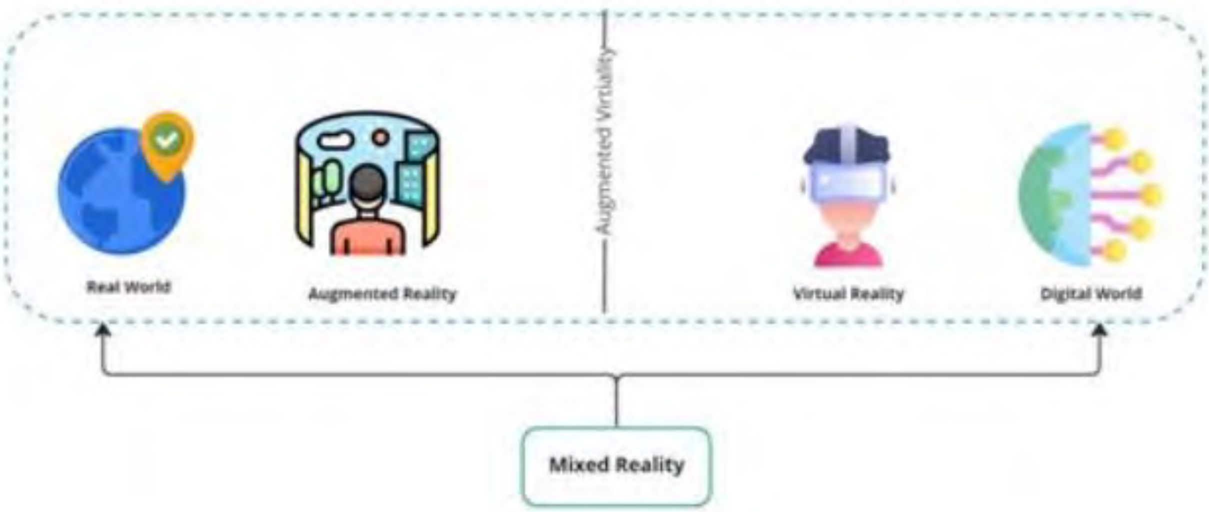

Figure 2. The Variations Among Mixed Reality, AR, and VR

3.6.1. Virtual Reality

The idea of building a realistic, synthetic reality predates AR. The concept of living in a technology-driven, manufactured world was explored in early science fiction and fantasy books. Panoramic images that covered the viewer's field of view, giving the impression of being present in

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the scene, were used in the earliest efforts to develop VR. This idea was enhanced by stereoscopic picture viewers, which provided a more accurate representation of the sensation of "being there" (Yaoyuneyong et al., 2018). A precursor to modern Virtual technology was the Link Trainer, a program used to teach pilots during World War II. Today, when we think of VR, we frequently picture a head-mounted display that presents the user with a simulated environment while hiding information from the outside world.

These "head-mounted displays" (HMDs) were originally intended for gaming and amusement, but usage has steadily expanded to include areas like work training, prototyping, marketing, and tourism (Berg & Vance, 2017). Researchers have also examined the use of VR in a number of business applications, including retail stores and supermarkets (Lee et al., 2020), the fashion industry (Fertleman et al., 2018), manufacturing (Mintz et al., 2001), tourism (Knudsen & Naeve, 2002), healthcare (Adams & Hotrop, 2008), and as a research tool.

Table 4. List of VR Used from 2001 to 2019

Year	REF	Topic	Equipment Used
2001	(Mintz et al., 2001)	Astronomy/Physics	Computer
2002	(Knudsen & Naeve, 2002)	Mathematics	Head Mounted Displays (HMD)
2008	(Adams & Hotrop, 2008)	Computer Science	Computer, HMD
2016	(Parmar et al., 2016)	STEM	Oculus Rift HMD
2018	(Ip et al., 2018)	Autism students	Camera, Projection Screens
2018	(Blyth, 2018)	Geography	Computer
2019	(Alfalah et al., 2019)	Medicine	PC, projector, and 3D glasses

Virtual Reality in Education

VR has been a useful instrument for teaching a variety of subjects (see Table 4). According to Parmar et al. (2016), the two approaches most commonly used to provide complete and semi-immersive VR experiences in smart classrooms are interactive school desks, HMDs, and CAVE (Cave Automated Virtual Environment). HMDs are appropriate tools that provide a virtual environment for a single user at a time in a CAVE, a room-sized area with numerous projection displays where the user can walk freely and experience their body in direct contact with the virtual scene. HMDs and CAVEs can be used in conjunction with a variety of VR add-ons, such as gloves, outfits, and devices, to create an even more thrilling experience.

The use of VR in education has altered prior teaching philosophies and current teaching models (Hampel & Dancsházy, 2014; Manouchou et al., 2016). Numerous studies have concluded that Virtual technologies are more likely to positively influence students' motivation and scholastic success (Manouchou et al., 2016). Furthermore, Baum (1901) contends that the development of a Virtual Learning (VL) setting is beneficial for students because they can study independently. Additionally, there is proof that VR technologies improve students' cognitive and psychomotor abilities as well as their creative and communicative skills (Manouchou et al., 2016); however, VR technologies can also be used to educate instructors (Torres & others, 2011).

3.6.2. Augmented Reality

The practice of enhancing perspective has a lengthy past. A protagonist is given the supernatural ability of a "character marker" in the book (Baum, 1901), "The Master Key"—a unique pair of glasses that superimpose a letter signifying a person's underlying personality on their brow. Even earlier, in the 1860s, the idea of Pepper's phantom served as a stage performance illusion method similar to AR, though without digital technology.

Augmented Reality in Education

Smart classrooms use a variety of augmented display technologies, such as iPads, cellphones, smartboards, and numerous software programs, such as Aurasma, Layar, Augment, and Aumentaty. Additionally, enhanced display devices can be used with AR headsets/glasses, such as the Oculus Quest, Microsoft HoloLens, and Windows Mixed Reality. The use of AR in smart classrooms can take many different forms, according to Abbasy & Quesada (2017), including enlarged books, virtual representations of intricate structures, educational games, virtual representations with sound, navigation support, magic eyeglasses, magic doors and windows, magic mirrors, as well as cooperative space. It is advised to use AR to address several issues that may arise in smart classrooms, including difficulties conducting complex and risky experiments, high equipment costs, and a lack of suitable facilities (Queiroz et al., 2022). Additionally, Stanford University research revealed that students who use AR technology in their learning exhibit better information retention and problem-solving abilities (Cai et al., 2019). As shown in Table 5, different subjects have adopted AR technology due to its significance in education.

Table 5. List of AR from 2019 to 2022

Year	REF	Topic	Equipment Used
2019	(Cai et al., 2019)	Mathematics	Tablet
2020	(Kerr&Lawson,2020)	Landscape Architecture	Google Assistant
2020	(Demitriadou et al., 2020)	Mathematics	Tablet/mobile, AR markers
2021	(Reeves et al., 2021)	Biochemistry	AR markers, Tablet
2022	(Kim & Shim, 2022)	Computer Sc and Engineering	Cam, AR markers

4. Traditional VS E-Learning

While E-Learning shifts attention to students, who take an active role in the learning process, traditional learning is often more concerned with the teacher's role and less interactive. Features like group and individual study, as well as the students' participation in choosing topic matter from a variety of sources, represent this. Technology and a stronger link to real-world applications are considered the driving forces behind eLearning's engaging qualities, which, in turn, inspire students to work harder.

The COVID-19 pandemic has had a big effect on how we communicate, learn, and perform. Many resorted to e-learning to continue teaching students. At the same time, they were being educated afar, as schools, colleges, and other educational institutions were forced to close to stop the spread of the virus. E-learning is the delivery of instructional material and improvement of teacher-student communication through the use of digital tools and technologies. During the COVID-19 epidemic, e-learning has emerged as a crucial and well-liked alternative to conventional classroom instruction, thanks to a variety of online tools and resources.

There have been significant delays for students as educational establishments have shut their doors worldwide due to the COVID-19 epidemic. VL has taken the place of conventional classroom education in order to continue educating while reducing the risk of infection. In this research, we compared the efficiency of conventional and online instructional methods for undergraduate dentistry students enrolled in the Oral Biology course in 2020 and 2021. To understand how students in both groups felt about online learning, we also sought their input.

Despite the ongoing COVID-19 pandemic, digital technology was crucial in ensuring that dentistry instruction continued. In contrast to most students learning on campus, who found it easy to understand, the current research found that a sizable percentage of students taught online (43%) reported trouble understanding the concepts related to oral biology. These results imply that, in order to better assist students in their learning, online dentistry education may require change. In comparison, more than 50% of students in Amir et al.'s prior research demonstrated a favorable attitude toward online learning and education (Amir et al., 2020). Notably, the COVID-19 pandemic had just begun when the class of 2020 entered dentistry school, forcing the abrupt closure of all institutions and the switch to online learning. The majority of students may not have received a complete introduction to the challenging field of dentistry education, which requires a comprehensive grasp of ideas, given the online content provided, which may have contributed to the stated difficulty in comprehending the material.

A recent study found that dentistry students who received instruction both in person and virtually felt their queries were sufficiently answered during the meetings. These findings are consistent with earlier studies in the area (Rashid & Elahi, 2012). Additionally, the online assessment format used during the 2020 classes received positive feedback from the students. Basic comprehension questions (BCQs) with time limits and theoretical tests with brief response questions (SAQs) were used in the tests. It was discovered that students preferred the theoretical tests because they could finish them at home.

VL is very different from conventional learning and has special requirements for implementation to be effective. These include having access to appropriate tools, dependable power supply, and adequate internet connectivity (Rashid & Elahi, 2012; Sarwar et al., 2020). However, those who participated in online learning reported difficulty comprehending the material and feeling stressed. These results are in line with earlier studies in the area (Amir et al., 2020; Sharma et al., 2020). Problems with internet connectivity, inadequate electricity in rural areas, and the high cost of laptops, which are necessary for participating in virtual learning, could all contribute to these challenges.

The majority of students in both categories said they were able to study the content in advance and get ready for the sessions. These data support the observations of Amir et al., who found that although students may not favor virtual learning, they are still motivated to create study materials (Rashid & Elahi, 2012).

According to the present study's findings, both sets of students voiced dissatisfaction with the virtual method of instruction. Prior studies in the area, however, were different from ours in that their participants had a greater grasp of contemporary technology and could thus continue their studies with ease, leading to higher levels of happiness (Johnson et al., 2016; Bansal et al., 2020). These results underscore how crucial it is to provide students with the latest technology to achieve the best results for efficient learning. According to the current study's findings, online instruction was difficult for both conventional and virtual groups of pupils. These results are in accordance with research by Sarwar et al., in which the majority of students expressed dissatisfaction with the value of online classes (Muthuprasad et al., 2021). Additionally, neither set of students favored online learning over conventional teaching methods, which is consistent with earlier studies that found a preference for in-person instruction (Muthuprasad et al., 2021), (Paul & Jefferson, 2019). It is advised to cut lengthy lessons short and allow sufficient breaks between them to increase the effectiveness of the student's learning. This strategy would lessen the physical tension brought on by prolonged use of technological devices as well as the cerebral strain.

According to studies, students typically express a favorable view towards the potential use of AR in the classroom. Many students believe that incorporating these tools could enhance their motivation, engagement, and understanding of complex concepts. Moreover, it is suggested that AR has the potential to improve learning outcomes and increase the availability of immersive and hands-on learning opportunities. It is essential to note that the success of integrating AR, or any other technology, into education depends on various factors, including the quality of the content, the required hardware and software, the level of teacher and student support, and the cost and accessibility of the technology. Focusing on AR as a suggested solution offers an advantage: it does not require special hardware, making it a more accessible option for students to improve their online learning experience. Expectations for AR integration include enhanced visuals and clearer demonstrations of concepts, which may contribute to more effective learning.

Difference in Student Performance between Face-to-Face (F2F) and Online Learners

Table 6. Environmental Science Data Set Means and Standard Deviations for 8 Semesters

Variable	F2F sec. (n=401)		Online sec. (n = 147)		Men (n = 246)		Women (n = 302)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grade	69.35	12.128	68.64	14.125	3.23	1.19	2.9	1.20

The chi-square technique, which the authors (Paul & Jefferson, 2019) used to evaluate the data, is suitable for assessing the relationship between the teaching method and success in the sample group and in the general population. A numerical result from the chi-square test can be used to assess whether there is a statistically meaningful difference between the two categories.

Table 6 presents a graphical depiction of differences in scores and deviations, showing the mean and standard deviation (SD) by modality and gender. With comparable SDs for both categories, the mean GPA for F2F and online students was 69.35 and 68.64, respectively. The typical GPAs that men and women received, however, were noticeably different, with males earning a 3.23 and women a 2.9. Although the number difference of 0.33 may seem insignificant, it is important because on a categorical scale of A to F, a 3.23 corresponds to a B+ and a 2.9 corresponds to a B. The authors discovered that the mean grade for males taking environmental online courses was higher than that for women ($M = 2.9$, $N = 302$, $SD = 1.20$) ($M = 3.23$, $N = 246$, $SD = 1.19$) (see Table 6).

Table 7. Academic Achievement of Students (N = 548): Contingency Chart

Comparison	A	B	C	D	F	Total
F2F	28	121	131	49	72	401
F2F % within grade	63.60%	79.10%	70.80%	77.80%	69.90%	73.20%
Online	16	32	54	14	31	147
Online % within grade	36.40%	20.90%	29.20%	22.20%	30.10%	26.80%

$\chi 2 = 6.531$, Critical value = 7.7, d. f . = 4.

Table 8. Performance x Gender Crosstabulation

Gender	A	B	C	D	F	Total
Male count	15	54	89	34	54	246
Expected	19.0	68.7	83.0	28.3	46.2	246
Female count	29	99	96	29	49	302
Expected	24.0	84.3	102	34.7	56.8	302
Total count	44	153	185	63	103	548

Table 9. Chi-Squared for Grade Distribution Between Online and F2F Pupils

	Chi-square tests		
Test	**Value**	**df**	**Asymptotic Significance (2-sided)**
Pearson Chi-Square	13.007[a]	4	0.011
Likelihood Ratio	13.138	4	0.011
Linear-by-Linear Association	10.376	1	0.001
N of Valid Cases		548	

**0 cells (0.0%) have expected count <5. The minimum expected count is 19.75. χ2 test of independence with alpha = 0.05.*

A chi-square analysis was carried out using SPSS to determine whether there was a significant variation in the grade distribution between online and F2F pupils. According to Table 7, the F2F session had a higher percentage of A grades (63.60%) than the online program (36.40%). With a chi-square value of 6.531 and 4 degrees of freedom (N = 548), the analysis revealed a statistically significant difference in pupil achievement. This difference was greater than 0.05. The gender disparity in pupil success between online and face-to-face classes is shown in Table 9.

5. Conclusion

This study has explored the increasing use of technological advancements, such as VR/AR, in education and learning. Our findings suggest that integrating VR/AR into teaching can enhance student engagement, motivation, and understanding of complex concepts, thereby improving the overall learning process. We have compared the effectiveness of traditional teaching methods with technology-based approaches, providing examples of how VR/AR technology has been successfully implemented in classrooms. Our results indicate that, while there are challenges associated with online learning, such as internet connectivity issues and the high cost of necessary equipment, students remain motivated to prepare and study the materials. Furthermore, we have sought students' opinions on the potential use of AR in classrooms. Many students believe that the inclusion of these tools could improve their motivation, engagement, and comprehension of complex concepts. They also see AR as a more accessible option to enhance their online learning experience, as it does not require special hardware. However, the success of integrating AR, or any other technology, into education depends on various factors, including the quality of the content, the required hardware and software, the level of teacher and student support, and the cost and accessibility of the technology. In light of these findings, we recommend shortening lengthy lessons

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and allowing sufficient breaks in between to increase the effectiveness of student learning. This strategy would reduce the physical strain caused by prolonged use of technological devices and mental fatigue. Moving forward, it is crucial to continue investigating and employing technological advancements to improve learning and education. This includes focusing on the potential of AR in the classroom, which our study has shown to be a promising area for future research and development.

Declarations

Author Contributions. (S.F.M.A.: Literature review, conceptualization. T.A.: methodology, data analysis. J.A. and S.B: review-editing and writing, original manuscript preparation. All authors have read and approved the published version of the article.

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