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A Comprehensive Survey of Smart Classroom Technologies: Objectives, Methodologies, Datasets, and Challenges

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Abstract

Recent advances in Artificial Intelligence (AI), the Internet of Things (IoT), and machine learning have significantly influenced the development of smart classrooms. These technologies are gradually transforming traditional teaching environments into more automated and data-driven systems. Conventional methods of taking attendance and observing student engagement are often time-consuming, prone to errors, and difficult to manage in large or hybrid classrooms.

This paper presents a survey of more than sixty research studies published between 2010 and 2025, focusing on three closely related areas: automated attendance using facial and biometric recognition, student engagement analysis through computer vision and deep learning, and IoT-based classroom management systems. Unlike many existing reviews that examine these topics separately, this work considers how they come together within integrated smart classroom frameworks.

The survey examines research goals, methodologies, datasets, and reported performance trends. It highlights a clear shift from traditional approaches to deep learning-based methods, particularly convolutional neural networks and real-time detection systems. Key challenges identified across the literature include privacy concerns, demographic bias, environmental variability, and issues related to scalability. Based on these observations, potential future directions are discussed, including privacy-aware learning models, secure data handling, and lightweight edge-based solutions.

Keywords: Smart Classroom, Face Recognition, Student Engagement, Internet of Things, Deep Learning

1. Introduction

The rapid advancement of AI, IoT, and computer vision is reshaping traditional educational environments, gradually turning them into more data-driven, adaptive, and intelligent systems. In this context, conventional methods such as manual attendance registers and subjective observation of student engagement are becoming increasingly ineffective. This is especially evident in modern classrooms, where larger class sizes and hybrid modes of teaching require more reliable, scalable, and accurate monitoring approaches.

To address these limitations, smart classroom technologies introduce automated solutions that go beyond simple attendance tracking. By leveraging biometric systems, attendance can be recorded efficiently, while real-time video analytics provide deeper insights into student behavior and engagement. These systems typically combine computer vision, machine learning, and interconnected IoT devices to enable a seamless and contactless learning experience. For instance, face recognition techniques can be used to verify attendance instantly, whereas expression analysis and gesture tracking allow educators to better understand patterns of student attention, fatigue, and distraction [28, 26].

The importance of this survey lies in its ability to bring together research from multiple interconnected domains. While many existing reviews tend to treat attendance management and IoT-based classroom systems separately, this work takes a more integrated approach. It connects attendance tracking, student engagement analysis, and IoT-enabled monitoring to present a more comprehensive view of smart classroom technologies. In doing so, the survey examines methodological developments, compares commonly used datasets, analyzes performance trends, and discusses key limitations identified in the literature.

The rest of the paper is structured as follows. Section 2 discusses the primary objectives identified in the reviewed studies. Section 3 presents an overview of the methodologies used, ranging from traditional PCA-based techniques to more recent deep learning and transformer-based models. Section 4 provides a summary of the datasets and tools employed, while Section 5 outlines the results along with comparative analysis. Sections 6 and 7 focus on the strengths and limitations of current approaches. Finally, Section 8 explores potential future directions, and Section 9 concludes the survey.

2. Objectives

The surveyed papers reflect three primary objectives, with overlaps in some cases.

2.1 Face Recognition-Based Attendance Systems

This section brings together the key objectives identified across a broad range of studies focused on automating attendance using facial recognition. At its core, the research aims to design systems that are reliable, efficient, and easy to use, ultimately replacing traditional manual attendance methods. As a fundamental component of smart classroom technology, this area has progressed significantly, evolving from early algorithmic approaches to more advanced, real-time systems capable of practical deployment.

2.1.1 Core Algorithm Development and Optimization

Research in this domain primarily centers on the core technologies underlying face recognition systems. The main objective is to develop and refine algorithms that can improve accuracy, processing speed, and overall reliability. Earlier studies largely relied on traditional techniques such as Principal Component Analysis (PCA) [31], whereas more recent work has shifted toward deep learning approaches, particularly Convolutional Neural Networks (CNNs) [59, 41].

A key challenge is maintaining consistent performance under real-world conditions, including variations in lighting, changes in student posture, and partial occlusions. Several studies report foundational advancements in real-time face recognition [2], along with the design of algorithms specifically tailored for efficient attendance management [58]. In addition, models such as YOLOv5 have been adapted and optimized for face detection and landmark regression, further improving system accuracy [36].

2.1.2 System Implementation and Practical Application

An important focus of this research is the transition from theoretical models to practical, real-world implementations. Rather than remaining at the conceptual level, efforts are directed toward building systems that can be effectively deployed in actual environments. This requires integrating the core facial recognition components with a range of hardware and software platforms.

Several studies describe the development of such systems on embedded devices, including the Raspberry Pi [1, 38], highlighting their feasibility for low-cost and portable solutions. In parallel, user-oriented applications have been designed using frameworks like Flutter [52, 51, 22], enabling accessible and interactive interfaces. Additionally, a number of implementations rely on open-source tools and web-based platforms to create fully functional systems suited for both educational and professional use cases [40, 46].

2.2 Student Behavior, Engagement, and Attention Monitoring

This area of research broadens the scope of smart classroom systems beyond simple attendance tracking. It focuses on monitoring and analyzing student behavior, engagement, and levels of attention in a more comprehensive manner. The aim is to generate meaningful insights that can support educators in understanding classroom dynamics and, ultimately, contribute to improved learning outcomes.

2.2.1 Automated Engagement and Attention Analysis

In this area, research efforts are directed toward developing systems capable of automatically detecting and measuring student engagement. This is typically done by examining facial expressions, head posture, and other non-verbal behavioral cues [28, 5, 47]. Many studies emphasize the use of advanced computer vision models, such as YOLOv5, to enable real-time tracking of attention levels [60]. In addition, some approaches incorporate machine learning techniques, including Adam Robust Optimization, to analyze learner engagement in online settings [45]. Together, these systems offer a more dynamic understanding of classroom interactions, which is especially valuable in today's remote and hybrid learning environments.

2.2.2 Comprehensive Behavior Recognition

Beyond engagement analysis, several studies extend their focus to identifying a broader spectrum of student behaviors. The goal here is to detect actions that may reflect restlessness, active participation, or confusion [53, 6]. Such insights can support the refinement of teaching strategies and contribute to more effective classroom management [55]. To achieve this, researchers have proposed specialized models, including SBD-Net [56] and Dense Student Behavior Algorithms [12], aimed at improving both detection accuracy and computational efficiency. Additionally, some works examine patterns of teacher-student interaction, providing further insight for optimizing instructional approaches [61].

2.3 Smart Classroom Systems and IoT Integration

This area of research adopts a broader perspective by examining how multiple technologies can be combined to form a cohesive and intelligent classroom ecosystem. Rather than focusing on isolated solutions, the emphasis is on building interconnected systems that support a data-driven approach to teaching and learning.

2.3.1 IoT and Hybrid System Architectures

A number of studies propose system architectures that leverage the Internet of Things (IoT) to connect devices such as cameras, RFID tags, and various sensors [11, 7]. The intention is to create a reliable communication framework that enables efficient data collection and exchange. In addition, several works investigate hybrid approaches that integrate multiple technologies - for instance, combining facial recognition with RFID [4, 3] or Bluetooth Low Energy (BLE) [15] - to improve both system security and operational reliability. Some research also explores the use of blockchain technology to ensure that attendance records remain secure and resistant to tampering [13].

2.3.2 Adaptive Learning and Future Trends

Another important direction involves making effective use of the data generated by these systems to support adaptive learning. By analyzing patterns in attendance and student behavior, such systems can deliver real-time feedback to educators and, in certain cases, adjust learning content dynamically [20]. Additional studies examine emerging trends in IoT-based smart classrooms, offering insights into how these technologies may shape the future of education [18]. The continued development of AI-driven attendance and classroom management systems is also identified as a key focus for future advancements [30, 26].

3. Methodologies and Technologies

This section provides an overview of the wide range of approaches used in the literature, covering both fundamental algorithms and complete system architectures. The discussion is organized in a structured manner to clearly present the different techniques and technologies involved.

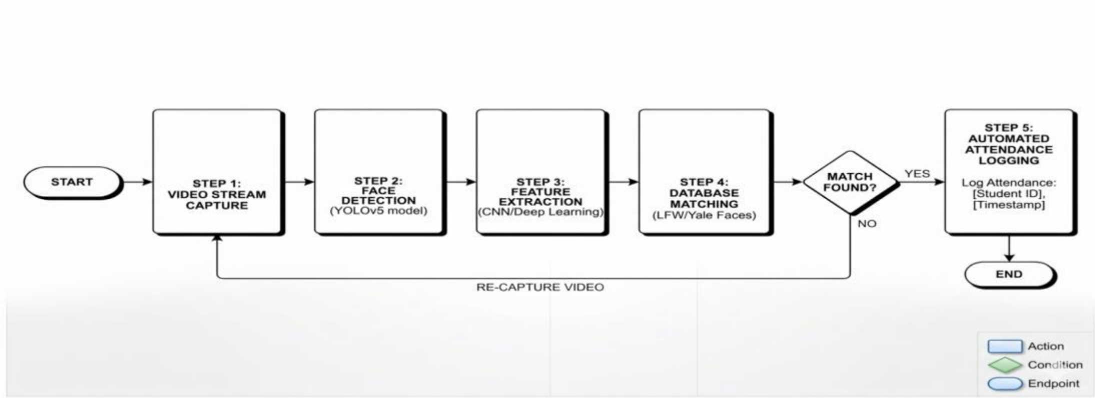

Figure 1: Typical Workflow of an Automated Facial Recognition-Based Attendance System

3.1 Face Recognition Technologies

In recent years, face recognition systems have increasingly relied on deep learning techniques, particularly Convolutional Neural Networks (CNNs), due to their high accuracy and robustness [59]. Studies such as "YOLO5Face: Why Reinventing a Face Detector" (2022) demonstrate the use of advanced object detection frameworks like YOLOv5 for efficient and real-time face detection [60].

3.1.1 Traditional Computer Vision

Earlier research largely depended on classical computer vision methods. Principal Component Analysis (PCA) was widely used for dimensionality reduction and feature extraction from facial images [31]. Other techniques, including Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT), were also applied for effective feature representation [34].

3.1.2 Hybrid and Hybrid-DNN Architectures

In some cases, researchers combine traditional techniques with deep learning models to improve performance. For instance, hybrid approaches incorporating models such as MLBP-HOG-G have been explored to take advantage of both methodologies [25].

3.1.3 Open-Source Frameworks

A large portion of the literature makes use of open-source libraries such as OpenCV, along with deep learning frameworks like TensorFlow and Keras, to develop and implement face recognition and attendance systems [21, 33].

3.1.4 Spoofing Detection

To address security concerns, certain systems include anti-spoofing techniques designed to distinguish between a real human face and representations such as photographs or videos [27].

3.2 Student Behavior and Engagement Monitoring

3.2.1 Facial Expression Recognition

Deep learning approaches, especially CNN-based models, are commonly trained on large datasets to identify and classify student emotions, such as happiness, boredom, or confusion, based on facial expressions [5].

3.2.2 Body Pose and Gesture Analysis

In addition to facial features, many systems analyze body posture and head movements, which can serve as useful indicators of attention and engagement [53]. More advanced methods, including Dense Student Behavior Recognition Algorithms using DETR and Multi-Scale Deformable Transformers, are applied for complex behavior detection tasks [12].

3.2.3 Multi-Modal Data Fusion

Some advanced approaches integrate multiple data sources - such as video, audio, and interaction data from learning platforms - to obtain a more comprehensive understanding of student engagement [45].

3.2.4 Computer Vision-Based Systems

Several studies focus on general-purpose computer vision systems that monitor student activities and generate insights to assist instructors in managing the classroom more effectively [6].

3.2.5 Hardware and Software Integration

These systems typically rely on cameras to capture real-time video, which is then processed using a computer or an embedded platform such as the Raspberry Pi [1].

3.3 Smart Classroom Systems and IoT Integration

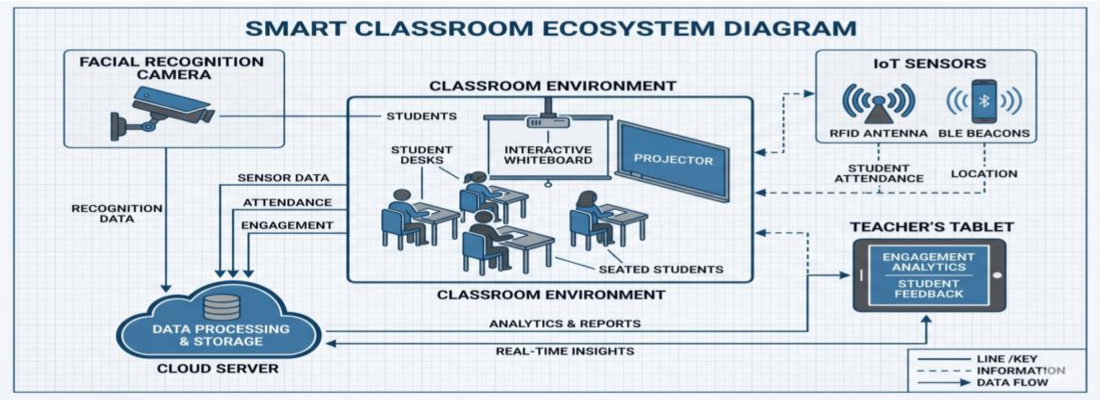

Figure 2: Integrated Smart Classroom Ecosystem Showing Facial Recognition Cameras, IoT Sensors, BLE/RFID-Based Attendance Tracking, Cloud Data Processing, and Teacher Analytics Dashboard

3.3.1 IoT Architecture

Most smart classroom systems are built on IoT-based architectures, generally consisting of multiple layers, including sensor, network, data processing, and application layers [11]. Devices such as cameras and sensors operate at the sensor level, while centralized servers or cloud platforms handle data processing and application management [13].

3.3.2 Biometric Fusion

To improve system reliability and security, some implementations combine facial recognition with additional biometric methods, such as RFID [4] or Bluetooth Low Energy (BLE) for proximity-based detection [15].

3.3.3 Embedded Systems

For practical and cost-effective deployment, embedded platforms like the Raspberry Pi are often used, as they support both data collection and local processing within the classroom environment [1].

3.3.4 Blockchain Technology

In certain designs, blockchain technology is incorporated to ensure that attendance records remain secure, tamper-resistant, and verifiable over time [13].

3.4 Alternative Biometrics and Recognition Methods

3.4.1 Iris Recognition

Iris recognition represents an alternative biometric technique known for its high accuracy and security. The process involves capturing an image of the iris and matching it against stored data for attendance verification [32].

3.4.2 Hand Gesture Recognition

Some studies also explore hand gesture recognition as a means of interaction and control. In these systems, cameras capture hand movements, which are then analyzed and classified using computer vision and machine learning techniques [42].

4. Datasets and Tools

This section outlines the datasets and the software and hardware tools commonly used across the reviewed studies. The literature reflects a combination of publicly available benchmark datasets and custom-built data collections, along with a consistent reliance on widely adopted open-source tools and development platforms.

4.1 Datasets

A large number of face recognition studies make use of established public datasets for training and evaluation, which helps ensure consistency and reproducibility across different research works [36]. In many cases, researchers also develop custom datasets using classroom video recordings, allowing systems to be trained and tested under specific environmental conditions such as lighting and seating arrangements [53, 2]. For facial expression recognition, specialized datasets containing annotated images with various emotional states are commonly used to support engagement analysis [5]. Hand gesture recognition systems are typically trained on custom datasets collected in real-time scenarios to improve the accuracy of gesture detection and classification [42].

Table 1: Most Commonly Used Datasets and Tools Across Surveyed Studies

Dataset / Tool	Frequency
LFW / Yale Faces	21%
FER2013 / CK+	12%
Custom Classroom Datasets	49%
OpenCV (Python)	68%
TensorFlow / PyTorch	37%

IoT Hardware (Raspberry Pi, BLE)	19%

4.2 Tools and Technologies

4.2.1 Programming Languages and Frameworks

Python remains the most widely used programming language in this domain, largely due to its rich ecosystem of libraries for machine learning and computer vision tasks [39]. OpenCV serves as a core library for image and video processing, and is frequently employed for tasks such as face detection, video stream handling, and other computer vision operations [33, 21]. Deep learning frameworks, including TensorFlow and Keras, are commonly utilized to build and train advanced neural network models such as CNNs and Transformer-based architectures [54, 19]. Web technologies such as HTML, CSS, and JavaScript are often used to design user-friendly interfaces for attendance management and related applications [46].

4.2.2 Hardware and Embedded Systems

The Raspberry Pi is widely adopted for developing embedded, low-cost, and portable smart classroom solutions [1, 38]. Cameras act as the primary sensing component in most computer vision-based systems [6]. RFID is often integrated into hybrid systems to support identity verification alongside facial recognition [4]. Bluetooth Low Energy (BLE) is used for proximity-based detection and attendance verification [15]. Earlier implementations also incorporated GSM modules to send attendance notifications via SMS [24].

4.2.3 Platforms and Architectures

Flutter is commonly used to develop cross-platform mobile applications, enabling accessible interfaces for both students and administrators [22, 52]. IoT-based architectures facilitate communication between multiple devices and sensors, supporting coordinated data collection within the smart classroom environment [29, 11]. Cloud platforms are often integrated to handle scalable data storage, processing, and centralized management of attendance records and analytics [13].

5. Results

5.1 Performance and Accuracy Metrics

Findings across the literature consistently show that modern face recognition systems are capable of achieving high accuracy in attendance management tasks [31, 37]. The adoption of deep learning techniques, particularly CNNs, has played a major role in improving performance compared to traditional approaches [59, 21]. Studies involving YOLO-based models highlight their ability to deliver fast and efficient real-time detection, which is essential for live classroom environments [60, 36]. Earlier research primarily demonstrated the feasibility of these systems, often reporting strong results under controlled conditions [16, 10, 50]. In addition, several works suggest that hybrid approaches, which combine multiple biometric methods, tend to produce more reliable outcomes than single-modality systems [32, 4].

5.2 System Reliability and Security

A significant portion of the research focuses on ensuring that these systems are reliable and secure enough for real-world deployment. Evidence from various studies indicates that integrating technologies such as IoT and blockchain can help maintain secure and tamper-resistant attendance records [13]. Implementations based on embedded platforms, including the Raspberry Pi, have also demonstrated that cost-effective yet dependable solutions are achievable [1, 38]. Moreover, hybrid configurations - for example, combining BLE with facial recognition - have been shown to improve both system reliability and overall user experience [15].

5.3 Insights into Student Behavior and Engagement

Another important outcome highlighted in the literature is the ability of computer vision techniques to provide meaningful insights into student learning behavior. Deep learning models have been successfully used to detect and measure levels of engagement and attention from video data [28, 47]. Beyond this, automated systems are capable of identifying and categorizing a variety of student behaviors, offering valuable data that can support teaching improvements [49, 55, 56]. Some studies further extend this analysis to capture complex teacher-student interactions, using specialized models designed for this purpose [61]. Overall, these findings point to the growing potential of AI in enhancing classroom management and enabling more personalized learning experiences [30].

5.4 Feasibility and Scalability of Implementations

The reviewed studies collectively indicate that these technologies are both feasible and increasingly scalable. Research based on open-source implementations shows that effective systems can be developed without requiring substantial financial investment [40]. Frameworks such as Flutter have been used to create cross-platform applications, making these solutions accessible across a variety of devices [51, 22]. More recent AI-driven implementations demonstrate consistent effectiveness across different educational environments, ranging from individual classrooms to large academic institutions [10]. The use of web technologies and IoT-based architectures further supports the scalability of these systems at a campus-wide level [7, 8, 56].

5.5 Broader Technological Contributions

In addition to their primary objectives, the reviewed works also contribute to related technological areas. Hand gesture recognition has been shown to support interactive learning and user control effectively [42, 48]. Broader analyses suggest that IoT-based solutions are likely to play a key role in enabling real-time feedback and adaptive learning systems in the future [20]. Advanced AI models, particularly those based on Transformer architectures, have demonstrated promising capabilities in handling complex behavioral detection tasks [54, 12]. Taken together, these contributions highlight how intelligent and automated systems can enhance attendance management while also opening new possibilities for understanding and improving the overall learning process [44].

6. Strengths

The reviewed studies demonstrate several consistent advantages of smart classroom technologies over traditional approaches. In terms of efficiency, facial recognition-based attendance systems greatly reduce administrative burden by handling multiple students simultaneously in real time [14, 2, 31, 60], eliminating manual record-keeping and enabling cost-effective deployment on embedded hardware such as the Raspberry Pi [1, 8, 23].

Regarding accuracy and security, biometric systems - particularly those combining face recognition with RFID or BLE - provide additional verification layers that prevent proxy attendance and reduce human error [16, 52, 4, 13, 15]. Deep learning models maintain strong performance under challenging real-world conditions [59, 34], while blockchain integration ensures tamper-resistant records [13]. Contactless approaches further support hygienic and privacy-conscious environments [27, 17, 3].

Beyond attendance, these systems generate actionable pedagogical insights. Computer vision tools track engagement, detect emotional states, and flag disengaged students, enabling educators to adjust their teaching strategies dynamically [43, 6, 53, 61]. Gesture recognition adds interactive capabilities that enhance student participation [42, 57, 48]. Finally, the use of open-source frameworks (OpenCV, Python), cross-platform tools (Flutter), and IoT architectures makes these solutions scalable from individual classrooms to campus-wide deployments [33, 21, 11, 51, 22, 10, 9].

7. Limitations and Challenges

While the reviewed studies demonstrate notable strengths, they also point to several limitations and ongoing challenges that need further attention. Addressing these concerns is essential for ensuring the practical adoption and long-term success of smart classroom technologies.

7.1 Technical and Environmental Challenges

Real-time processing remains a challenge for many systems, particularly when handling high-resolution video streams and large classroom sizes [60, 33]. Environmental conditions, including poor or inconsistent lighting and the presence of shadows, can negatively affect the accuracy of computer vision models [2, 34]. Occlusion is another common issue, as objects such as glasses, scarves, or even hand movements can obstruct facial features and reduce system effectiveness [6]. Although deep learning methods have improved performance, they often require considerable computational resources, which may limit their use in low-cost or embedded systems [1].

7.2 Security and Privacy Concerns

The use of biometric data, including facial images and iris patterns, introduces important privacy considerations that must be carefully managed through appropriate safeguards and policies [17, 32]. Protecting sensitive student information from breaches or unauthorized access remains a key concern, requiring strong encryption and secure data management practices [13]. Systems are still vulnerable to spoofing attempts, where images or videos are used to mimic real individuals, making the development of reliable anti-spoofing methods essential [27]. Dependence on a single biometric modality can also be limiting, as it may increase the risk of errors or misuse, which is why multi-modal or hybrid approaches are often preferred [4, 3]. Integrating components from different technologies or vendors can introduce additional complexity and may lead to compatibility challenges.

7.3 Scalability and Implementation Issues

Scaling these systems to larger environments, such as entire campuses, brings challenges related to network capacity, data synchronization, and ongoing maintenance [10, 11]. The integration of multiple technologies, especially from different providers, can further complicate system design and deployment [7]. Initial setup and calibration for individual classrooms can require significant time and effort [37, 39]. Even when open-source solutions are available, the technical expertise needed for implementation and maintenance can be a barrier for institutions with limited resources [33].

Table 2: Common Limitations Across Surveyed Studies

Limitation	Occurrence Rate
Dataset Bias	39%
Privacy Concerns	27%
Environmental Issues	22%
Scalability	12%

7.4 Ethical and Social Challenges

Continuous monitoring of students raises ethical concerns, particularly regarding the potential for creating a surveillance-oriented learning environment and its impact on student comfort and autonomy [6, 53]. Bias in AI models is another concern, as it may lead to uneven performance across different demographic groups, emphasizing the need for fairness and inclusivity in system design [49]. Adoption can be hindered if students or educators perceive these systems as intrusive or difficult to use [52]. Maintaining a balance between technological support and the human aspects of teaching remains important, as these systems should complement rather than replace personal interaction [30]. Earlier studies (e.g., 2012-2014) highlight foundational challenges such as algorithm efficiency and system reliability, many of which have guided subsequent research developments [16, 58].

8. Future Directions

The literature points to several key directions for advancing smart classroom technologies. The first priority is deeper integration: future systems should combine IoT-based attendance management, real-time feedback, and LMS integration into unified ecosystems [11, 13, 20, 61]. Multi-modal architectures merging facial recognition, iris biometrics, gesture analysis, and transformer-based behaviour models will improve both reliability and analytical depth [32, 4, 42, 12, 54].

Ethical and privacy challenges must be addressed in parallel. Research should prioritize privacy-preserving computation, stronger anti-spoofing mechanisms, and fairness-aware training to ensure equitable performance across diverse student populations [17, 27, 49, 30]. Transparent deployment guidelines and informed-consent frameworks will be essential for responsible adoption.

On the accessibility front, future systems should offer modular, open-source architectures with user-friendly interfaces suited to institutions with limited technical resources [51, 22, 46, 1, 40, 42, 21, 50, 14]. Finally, the application scope can broaden beyond attendance to include real-time engagement analytics, adaptive content delivery, remote assessment via gesture recognition, and transfer of methods to other identity-verification domains [44, 5, 48, 35, 9, 45, 60, 19, 23].

9. Conclusion

The research on smart classrooms and automated attendance systems reflects a clear transition from traditional, manual approaches toward more intelligent and technology-driven solutions. As highlighted in this survey, the focus of research has gradually evolved - from early work centered on basic face recognition to more advanced systems capable of analyzing student behavior and supporting improved learning experiences [28, 60].

Methodologically, there has been a noticeable shift from classical computer vision techniques such as PCA [31] to more powerful deep learning approaches, including CNNs and Transformer-based models, which enable accurate and real-time processing [21, 54]. These advancements have been complemented by the integration of diverse tools and platforms, ranging from open-source libraries like OpenCV [42, 33] to embedded hardware such as the Raspberry Pi [1]. In addition, the use of mobile and web development frameworks has contributed to the creation of accessible and user-friendly systems [51, 46].

The findings reported across the literature underline the strong potential of these technologies to improve both the efficiency and accuracy of attendance management [23, 8]. At the same time, they offer meaningful insights into student behavior and engagement [53, 49]. Key advantages include improved security, increased reliability, and the ability to reduce administrative workload for educators and institutions [4, 13]. The contactless nature of many of these systems further enhances their practicality by supporting safer classroom environments [27].

However, several challenges remain. Issues related to privacy, ethical considerations, and large-scale deployment continue to require careful attention [17, 10]. Technical limitations, such as sensitivity to environmental conditions and occlusions, also affect system performance in real-world settings [47]. Ongoing research is actively addressing these concerns, indicating a clear direction for future improvements.

Looking ahead, the field is steadily moving toward more integrated and adaptive systems that can respond to pedagogical needs and provide personalized feedback [20]. Continued progress in hybrid technologies, advanced AI models, and user-centered design is expected to further enhance system capabilities and address existing limitations [15, 48, 25]. Overall, the developments reviewed in this survey point toward a more efficient, engaging, and data-driven future for educational environments [30, 5].

Declarations

Consent to Publish: Not applicable.

Competing Interests: The authors declare no competing interests.

Author Contributions: A.P. conceived the study and structured the manuscript. N.P. and K.V. conducted the literature review and compiled datasets. S.K. analyzed methodologies and comparative evaluations. P.A. contributed to writing on IoT integration and future directions. All authors reviewed and approved the final manuscript.

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References

1. Abderraouf T., Wassim A.A., Larabi S., "An Embedded Intelligent System for Attendance Monitoring", arXiv preprint arXiv:2406.13694, 2024.
2. Agrawal A., Sikarwar R., "Face Recognition in Real-Time Environments", International Journal of Computer Science and Information Technologies, 2010, 1 (5), 375-379.
3. Akbar M.S., Sarker A.T., Al Ashray A.M., Uddin J., "Face Recognition and RFID-Based Attendance Verification System", Journal of Innovations in Engineering, Science and Technology, 2018, 3 (1), 30-36.
4. Akbar M.S., Sarker A.T., Al Ashray A.M., Uddin J., "Face Recognition and RFID Verified Attendance System", Proceedings of the International Conference on Computing, Electronics and Communications Engineering (iCCECE), 2018, 47-52.
5. Aly M., "Revolutionizing Online Education via Advanced Facial Expression Recognition", Journal of Educational Technology and Society, 2024, 27 (1), 85-99.
6. Anh B.N., Son N.T., Lam P.T., Chi L.P., Tuan N.H., Dat N.C., Trung N.H., Aftab M.U., Dinh T.V., "Computer-Vision Based Application for Student Behaviour Monitoring in Classroom", International Journal of Advanced Computer Science and Applications, 2019, 10 (5), 276-284.

7. Anusha K., Pooja K.L., Ranjitha S., "Smart Classroom System with IoT", Proceedings of the International Conference on Smart IoT and Education, 2022, 1-6.
8. Band D., Agrawal G., Deo H., Dhengekar V., Dadanje R., Thakare Y., "Smart Attendance Management System (SAMS): Attendance Tracking Process in Educational Institution", International Journal of Computer Applications, 2024, 185 (50), 40-45.
9. Bheemesha K.M., Channabasava N., Basappa D., Suryanarayana G.R., Gowda V., "Human Face Recognition Based Employee Attendance System", International Journal of Engineering and Management Research, 2025, 15 (1), 1-6.
10. Chakravarthi S.P., Karikalan B., Wai S.L.K., "AI-Based Classroom Attendance Management in Higher Education", International Journal of Advanced Computer Science and Applications, 2023, 14 (4), 650-658.
11. Dimitriadou E., Leon C., Blessinger P., Saini N., Goel M., "Smart Classrooms in IoT: Issues, Architecture, and Challenges", Smart Learning Environments, 2023, 10 (1), 1-20.
12. Han L., Zhu W., Chen H., Wang Z., "Dense Student Behaviour Recognition Algorithm for Classroom Surveillance Based on Improved Real-Time Detection Transformer", Frontiers in Artificial Intelligence, 2025, 8, 1-15.
13. Islam A.U., Das S., Deka A., Bharadwaj C., Sarma P., "IoT and Blockchain Based Secure Attendance Monitoring", Indian Journal of Science and Technology, 2024, 17 (23), 2354-2363.
14. Jadhav A., Argade T., Darekar P., Badhe N., Badhe S., "Automated Attendance System Using Face Recognition", International Journal of Creative Research Thoughts (IJCRT), 2025, 13 (3), 1-7.
15. Jain A., "A BLE-Based Smart Attendance System for Scalable and Contactless Classroom Automation", International Journal of Engineering Research and Technology (IJERT), 2025, 14 (7).
16. Jha A., "Class Room Attendance System Using Facial Recognition System", Proceedings of the International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2013, 1781-1785.
17. Ji J., Wang H., Huang Y., Wu J., Xu X., Ding S., Zhang S., Cao L., Ji R., "Privacy-Preserving Face Recognition with Learnable Privacy Budgets in Frequency Domain", Proceedings of the European Conference on Computer Vision (ECCV), 2022, 475-491.
18. Kaiwen D., Yanbin L., "Design of Student Attendance System Using Internet of Things (IoT) Technology", International Journal of Recent Technology and Engineering, 2019, 8 (4), 3823-3829.
19. Kamra G., Divi A.M., Jain H., Maheshwari G., Atif M., Alashetty A., "AI-Based Classroom Monitoring and Attendance System", International Journal of Artificial Intelligence and Education, 2023, 5 (2), 112-120.
20. Khan S., Zhou L., Chen Y., "Future Trends in Smart Classrooms: A Review of IoT Applications in Real-Time Feedback and Adaptive Learning", International Journal of Advanced Research in Science, Communication and Technology, 2025.
21. Krishna K.S., Kumar M.C., Lahari M.S., Sandhya P.S.L., Meghana M.S., Chakraborty S., "Smart Attendance System Using CNN and OpenCV", International Journal of Research Publication and Reviews, 2024, 5 (3), 6217-6222.
22. Kulkarni V., Kokaje S., Shinde P., "Face Recognition in Flutter App Interface for Attendance Management", International Journal of Research in Engineering, Science and Management, 2023, 6 (2), 45-50.

23. Kumar P., Saha S., "Automated Attendance Management System Using Face Recognition", International Journal of Research in Engineering, Science and Management, 2025, 8 (2), 1-6.
24. Kumar V., Bala A., Rana K.S., "Student Attendance Recording System Using Face Recognition with GSM", International Journal of Advanced Research in Computer and Communication Engineering, 2014, 3 (6), 7030-7034.
25. Li X., "The Application of Face Recognition Model Based on MLBP-HOG-G in Smart Classroom", International Journal of Artificial Intelligence and Machine Learning, 2025, 15 (1), 1-12.
26. Mangalgiri V., Naaz Z., Bhuvana A., Shweta A., "AI-Based Smart Attendance Management System", International Journal of Computer Applications, 2025, 186 (31), 1-6.
27. Mangalgiri V., Naaz Z., Bhuvana A., Shweta A., "Smart Classroom Attendance: A Contactless Facial Recognition Approach", International Journal of Advanced Computer Science and Applications, 2025, 16 (2), 1-8.
28. Nezami O.M., Dras M., Hamey L., Richards D., Wan S., Paris C., "Automatic Recognition of Student Engagement Using Deep Learning and Facial Expression", arXiv preprint arXiv:1912.05359, 2019.
29. Nguyen V.D., Khoa H.V., Kieu T.N., Huh E., "Internet of Things-Based Intelligent Attendance System: Framework, Practice Implementation, and Application", Proceedings of the International Conference on Internet of Things, 2022, 1-10.
30. Niculescu A.I., Ehnes J., Yi C., Du J., "On the Development of an AI Performance and Behavioural Measures for Teaching and Classroom Management", EAI Endorsed Transactions on Pervasive Health and Technology, 2025, 11, 1-14.
31. Nithya D., "Automated Class Attendance System Based on Face Recognition Using PCA Algorithm", International Journal of Engineering Research and Technology (IJERT), 2015, 4 (3), 831-834.
32. Okokpujie K., Noma-Osaghae E., Okesola O., John S., Robert O., "Design and Implementation of Student Attendance Using Iris Biometrics", Proceedings of the International Conference on Computational Science and Computational Intelligence (CSCI), 2017, 1-5.
33. Patil M., Jadhav S., "An Automated Approach for Classroom Attendance Using OpenCV", International Journal of Advanced Research in Computer and Communication Engineering, 2024, 13 (2), 220-226.
34. Patil S., Kulkarni M., "Real-Time Attendance Using Discrete Wavelet Transform, DCT and RBF Networks", International Journal of Advanced Research in Computer Science and Software Engineering, 2016, 6 (3).
35. Perera R., "Remote Testing System with Gesture Recognition and Recording", International Journal of Computer Science and Information Security, 2012, 10 (4), 15-20.
36. Qi D., Tan W., Yao Q., Liu J., "YOLO5Face: Why Reinventing a Face Detector", Proceedings of the European Conference on Computer Vision Workshops, 2022, 228-244.
37. Rahsi D.K., Parekh Z., Mohite S., "Face Recognition-Based Lecture Attendance System", International Journal of Engineering Research and Technology (IJERT), 2014, 3 (3), 1289-1292.
38. Raizada T., Sharma A., Amaran S., Sreekumar S., "Embedded Intelligent Attendance System Using Raspberry Pi", Proceedings of the 3rd International Conference on Optimization Techniques in Engineering (ICOFE), 2024, 1-6.

39. Rao A., "AttenFace: A Real-Time Attendance System Using Face Recognition", Proceedings of the IEEE Conference on Information and Communication Technology (CICT), 2022.
40. Sanwariya B., Khan W., "Face-Based Attendance System Utilizing Python and Open-Source Technologies", Proceedings of the International Conference on Smart Computing and Communication, 2025, 1-6.
41. Sayyad S., Dange A., "Face Recognition for Classroom Attendance Based on Convolutional Neural Network", International Journal of Intelligent Systems and Applications in Engineering, 2023, 11 (1), 284-290.
42. Sharma S.N., Rengarajan A., "Hand Gesture Recognition Using Python and OpenCV", International Journal of Trend in Scientific Research and Development (IJTSRD), 2021, 5 (2), 1145-1149.
43. Sinha M., Gupta N., Yadu P., Sahu N., "Automated Attendance and Engagement Monitoring in Smart Classrooms", International Journal of Research Publication and Reviews, 2025, 6 (5), 1-8.
44. Sinha M., Gupta N., Yadu P., Sahu N., "Automated Attendance and Engagement Monitoring System", International Journal of Research Publication and Reviews, 2025, 6 (5), 1-8.
45. Somu N., Raman R., Kirthivasan K., "Learner Engagement in Online Learning Using Machine Learning and Adam Robust Optimization", Neural Computing and Applications, 2024, 36, 1-15.
46. Suresh V., Srinivas G.R., Nagaraj N., "Facial Recognition Attendance System Using Python and Web Technologies", International Journal of Scientific Research in Computer Science, 2023, 8 (5), 1-6.
47. Trabelsi Z., Ben Ayed Y., Daoudi A., "Real-Time Attention Monitoring System for Classroom: A Deep Learning Approach for Student Behaviour Recognition", Big Data and Cognitive Computing, 2023, 7 (1), 1-20.
48. Uchale B.S., Kadu J.S., Hol M.N., Jadhav G.S., Kadam V.D., "Learning System for Mathematics Using Hand Gesture Recognition", International Journal of Advanced Research in Electronics and Communication Engineering, 2025, 14 (1), 1-7.
49. Vaghela J., Jasani J., Bambhaniya A., Dave K., "AI-Driven Automated Analysis of Student Behaviour", Journal of Educational Data Mining, 2025, 17 (1), 1-15.
50. Vishwakarma S., Pathak K.K., "Attendance System Utilizing Face Recognition Technology", International Journal of Computer Applications, 2013, 63 (4), 1-5.
51. Viswanathan J., Kuralamudhan E., Navaneethan S., Veluchamy S., "Face Recognition Application in Flutter", EAI Endorsed Transactions on Smart Cities, 2023, 7 (1).
52. Wande P., Pradhan A., Thakker J., Dongare S., Mane D., "Face Recognition Attendance System Using Flutter App Interface", International Journal of Engineering Research and Applications, 2023, 13 (4), 1-6.
53. Wang X., Wang C., Wu C., "Student Behavior Recognition Model Based on Classroom Video Monitoring", Journal of Intelligent and Fuzzy Systems, 2021, 40 (4), 6773-6784.
54. Wang Z., Wang M., Zeng C., Li L., "Multi-Scale Deformable Transformers for Student Learning Behaviour Detection in Smart Classroom", arXiv preprint arXiv:2410.07834, 2024.
55. Xie J., "Research on Student Behaviour Analysis and Teaching Optimization Based on Artificial Intelligence", International Journal of Emerging Technologies in Learning, 2024, 19 (5), 60-75.

56. Xie W., Peng Q., Chen H., Zhu W., Han L., "SBD-Net: Incorporating Multi-Level Features for an Efficient Detection Network of Student Behaviour in Smart Classrooms", Applied Sciences, 2024, 14 (3), 1-18.
57. Xu P., "A Real-Time Hand Gesture Recognition and Human-Computer Interaction System", Proceedings of the International Conference on Advanced Computing and Communication Systems, 2017, 1-5.
58. Yadav R., Chauhan S., Meenu, Gupta S., "Algorithm for Efficient Attendance Management: Face Recognition Based Approach", International Journal of Innovative Research in Computer Science and Technology (IJIRCST), 2012, 1 (1), 1-5.
59. Zeng W., Meng Q., Li R., "Design of Intelligent Classroom Facial Recognition Based on Deep Learning", International Journal of Recent Technology and Engineering, 2019, 8 (4), 12154-12158.
60. Zhang P., Sun Y., Liu Y., "Real-Time Attention Monitoring System for Classroom Using YOLOv5", Proceedings of the IEEE International Conference on Artificial Intelligence and Computer Applications, 2023, 112-118.
61. Zhou M., Pan W., "A Model for Analyzing the Behaviour of Classroom Teacher-Student Interaction", International Journal of Innovative Computing, Information and Control, 2023, 19 (2), 467-480.