

Which method of attendance-taking is superior? A systematic review of class attendance monitoring systems

Charles Tochukwu **Orjiakor**¹, Chijioke K. **Ayogu**¹, Chijioke Jonathan **Olelewe**²,
Edward **Anoliefo**³, Emmanuel Onwuka **Ibam**⁴, Kalu T. U. **Ogba**¹, Chiemezie **Atama**⁵,
Damian C. **Ugwu**¹, Ngozi Justina **Igwe**⁶, Christian Basil **Omeh**², Chiugo C. **Kanu**⁷,
Hassan S. **Abu**⁸ & *Ike E. **Onyishi**¹

University of Nigeria, Nsukka

¹Department of Psychology, ²Department of Computer & Robotics Education,

³Department of Electronic Engineering ⁵Department of Sociology & Anthropology,

⁶Department of Adult Education, University of Nigeria, ⁷Department of Business
Education,

Federal University of Technology, Akure

⁴Department of Information Systems,

⁸Police Academy, Wudil, Kano, Nigeria

* Corresponding author: ernest.onyishi@unn.edu.ng

Abstract

Ensuring student attendance in higher education is important for wider academic performance. Many electronic attendance systems (EAS) which monitor and improve students' attendance have emerged lately. However, it remains unclear which TAASs yields better outcomes than traditional manual attendance systems or how TAASs compare against each other (e.g. fingerprint based TAAS vs face recognition TAAS). This systematic review examines the effectiveness of different TAASs compared against each other or to manual attendance systems. Articles were systematically retrieved using Boolean operators, and findings were extracted through the use of a grid format. From

a trawl of articles, a total of twenty-two papers were found to have utilised comparative measures. Hence, they were reviewed in depth to identify the utility and deficiencies of technologies and also how they perform compared to others. We found that TAASs typically outperformed manual attendance systems, however there was no clear superiority amongst the different types of TAASs as each technology presents peculiar advantages and shortfalls. Although variant technologies have been utilized in studies on TAASs in higher education, water-tight comparative studies were scarce, which meant that it was difficult to assess which specific technology was superior. The strengths and weaknesses of the variant technologies were examined and presented. Therefore, the researcher recommends that studies on TAASs should be more critical and adopt higher comparative standards in studying the utility of TAASs.

Keywords: Technology Assisted Attendance Systems (TAAS), biometrics, higher education, class attendance, systematic review, comparative study

Introduction

In higher education, class attendance is one important criterion for ensuring active learner engagement in the learning process and improving academic success (Bijsmans & Schakel, 2018; Büchele, 2021; Lu & Cutumisu, 2022). In recognizing the importance of class attendance in higher education, many institutions require attendance rates as high as 80 percent as a prerequisite to satisfactorily complete a session (Noh, et al., 2019). The conventional wisdom is that poor student lecture attendance is expected to translate to poorer academic engagement and performance. In many

settings, especially where there are many students, traditional attendance taking often uses manual methods of managing students' attendance which is often cumbersome (Adesoba & Joseph, 2024), time-consuming, and could undermine institutional objectives (Nurhakim et al., 2024). Some of the major drawbacks of the use of the manual attendance monitoring system include labour intensiveness, time constraints, and inaccuracy data due to human errors and distractions (Bowen, et al., 2005). Other disadvantages of manual paper method of managing students' attendance include students not signing in at all or

signing in another student, unreadable signatures, and poor data management (Hingorani et al., 2013). Thus the need for automating attendance systems is recognised.

Technology Assisted Attendance Systems (TAASs) refer to the use of technology-based solutions such as biometric verification, radio frequency identification (RFID) devices, barcode scanning, or mobile applications. A typical electronic or information technology or automated attendance consists of a biometric attendance marking system, an electronic storage, and/or a transmission system. Generally, technology-based attendance monitoring systems are often less susceptible to manipulation by students (Newman-Ford, et al., 2008). The biometric attendance marking system relies on the use of a biological or behavioural trait of a person to authenticate an individual. Common biological/behavioural traits used include face recognition, retina recognition, iris recognition, fingerprint recognition, among others (Batista et al., 2021). One significant advantage of biometric based attendance system is that it reduces the possibility of attendance fraud, as it often takes attendance using each individual's unique biometric characteristics (Ahmed et al., 2023). Using electronic

transmission technologies such as Wireless Fidelity (WiFi), low range (LoRa), Bluetooth, and Zigbee, among others to transmit attendance records reduces the cumbersomeness associated with the traditional method of attendance-taking (Akinduyite et al., 2013).

Interestingly, TAAS are often evaluated with regard to their ease of operation, minimization of human intervention, time, security of the attendance records, management and accuracy (Sittamparam & Ratnarajah, 2019). Several TAASs have their different strengths and weaknesses (see Singh, *et. al.*, 2020), but are always projected to have advantages over traditional manual-based attendance monitoring systems. But the magnitude and quality of these advantages, and which systems are more advantageous compared to others is not well researched. Understanding how TAASs compare to each other or indeed to manual attendance mechanisms is essential for informed adoption in educational institutions. While numerous studies examine TAASs individually, typically in comparison to manual systems of attendance monitoring, aggregate studies evaluating these comparisons are scarce. This study aims to conduct a systematic review of studies that have adopted comparative measures

to evaluate the effectiveness of attendance monitoring systems for students worldwide to bridge this gap.

Method

Inclusion criteria

Participants/population

This review focused on the students' population in tertiary academic settings. We specifically focused on literature that described the use of any electronic medium to monitor the attendance of students

Interventions or exposures of interest

The current review attempted to identify comparative studies that looked at how different types of attendance systems performed in attendance/academic outcomes. We looked out for studies that compared one TAAS with another TAAS (e.g, fingerprint attendance systems vs facial recognition technology). We also investigated the comparative studies that looked at TAAS compared to manual attendance taking systems.

Phenomenon of interest

Our phenomenon of interest was specifically attendance-related changes (e.g. reduction of time taken to conduct

attendance, increment in the number of students attending classes) and other academic related outcomes such as academic performance.

Search strategy

Four researchers systematically scouted and retrieved studies from online databases using Structured Boolean operators designed to capture information on electronic and biometric attendance systems. Databases searched included Google, Google Scholar, HINARI, PubMed, and ResearchGate. Topics from journal articles and grey literature were initially scanned for relevant topics, then abstracts were thoroughly read for relevance. Papers adjudged to be relevant based on the inclusion criteria stated above (comparative studies comparing at least one technology based attendance system to another system, focused on tertiary education, published between 2010 and 2021) were then fully read and information extracted. Information was extracted based on the type of technology used, the key benefits, and the challenges experienced. Hence, articles included in the review are published in English or at least have an English version from 2010–2021. The timeframe of 2010–2021 was chosen to capture advancements in TAAS technologies over the last decade while

ensuring relevance to current educational settings. Many studies were also reported in conference proceedings.

Study selection

Screening titles and abstracts helped us to eliminate studies that were not related to our interest. It helped us especially to isolate studies that used electronic attendance to monitor staff in work settings. We then read the remaining articles thoroughly to identify studies that had specific and measurable outcomes (e.g. attendance) and at least compared two methods of monitoring attendance.

Critical appraisal for quality

Efforts were made to identify and remove journal articles published in predatory journals by following the recommendations of Rice, *et. al.* (2021) in dealing with poor quality articles in systematic reviews. We screened articles from open access (OA) journals to ensure that they were registered with DOAJ. We specifically selected studies that used tables, graphs, or other statistical tests of comparison to depict the differences between different measures of attendance in relation to specific outcomes. A total of 538 articles were initially retrieved. After removing duplicates and non-relevant studies, 89

articles were fully reviewed, and 22 met the inclusion criteria for final analysis.

Data extraction

We used a Microsoft Excel template designed by the researchers to extract information from the studies reviewed. The template was designed to identify the key methodology used in the study (e.g. experimental, survey, research and development), the specific technology used or compared, the continent and country where the study was conducted, and the strengths and weaknesses reported in studies.

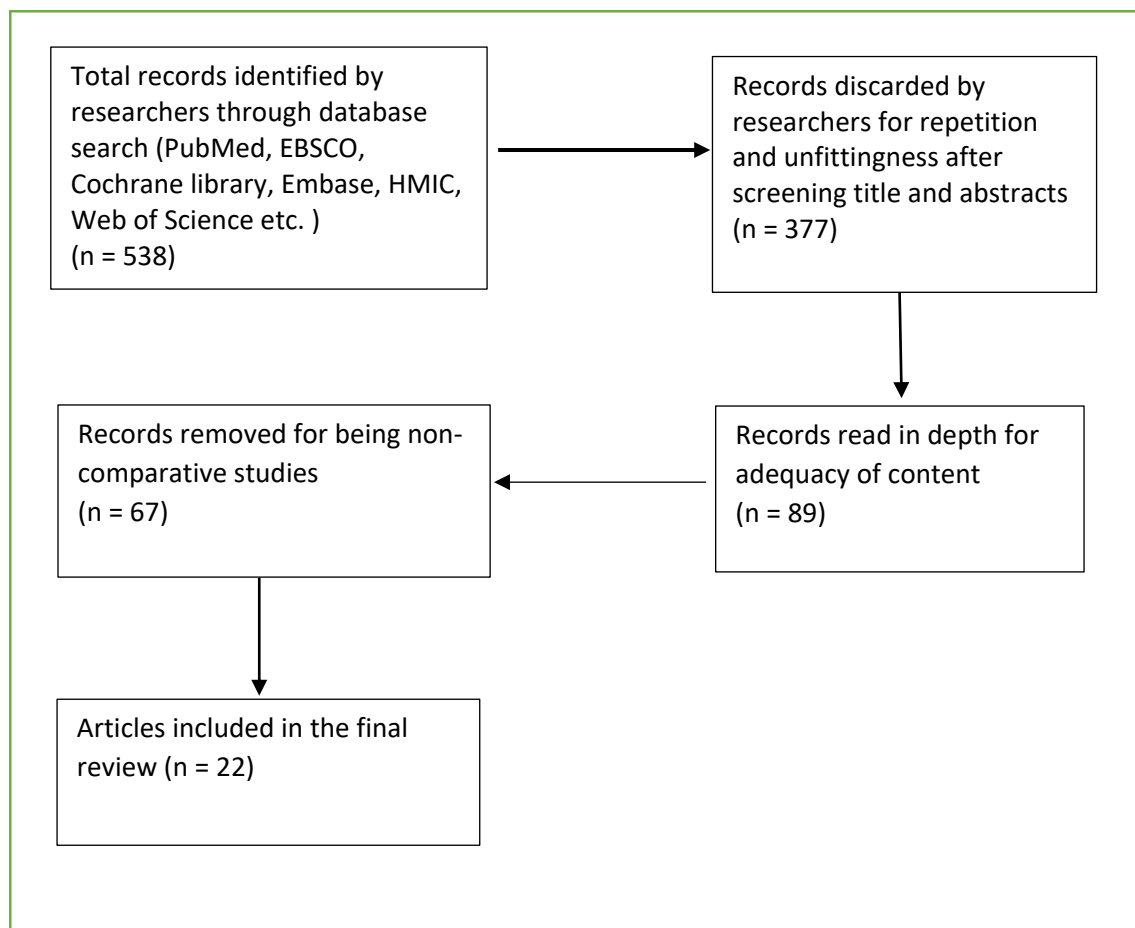
Data synthesis

To ensure a robust and exhaustive retrieval of literature of interest, each of the four researchers worked independently using the Boolean operators to retrieve articles across the databases. The researchers then extracted the key information from the articles using the Microsoft Excel template. After 2 months of sourcing article and after each scouter had reported saturation, we held 2 research meetings to merge the findings (contained in the Excel templates) into one document. We then sieved through for repetitions which we merged. Several other research meetings were held to judge the adequacy of each article in the pool of retrieved documents.

We kept independent records of the number of articles retrieved, and how many were removed for specific reasons (e.g. methodology flaw, inadequate focus

on students, non-comparative). We then advanced a narrative from the findings focusing on the themes of interest in this review as shown in Figure

Figure 1: Flowchart of the systematic review



Findings

Although numerous studies have looked at diverse TAASs to monitor students' attendance in tertiary academic settings, comparative studies are not plentiful. We did not see any randomized control trial. Many studies that were described as experimental by their authors turned out to be a detailed description of the development process of an electronic attendance monitoring device, and at most sketchy information regarding its success in attendance taking (e.g. Shoewu & Idowu, 2012; Trabelsi & Shuaib, 2011). Thus, the 22 articles that were reviewed typically featured the design and testing of diverse TAAS (e.g. Abdulkadhim, 2021; Akor et al., 2019; Ikumola, 2015). These articles featured studies from almost all continents of the globe, albeit, Asia and Africa were dominantly represented in the studies reviewed. This may depict contexts where there are large number of students in classes and often scarce resources to support academic/administrative processes, leading to complex challenges. Interestingly, none of the studies reviewed were from the American continent. Most of the articles reviewed were in the recent past (within the last 5 years of conducting the review),

indicating that attendance problems and solutions are contemporary concerns. The tones of the articles were examined to weigh the benefits in using specific electronic attendance monitoring mechanisms.

Reported technologies used

A wide range of technologies were used in studies that were reviewed. They included: fingerprint recognition devices (Khan et al., 2020; Shoewu et al., 2018), facial recognition technology (Budi, et al, 2018; Karthikeyan, et al. 2019), barcode scanner technology that utilized student cards (Dewa & Nyanga, 2020), iris readers (Trabelsi & Shuaib, 2011), mobile (smart phone) applications (Ahmed, et al., 2020), bluetooth low energy (BLE) (Beacon-Based Electronic Attendance System) (Puckdeevongs, et al. 2020), and global positioning systems (GPS) (Singh, et al., 2020). Nonetheless fingerprint technology was the most common technology deployed to monitor attendance electronically across the studies as 50% of the studies were noted to have used it. The summary of the key comparative findings is presented in

Table 1: Summary of comparative findings

	Studies	Key comparative findings	Key advantages	Key weaknesses
Fingerprint technology	Abdulkadhim, 2021; Akor, et al., 2019; Ikumola, 2015; Khan, et al., 2020; Singh et al., 2020; Sittampalam & Ratnarajah, 2019; Shoewu & Idowu, 2012; Shoewu et al., 2018; Trabelsi & Shuaib, 2011; Wale & Patil, 2014;	<p>Lower rate of absenteeism (including source)</p> <p>Fingerprinting takes less time compared to the iris scanning technology (Trabelsi & Shuaib, 2011)</p> <p>Time: The automated attendance system used 10 minutes less time compared to the traditional attendance system. (Sittampalam & Ratnarajah, 2019)</p> <p>Reduces reliance on stationary materials (Singh et al., 2020)</p> <p>Time: Takes lesser time for the electronic attendance system compared</p>	<p>High secureness, difficult to fake (Akor et al., 2019)</p> <p>Less involvement of staff personnel in attendance taking (Khan et al., 2020),</p> <p>Prevents impersonation (Shoewu & Idowu, 2012)</p> <p>Captures other details such as the time when the student arrives at class (Trabelsi & Shuaib, 2011)</p> <p>Reliable and user-friendly (Abdulkadhim, 2021)</p> <p>User-friendly, flexible, less human/labour involvement,</p>	<p>Takes time for students to scan their fingerprints especially when the class is large (Akor et al., 2019)</p> <p>Students may have problems with fingerprinting when their fingers are not recognized immediately (Khan et al., 2020)</p>

		to the manual methods (Ikumola, 2015)	highly secure, cheaper and applicability to a large set of students (Sittampalam & Ratnarajah, 2019) Reduces the time taken to decipher attendance exam eligibility requirements (Singh et al., 2020) Secure, fast and reliable (Wale & Patil, 2014) Short execution time (Shoewu et al., 2018)	
Facial recognition technology	Budi, 201; Chowdhury et al., 2019; Son et al., 2019; Karthikeyan et al., 2019	Time: Image-taking technology took less time to complete attendance compared to manual systems (roll call and signing of attendance	Avoids proxy attendance taking and lesser time in taking attendance as tutors and students have to do less	Expensive to install per unit, (Chowdhury et al., 2019) The tutor is required to take multiple pictures of the class to ensure the

		sheets) (Budi, 2018)	(Chowdhury et al., 2019) Able to apply quickly to a large number of students (Son et al., 2019)	effectiveness of the technology (Budi, 2018) Lighting, mood differences in training and real deployment of equipment and position of the student may decrease the effectiveness of facial recognition (Karthikeyan et al., 2019)
Barcode scanning systems	Dewa & Nyanga, 2020.		Cheap and easy to implement and eco-friendly (Dewa & Nyanga, 2020)	Easily compromised-students can make use of other student's cards (Dewa & Nyanga, 2020) If the students forget their cards, there is no alternative to take attendance (Dewa & Nyanga, 2020)
Bluetooth enabled systems	Puckdeevongs, et al., 2020.	The use of a combination of multilayer perceptron (MLP)	Achieve attendance monitoring goals with	Attendance not taken in real time, students must have

		and radial basics function (RBF) was significantly better in picking student Bluetooth device positions than using MLP. Thus MLP + RBF means better attendance accuracy and lower error rates (Puckdeevongs, et al., 2020)	reduced costs as many students have Bluetooth-enabled devices.	Bluetooth-enabled devices.
Iris scanning technology	Trabelsi & Shuaib, 2011.	Drop in student absenteeism (Trabelsi & Shuaib, 2011). Iris scanners are more expensive compared to fingerprint setups. Iris scanning was considered more intrusive compared to fingerprinting	Prevents students impersonation (Trabelsi & Shuaib, 2011)	Iris scanning was more expensive and considered more intrusive and less easy to use
Mobile application attendance systems	Ahmad et al., 2020, Rahim, et al., 2017	Attendance: Attendance rate improved amongst students monitored with a mobile attendance monitoring system compared to those	Used to prompt students and guardians about student absence (Ahmad, et al., 2020)	None indicated

		<p>monitored with manual attendance (t = 11.85). (Ahmad, et al., 2020)</p> <p>Exam scores: Exam scores improved for students monitored with the mobile attendance system compared to those manually monitored (Ahmad et al., 2020)</p> <p>Time: Automated electronic system can send absenteeism information in 1 second compared to traditional systems which takes 1,800 seconds (Rahim et al., 2017)</p> <p>Cost: An automated system is reported to be 16 times cheaper than using a postal system to send absenteeism</p>		
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		warnings (Rahim et al., 2017)		
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Generally, the deployment of technologies in monitoring student attendance was described across the reviewed literature, as beneficial. Time savings was the most commonly reported outcome across studies. TAASs were consistently reported to have outperformed manual systems as technologies often required less time to complete attendance taking tasks (Trabelisi & Shuaib, 2011). More so, the percentage accuracy of the electronic attendance recording systems was reported to be high, mostly in the 90s percent (Abdulkadhim, 2021; Banpali, et. al., 2019; Chowdhury, et. al., 2019). Studies also reported that TAASs were cheap and easy to use (Elkasari, et. al., 2021; Rahim, et al., 2017). One study that monitored attendance using mobile phone application reported better academic performance for students monitored with an EAS compared to students who were monitored with manual/traditional mechanisms (Ahmad, et. al., 2020). The only study found to have compared two TAASs reported that

fingerprinting technology was preferred over iris scanning (Trabelisi & Shuaib, 2011). Overall, these studies share a consensus that TAASs monitoring of student attendance in higher education settings were superior to manual attendance taking. Although most studies tended to report these better performances of TAASs, only one study (i.e. Ahmad, et al, 2020) reported a statistically significant difference between an electronic monitoring attendance medium and manual attendance system.

Other key advantages

Benefits reported in using technologies compared to manual attendance records included being more reliable/accurate (Abdulkadhim, 2021; Chowdhury, et al., 2019), cost-effectiveness/affordability (Akor, et. al., 2019; Sittampalam & Ratnarajah, 2019), being secure, efficient and user friendly (Sittampalam & Ratnarajah, 2019). TAAS was also reported to be utilized in sending alerts to students and their guardians if they

begin to fall short of attendance requirements (Rahim, et. al., 2017). Sensofacial recognition technologies were reported to have the flexibility and also feasibility of applying on a large scale (Son et al., 2019).

Specific advantages and disadvantages of specific technologies

Given the uniqueness of fingerprints, fingerprinting technology in electronic attendance monitoring was lauded to be very secure and difficult to fake (Akor, et. al., 2019), and was considered reliable and user-friendly (Abdulkadhim, 2021). Finger printing arrangements were also considered cheap to install and use (Sittampalam & Ratnarajah, 2019). However fingerprinting technologies were noted to pose challenges when the class size is large as only one person is captured at a time (Ali, et al., 2020).

Facial recognition technologies remarkably took shorter time and lesser stress on class tutors and students as it often required an installed system to map faces, or take pictures and identify students who were present. However, its flaws include the high cost of the technology (Chowdhury et al., 2019) and factors such as student mood, lighting, and student positioning limit the ability

of the technology to effectively perform attendance taking functions (Karthikeyan et al. 2019). Although barcode technologies are lauded as being cheap and easy to use, they were also reported to be easily compromised as students could use others' cards to fake attendance (Dewa & Nyanga, 2020). Also, when students are not with their identity cards (ID), attendance using barcode scanning technologies is impossible thus denying the students the opportunity to register their attendance.

Bluetooth technologies have the advantage of being cheap to utilize as many students have access to Bluetooth enabled devices. However, when students do not have these devices, attendance taking is impeded (Puckdeevongs, et. al., 2020). Also, attendance is not taken in real time and the technology may be prone to faking as students holding other students' devices could indicate 'fake' presence.

Although iris scanning technologies have similar strengths with fingerprinting in terms of authenticity and indeed were lauded to have helped to reduce absenteeism (Trabelsi & Shuaib, 2011), users considered it a bit more burdensome and intrusive to use compared to fingerprint technologies

(Trabelsi & Shuaib, 2011). Lastly TAASs that utilize mobile applications had the advantage of lowered cost given that most students have access to smart phones. Also prompts/alerts could easily be generated and sent to students and their guardians when attendance is noticed to be on the decline (Ahmad, et. al., 2020). Few false rejections which were blamed on poor finger placement were also reported in a study that utilized fingerprint devices to monitor attendance (Shoewu, et. al., 2015). Sometimes there are instances where candidates' biometric details are not immediately identified (Khan et al., 2018). Some studies were reported to have been conducted in a laboratory setting rather than a real-life situation (Banepali et al., 2019, Miao, et. al., 2020). Sometimes readers may fail to read the cards. Kim et al. (2018) reported security challenges in using the Bluetooth low-energy system to monitor attendance. Proxy attendance fraud may be possible when students swap card when the barcode identification card systems are used (El-Salhi, et. al., 2019; Rjeib, et. al., 2018).

All of the TAASs have avoided the drawbacks of traditional ones such as being eco-friendly and ignoring the requirement for stationary materials and personnel for keeping records. These

TAASs were reported to be reliable, acceptable, efficient, affordable, user-friendly and secure. Using TAASs generally prevents issues such as damage or total loss of attendance sheets; it also makes analyzing student attendance records from time to time easier. The biometric attendance systems are reported to have the strength of preventing impersonation and buddy-signing (Budi, 2018; Shoewu et al., 2012).

Discussion

We systematically reviewed the literature on technology assisted attendance systems to identify quality studies that have comparatively examined the strengths and weaknesses of the different electronic monitoring attendance mechanisms. The perceptible evidence from the studies reviewed leaves little doubt that electronic or technology assisted attendance systems are helpful in monitoring students' attendance. More so, the diverse technologies—fingerprinting, iris scanning, bar code card readers, mobile app technologies etc., were reported to be gainful, at least in comparison to manual methods of attendance taking, albeit, each has peculiar flaws. The direction of evidence suggests that TAASs are indeed helpful in improving the attendance of students in higher education setting. However,

studies often fail to identify why these technologies improve attendance. Indeed, it may be that TAASs provides a more water-tight way of monitoring attendance and that poor attendance records could come with costlier sanctions such as forfeiting exams. This was however not clear across the studies reviewed. Studies were typically focused on demonstrating the practicality of each technology in taking attendance. Future studies could indeed examine why each TAAS is effective in improving student attendance.

The commonness of fingerprint methods amongst the TAASs possibly suggests its popularity, and possibly practicality, and wider acceptability of the technology. However, fingerprint scanners may be impacted by the recent COVID-19 crises that discourage contact with surfaces. Other contactless electronic media used for taking attendance such as facial recognition, Bluetooth-enabled technology and mobile phone applications may be preferred as they avoid physical contact that could mediate the transfer of pathogens in high-risk places such as institutions of learning.

TAASs were typically lauded across reviewed studies as time-saving and are even able to drive improvement in

attendance of students. Nonetheless, Trabelsi and Shuaib's (2011) study draws attention to the need to boost security and firewalls around it to secure the details of individuals as such settings are attractive to hackers. It is important to point out that only one study (i.e. Trabelsi & Shuaib, 2011) paid attention to the risk of hacking. TAASs developers must be sensitive to such risks and accommodate measures to secure the data of users from unauthorized persons. Approaches to evaluating information security risks should be accommodated in studies that test the effectiveness of TAASs.

Maintaining electronic attendance systems may be challenging, especially in low resource settings (Saheed, et. al., 2016) as the costs of installing devices are high (Tasleem, 2020). Moreso almost all TAASs require training of staff and students to use the devices- a situation that is not associated with the manual attendance taking methods. Expanded and robust research into TAAS will widen the understanding and deepen insights into the relative cost-benefit potentials of each technology. Other challenges include that face recognition technologies are sensitive to changes in lightening and the distance between the face and camera, lighting, the position of the student, the difference in the mood

of the student's expression while training and real-time and such issues may lead to errors in detection. Also while face recognition technologies in attendance monitoring attract higher costs, RFID card reader technologies sometimes fail to read student identity cards. Fingerprint systems could face situations with variable changes that could weaken efficiency such as a student's finger not being recognized instantaneously due to physical injuries (e.g. burns). It is also worth noting that in some of the studies, systems were not tested at remote locations where there is weak signal strength, as the experimentation was limited to laboratory setting, and in most cases with few participants. These raise the issue of generalizability.

Although there are numerous studies reporting the use, and indeed benefits of utilizing technology assisted devices to monitor attendance, we noted that methodological concerns on how comparative studies were conducted were rife across studies. Sifting down to 22 studies from the originally over 300 information sources that were focused on TAAS in tertiary education settings was rather surprising to us. Moreover, only one study was found to use null-hypothesis testing to examine the effect of deploying a TAAS. Studies examining

the usefulness of TAAS need to step up evaluations using more robust experimental designs and possibly statistical approaches in making comparisons.

Conclusion

This systematic review provides a comprehensive evaluation of the effectiveness of various Technology-Assisted Attendance Systems (TAASs) in higher education. The findings affirm that TAASs offer significant advantages over traditional manual attendance systems, primarily in terms of accuracy, efficiency, and fraud prevention. However, a critical analysis of the reviewed literature highlights several key gaps that have to be addressed to advance this field.

One of the primary contributions of this review is the identification of methodological weaknesses in existing comparative studies on Technology-Assisted Attendance Systems (TAASs). While many studies confirm the advantages of TAASs over manual attendance systems, most fail to establish robust experimental designs or utilize rigorous statistical analyses. This limitation raises concerns about the generalizability and reliability of findings, emphasizing the need for improved research methodologies in this field.

Several studies investigating TAASs rely on descriptive or quasi-experimental designs without implementing rigorous control mechanisms (e.g., Ahmed et al., 2020; Shoewu & Idowu, 2012). The absence of randomized controlled trials (RCTs) limits the ability to draw causal inferences regarding the effectiveness of different attendance monitoring systems.

Furthermore, most studies do not apply regression analysis, effect size estimation, or longitudinal data tracking, which are essential for understanding the long-term impact of TAASs on student engagement and learning outcomes (Chowdhury et al., 2019). The lack of diverse study samples further restricts the generalizability of findings. Many studies focus on single-institution case studies or small sample sizes, limiting their applicability to broader educational settings (Rahim et al., 2017). Studies conducted in controlled laboratory environments may not accurately reflect real-world classroom conditions, where factors such as lighting, network stability, and student behavior can influence TAAS effectiveness (Banepali et al., 2019). Without replication across multiple institutions and varied settings, the reliability of existing research remains questionable. To address these methodological gaps, future research

should prioritize the use of RCTs to compare the efficacy of different TAASs. Studies should also incorporate mixed-methods approaches, integrating qualitative data to explore student and instructor experiences alongside quantitative performance metrics (Newman-Ford et al., 2008). Furthermore, employing advanced statistical techniques such as multivariate regression and structural equation modeling can enhance the depth of analysis and provide more nuanced insights into the relationship between TAAS adoption and academic outcomes. By adopting more rigorous comparative frameworks, researchers can provide stronger evidence to guide educational institutions in selecting the most effective TAASs. Ensuring methodological rigor will not only improve the reliability of the findings but also contribute to the broader discourse on technology integration in higher education.

Beyond methodological concerns, another crucial but underexplored area in TAAS research is its economic viability. Many studies highlight the efficiency of Technology-Assisted Attendance Systems (TAASs) in improving attendance tracking, but there is a significant gap in the literature regarding their economic implications. Cost-benefit analyses,

which evaluate both the financial investment required and the long-term advantages of TAAS adoption, remain largely underexplored. Given the growing reliance on digital attendance systems, understanding the financial trade-offs associated with different TAASs is critical, especially for institutions in resource-constrained settings. Implementing TAASs involves several cost components, including initial investment, operational costs, and maintenance expenses. Studies indicate that while biometric attendance systems such as fingerprint and facial recognition offer higher accuracy and security, they also demand greater financial investment for hardware, software, and periodic system updates (Akor et al., 2019; Rahim et al., 2017). For example, fingerprint scanning systems require biometric readers and database management infrastructure, which can be costly to procure and maintain (Khan et al., 2020). Facial recognition systems, though efficient and contactless, often require high-resolution cameras and advanced image processing algorithms, making them more expensive compared to other TAASs (Chowdhury et al., 2019). Another overlooked aspect in the literature is the long-term sustainability of TAASs. Institutions adopting TAASs must consider recurring expenses such as software licensing, data storage, system

upgrades, and technical support (Shoewu & Idowu, 2012). The lack of comprehensive economic evaluations limits institutional decision-makers from selecting the most cost-effective system for their needs. Future research should integrate financial models such as return on investment (ROI) calculations, cost-effectiveness analysis (CEA), and total cost of ownership (TCO) assessments to provide clearer insights into the long-term viability of different TAASs. A systematic economic evaluation of TAASs is necessary to guide policymakers and educational institutions in making informed investment decisions. Without clear cost-benefit analyses, institutions risk adopting systems that may be technologically efficient but financially unsustainable. Future research should address these gaps by systematically evaluating the economic trade-offs of various TAASs, ensuring that both financial and operational feasibility are taken into account.

While financial considerations are critical, ensuring the security of TAASs is equally important. One of the key insights from this review is the necessity for improved security measures in Technology-Assisted Attendance Systems (TAASs). While electronic attendance systems help mitigate fraud associated

with manual methods, they introduce new challenges related to cybersecurity. Risks such as data breaches, unauthorized access, and system hacking pose significant threats to the integrity and confidentiality of attendance records. Despite these concerns, security risks are largely underexplored in the existing literature, with only a handful of studies addressing them directly (Trabelsi & Shuaib, 2011). Given the increasing reliance on digital technologies in educational settings, future research and system development must prioritize cybersecurity to ensure the safe deployment of TAASs. Several studies highlight the vulnerabilities of TAASs, particularly in terms of data privacy and system integrity (Dewa & Nyanga, 2020; Trabelsi & Shuaib, 2011). Future studies should focus on evaluating the effectiveness of different security mechanisms in preventing attendance fraud and data breaches. Additionally, developing artificial intelligence-powered intrusion detection systems for TAASs can enhance real-time threat monitoring and response capabilities. As educational institutions continue transitioning toward digital attendance monitoring, ensuring the security of these systems must be a top priority. Addressing cybersecurity challenges will not only protect sensitive

student data but also foster trust in the adoption of TAASs.

The review reveals that fingerprint-based TAASs dominate the field, largely due to their established reliability, affordability, and ease of use (Akor et al., 2019). These systems rely on unique biometric features, making them highly resistant to fraud such as proxy attendance (Shoewu & Idowu, 2012). Studies have shown that fingerprint recognition achieves an accuracy rate above 95%, making it one of the most reliable forms of biometric authentication for attendance tracking (Abdulkadhim, 2021). However, with the emergence of contactless technologies such as facial recognition and Bluetooth-enabled attendance systems, institutions are increasingly considering alternative methods that minimize physical contact. The COVID-19 pandemic has further highlighted the need for non-contact solutions to reduce the risk of disease transmission, yet research on these alternatives remains relatively limited. As educational institutions navigate this shift, a balanced approach considering cost, effectiveness, and user acceptability is necessary.

This review offers a nuanced perspective on the impact of Technology-Assisted Attendance Systems (TAASs) on student

engagement and academic performance. While numerous studies indicate that TAASs improve attendance rates, the mechanisms underlying this improvement remain unclear. It is uncertain whether these systems enhance genuine student engagement or merely enforce compliance through stricter monitoring. This raises the question of whether TAASs encourage meaningful learning or merely ensure that students are physically present without active participation. From a psychological standpoint, extrinsic motivation—in the form of enforced attendance policies—may increase compliance but does not necessarily foster deeper academic engagement. Self-determination theory suggests that students who feel coerced into attending classes may not experience enhanced intrinsic motivation or academic interest (Deci & Ryan, 2000). Conversely, students who perceive attendance tracking as a supportive tool rather than a punitive measure may engage more actively in their learning (Pinter et al., 2020). Behavioral research also highlights the role of habit formation in academic participation and learning outcomes

(David et al., 2024). TAASs that integrate positive reinforcement, such as attendance-based incentives or gamified learning experiences, may promote better engagement compared to rigid enforcement mechanisms (Pinter et al., 2020). Future research should explore the psychological and behavioral dimensions of attendance monitoring to ensure that technological interventions foster meaningful participation rather than passive adherence.

In conclusion, while TAASs present clear advantages over manual attendance systems, this review highlights critical areas requiring further exploration. More rigorous comparative studies, cost-benefit analyses, security assessments, and investigations into non-contact technologies are necessary to optimize TAASs in higher education contexts. Institutions should make evidence-based decisions that consider efficient, ethical, financial, and pedagogical implications. By addressing these gaps, future research and practice can move towards more effective, secure, and equitable attendance monitoring solutions.

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ORCID

Ike E. Onyishi: Orcid number: <https://orcid.org/0000-0003-0908-6413>

Charles T. Orjiakor: Orcid number: <https://orcid.org/0000-0001-5379-8915>

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