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TECH-CLASS: A Geofencing-Driven Attendance Management System for Higher Education

Ainul Azila Che Fauzi[1]*, Nur Ruzana[2], Asiah Mat[3], Noor Ashafiqa[4] and Auni Fauzi[5]

[1,2,3,4] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Kelantan, Bukit Ilmu, Machang, Kelantan, Malaysia
[5]Candy Muse Group Sdn Bhd, Tampin, Negeri Sembilan, Malaysia

Authors' email: ainulazila@uitm.edu.my⋆, 2022887548@student.uitm.edu.my, asiahmat@uitm.edu.my, 2025384141@student.uitm.edu.my and ainulauni@gmail.com

*Corresponding author

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Abstract: Reliable and verifiable attendance monitoring continues to be a significant difficulty in higher education, as traditional manual and digital solutions are susceptible to fraudulent attendance and administrative inefficiencies. This study introduces TECH-CLASS, a geofencing mobile attendance system that automates the validation of physical presence through location-aware triggers. The system, developed with Android Studio, Google's Geofencing API, and Firebase Realtime Database, underwent evaluation via functional testing and a System Usability Scale (SUS) assessment with 50 students at UiTM Machang. The results indicate a SUS score of 95.2 and a complete correspondence of 100% between geofence-triggered detection and verified in-class presence. The system's innovation is attributed to its adaptive geofence setup, integration of academic-specific workflows, and real-time synchronisation, which are absent in current institutional or prototype solutions. Recognised constraints encompass indoor GPS inconsistency, exclusive Android compatibility, and reliance on stable connectivity. TECH-CLASS exhibits significant potential as a scalable attendance verification solution, with next studies aimed at cross-platform compatibility and improved indoor positioning precision.

Keywords: Attendance system, Geofencing, GPS, Location-Based Service

1 Introduction

Attendance is a critical metric in higher education, functioning not only as a record of presence but also as an indicator of academic engagement and performance [1]. Numerous studies show a strong correlation between class attendance and academic achievement, prompting institutions to prioritize accurate, transparent, and efficient attendance mechanisms [2]. However, despite the importance of attendance, many Malaysian universities including UiTM continue to rely on outdated processes that introduce inefficiencies and compromise data integrity.

Manual attendance practices, such as signature sheets and instructor-led roll calls, are labor-intensive and prone to manipulation. Proxy attendance, inaccurate record entries, and processing delays collectively undermine data reliability and significantly increase administrative workload [3]. Even when universities adopt digital attendance platforms, such as UiTM's u-Future, practical issues persist. Students frequently report login failures, slow server responses, and the ability to mark attendance remotely, highlighting the absence of physical verification mechanisms [4]. Biometric technologies, such as fingerprint and facial recognition systems, offer improved accuracy but are impractical for campus environments with multiple buildings, numerous classroom changes, and large student populations [5]. They require substantial hardware investment, regular calibration, and maintenance, rendering them impractical for large, mobile learning environments.

The rapid development of mobile technologies and location-based services (LBS) introduces new opportunities to modernize attendance tracking. Geofencing enables the creation of virtual boundaries that trigger system actions when users enter or exit designated areas [6]. It has been widely applied in logistics, fleet management, smart retail and behavioral analytics due to its capability to automate location verification with minimal human intervention. In educational settings, geofencing offers a compelling solution by validating student presence through mobile-device GPS data. This eliminates the possibility of remote check-ins, reduces administrative intervention, and leverages existing student-owned devices, making it cost-effective and scalable [7]. Despite its potential, the adoption of geofencing for attendance in Malaysian higher education remains limited, with scarce empirical studies documenting system design, implementation, and user evaluation.

To address this gap, this paper presents TECH-CLASS, a geofencing-driven attendance management system developed for UiTM Machang. The system detects student presence within classroom geofences and automates attendance marking through a mobile application integrated with Firebase Realtime Database. This study aims to develop a geofencing-based attendance system applicable to classroom environments and to evaluate its usability and acceptance among both students and lecturers. The rest of this paper is organized as follows. Section II reviews related studies on attendance systems and geofencing technologies. Section III describes the methodology used to design and develop the TECH-CLASS system. Section IV presents the system evaluation and discusses the key findings and limitations. Finally, Section V concludes the study and outlines recommendations for future improvements.

2 Related Work

Attendance management has long been a significant focus within educational technology, largely due to its influence on student engagement, academic outcomes, and institutional oversight. Prior research has examined diverse methods, ranging from traditional manual tracking to advanced biometric and location-aware systems, each presenting unique advantages and inherent constraints. This section reviews the evolution of attendance technologies, the application of geofencing and location-based services, and the limitations of existing institutional tools that inform the development of TECH-CLASS.

A Traditional and Digital Attendance Approaches

Conventional attendance methods, such as roll-calls and signature sheets, remain widely used in universities due to their simplicity and low cost. However, empirical studies report that manual attendance is prone to systematic errors rather than occasional mistakes. Previous study found that signature-based attendance produced up to 18–25% inconsistency in large classes because students frequently filled in attendance for absent peers. These operational weaknesses directly undermine academic integrity and create unreliable datasets for institutional reporting. [3]. In large classrooms, these limitations are amplified, often resulting in unreliable records and considerable administrative burden for lecturers.

Although digital systems were introduced to address these issues, their effectiveness remains limited. Systems like Google Classroom and Moodle rely on self-reporting without enforcing physical presence, leading to unchanged fraud rates. In the Malaysian context, it shows that UiTM's u-Future allowed students to mark attendance off-site up to several kilometers away, demonstrating a core design flaw: the system validates login, not location [4].

Biometric systems such as fingerprint and facial recognition offer strong identity verification but suffer from practical constraints. Rahman et al. [5] reported persistent hardware calibration issues and long queues during peak lecture transitions, making biometrics unsuitable for high-mobility academic environments. Additionally, these systems lack integration with class schedules, require fixed checkpoints, and cannot accommodate mobile or short-duration classes. These limitations justify the need for geofencing-based alternatives that rely solely on students' mobile devices. In addition, post-pandemic health considerations have increased the demand for contactless alternatives. Taken together, these limitations highlight the need for a more flexible, scalable, and verifiable attendance mechanism that does not rely on dedicated hardware or continuous lecturer intervention.

B Geofencing and Location-Based Services in Education

Geofencing has gained attention in various domains due to its ability to automate processes based on user movement. Defined as a virtual boundary generated using GPS, Wi-Fi, or cellular networks, a geofence enables a device to detect when it enters or exits a specified location radius [6]. It has been applied extensively in fields such as logistics, mobile marketing, transportation monitoring, smart city management, and field service coordination. Geofencing-based systems have been examined in various academic environments for applications such as campus navigation, access control, student safety monitoring, and event participation [7]. Prior studies demonstrate that geofencing supports real-time validation and reduces the need for manual supervision, making it well suited for contexts with large populations and frequent movement, such as universities. When integrated into mobile applications, geofencing also makes use of students' existing devices, thereby removing the need for specialized hardware and significantly reducing operational costs.

Research findings on geofencing-based attendance prototypes indicate promising outcomes. A study demonstrated that Global Positioning System (GPS)-triggered attendance solutions achieved high levels of accuracy, particularly within outdoor or semi-outdoor settings [8]. Furthermore, another investigation observed enhanced student compliance and a significant reduction in fraudulent check-ins following the implementation of a geofencing-enabled attendance application [9]. Despite this documented progress, the available literature suggests that widespread adoption of these systems within Malaysian higher education institutions remains minimal, with the majority of existing implementations currently confined to experimental stages.

In addition to educational settings, numerous studies substantiate the efficacy of geofencing and mobility tracking systems in transportation and employment domains. Geofence-triggered mobility validation has been employed for monitoring bus fleets, ensuring delivery route compliance, and tracking workforce attendance [14, 15]. Mobility-centric assessments often highlight problems such as GPS drift, signal interference, and device variability—issues that are equally pertinent in campus settings. The findings from these mobility validation trials underscore the necessity for enhanced geofence logic and adaptive accuracy management, both of which are incorporated in TECH-CLASS. While these studies illustrate the viability of geofencing for diverse campus-related activities, the majority of systems are confined to experimental prototypes without incorporation into institutional workflows. Moreover, current implementations seldom tackle GPS variability, device diversity, or widespread user adoption. These deficiencies underscore the necessity for a more operationalized and context-sensitive geofencing solution like TECH-CLASS.

C Technical Challenges in GPS-Based Attendance Systems

Although geofencing presents a compelling solution, several technical challenges have been documented. GPS accuracy can vary depending on environmental factors such as building density, signal blockage, and weather conditions [10]. Indoor locations may require hybrid techniques, integrating Wi-Fi or Bluetooth to improve precision. Energy consumption is another concern, as continuous GPS monitoring can drain smartphone batteries, though recent studies show that modern APIs and adaptive location polling significantly mitigate this issue [11].

Privacy and data security are additional factors. Institutions must ensure that location tracking is limited to attendance purposes and compliant with ethical guidelines. Solutions often incorporate device-level verification, encryption, and selective tracking (i.e., tracking only during class time), as implemented in many modern mobile attendance prototypes. The TECH-CLASS system adopts several of these recommended practices, such as a controlled geofence radius, device-based authentication, and real-time data synchronization through Firebase.

D Comparison with Existing Commercial Applications

Commercial applications such as Timeero, Hubstaff, and HelloTracks incorporate GPS tracking, real-time location monitoring, and basic geofencing for workforce management. These tools excel in employee scheduling, task allocation, and monitoring field service workers but are not optimized for academic attendance. Research comparing these tools shows a lack of features essential for educational environments, including class schedule integration, lecturer validation mechanisms, automated academic reporting, and MIS integration [12]. Timeero, although offering GPS timestamps, does not support true geofence-triggered attendance. Hubstaff emphasizes productivity tracking and remote monitoring but lacks academic role segmentation. HelloTracks supports geofencing but targets field staff and delivery operations, with no support for academic outcome reporting or student record integration.

To address limitations found in prior geofencing prototypes, this study emphasizes several key advancements introduced by TECH-CLASS. First, existing geofencing solutions often rely on fixed-radius triggers without mechanisms to reduce GPS fluctuation, making them unreliable in dense campus environments. TECH-CLASS improves this by incorporating a controlled-radius geofence design and adaptive trigger logic, which minimizes false entry/exit events. Second, unlike earlier systems that operate as standalone prototypes, TECH-CLASS integrates academic-specific features such as course-session validation, lecturer-side dashboards, and Firebase-backed real-time synchronization, enabling institutional scalability. Third, the system adopts a simplified and mobile-first UI/UX design tailored for large student groups, addressing usability gaps in earlier experimental systems. Collectively, these enhancements highlight TECH-CLASS as a more accurate, institutionally aligned, and user centred geofencing attendance solution.

3 Methodology

This study utilised the Waterfall Software Development Model to guarantee a planned and systematic approach in designing the TECH-CLASS attendance system. This model was chosen due to initial analyses demonstrating well-defined system objectives and steady needs, rendering a linear, phase-based approach suitable for the project. To enhance methodological rigour, the development framework used engineering-focused design processes and empirical validation methods. The Waterfall Model established the structural framework for system development, while the scientific aspect of the study was underpinned by methodical data gathering, regulated pilot testing, and statistically analysable usability evaluation. Each phase generated quantifiable artefacts, including requirement specifications, UML design diagrams, geofence trigger logs, and SUS item scores, which enhance the reproducibility and empirical rigour of the research. Figure 1 depicts the whole development process, which includes the five phases of requirements analysis, system design, implementation, testing, and deployment.

Figure 1: TECH-CLASS System Development Framework

The first phase, requirements analysis, involved identifying weaknesses in UiTM Machang's current attendance process through interviews, informal discussions, and direct observations involving students and lecturers. Key concerns such as system latency, login failures, and the potential for attendance falsification were consistently noted. Additional constraints related to mobile device compatibility, GPS accuracy, and data security informed the system's functional and non-functional requirements.

The second phase, system design, translated these requirements into detailed technical specifications. UML diagrams including use case, class, and activity models were developed to document system behaviour and interactions. The architecture was mapped to incorporate the mobile application, Firebase Realtime Database, and authentication modules, along with the configuration of geofence boundaries and workflow logic. User interface (UI) mockups were also created to ensure clarity and ease of use for both student and lecturer roles.

The third phase, implementation, involved developing the TECH-CLASS mobile application using Android Studio (Java/Kotlin). Google's Geofencing API was integrated to detect device entry into predefined classroom areas, while Firebase Realtime Database enabled real-time attendance synchronization. Firebase Authentication provided secure login and role-based access control. Special attention was given to optimizing geofence stability, minimizing false triggers, and ensuring consistent behaviour across varying device models.

In the fourth phase, testing, the system underwent both functional and usability evaluation. Functional testing assessed geofence trigger accuracy, attendance recording, and database synchronization under indoor and outdoor conditions. Usability testing was conducted using the System Usability Scale (SUS), where participants completed typical tasks and provided feedback on interface clarity, navigation flow, and system responsiveness. A total of 50 students participated in the usability evaluation. This sample size aligns with SUS evaluation guidelines [13, 14], which stated that 20–30 participants are sufficient to achieve stable SUS scores, and larger samples (40–50) improve reliability without significantly altering the mean. The 50-student sample therefore exceeds the minimum recommended threshold for SUS-based system evaluations and is considered scientifically adequate for determining usability trends. Feedback from this phase informed several refinements to improve user experience.

The final phase, deployment and evaluation, involved pilot testing TECH-CLASS in real classroom settings. During this stage, GPS accuracy was measured using on-device diagnostics. Outdoor accuracy averaged 6–12 meters, while indoor accuracy ranged from 10–18 meters, which aligns with reported values for Malaysian university environments [7, 10]. Although the geofence radius was set at 4 meters, this value does not represent a strict physical boundary. Google's Geofencing API applies smoothing and dwell-time filtering, creating an actual trigger zone of about 8–20 meters, depending on device model and signal conditions. The smaller configured radius was chosen to reduce the risk of remote check-ins while still ensuring reliable detection. Throughout the pilot, student interactions and attendance logs were monitored to assess real-time performance. Results showed that TECH-CLASS accurately verified physical presence, verified physical presence, and received positive user feedback. The structured Waterfall approach supported systematic development and produced a stable system ready for broader deployment.

4 Results and Discussion

This section presents the empirical findings from the pilot deployment and the System Usability Scale (SUS) evaluation of the TECH-CLASS system. Quantitative data were collected from 50 UiTM Machang students who participated in the study. A convenience sampling technique was used, focusing on students enrolled in courses held in the pilot classrooms during the testing period. This approach was appropriate given the classroom-based deployment and the nature of usability studies, which emphasize real user interaction rather than random sampling. The results offer a comprehensive assessment of system performance and usability, reflecting participants' perceptions of the effectiveness of the geofencing-based attendance features.

A Pilot Deployment

A pilot deployment was conducted across selected classrooms at UiTM Machang, integrating the TECH-CLASS system into scheduled lecture sessions. Attendance logs confirmed the consistent validation of student presence, recording zero instances of impersonation attempts. This automated workflow successfully reduced the requirement for manual lecturer monitoring, with the real-time dashboard minimizing administrative processing delays. User behavior observed during the pilot phase reflected improved efficiency and orderliness in the classroom entry process, as most students automatically received attendance prompts upon entering the designated geofenced area. Furthermore, the system demonstrated functional robustness across various smartphone platforms, although variations in GPS sensitivity were observed. Collectively, these findings confirm the operational effectiveness of TECH-CLASS within authentic academic environments. The functionalities of the graphical user interface (GUI) of the TECH-CLASS system are presented in Table 1 below.

Table 1: the graphical user interface (GUI) of the TECH-CLASS

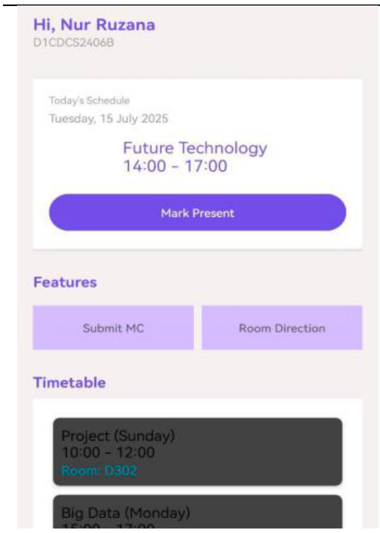

Figure 2: Student - Dashboard

Figure 2 presents essential information such as the user's name, ID, and daily schedule, with an active class highlighted alongside a "Mark Present" option. Additional functions—including medical certificate submission and room navigation—are accessible through quick-action buttons, while weekly schedules and other modules (e.g., History, Profile) are organized within a navigation bar. The streamlined layout reduces cognitive load and enables students to complete attendance-related tasks efficiently with minimal interaction.

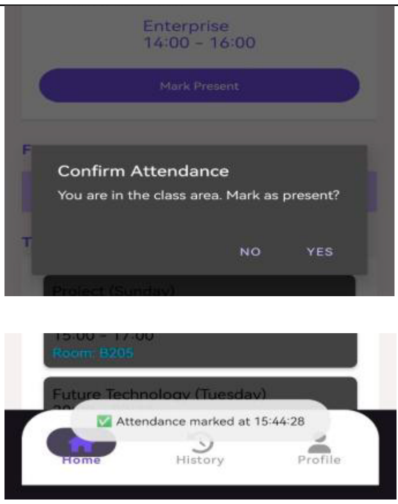

Figure 3: Student - Mark attendance

The TECH-CLASS attendance interface verifies student presence by activating a prompt when the user enters the designated classroom geofence during the scheduled session. Once confirmed, the system records attendance automatically with a precise timestamp, ensuring location-validated and time-bound entries as shown in Figure 3. The interface also includes essential functions—such as timetable access, room navigation, and medical certificate submission—to support routine academic tasks. This streamlined design reduces user effort and strengthens the accuracy and authenticity of attendance records.

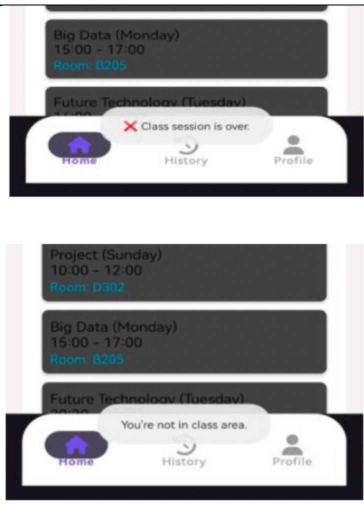

Figure 4: Student - Class session is over

The system applies strict temporal and spatial validation. Figure 4 shows that if a student attempts to mark attendance after the scheduled session has ended, a notification is issued and the entry is rejected. Likewise, attempts made outside the defined geofenced area trigger an alert indicating that the student is not within the classroom boundary. These controls ensure that attendance is recorded only within the correct time window and physical location, thereby preserving the integrity and authenticity of the attendance data.

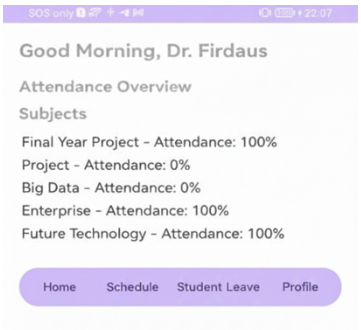

Figure 5: Teacher - Dashboard

Figure 5 shows the teacher dashboard which consolidates all

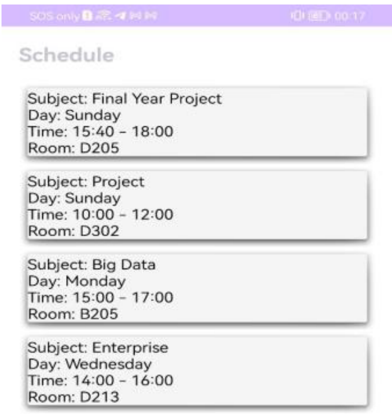

Figure 6: Teacher - Schedule

This interface shown in Figure 6 depicts the instructor's weekly

Figure 7: Teacher - Report

This interface displays the attendance register for a specific subjects assigned to an instructor and presents the corresponding attendance rates for each class, providing an immediate overview of student participation patterns. Core navigation functions such as Home, Schedule, Student Leave, and Profile are organized through a structured menu, enabling efficient access to key instructional tools. The streamlined layout reduces interface complexity and supports rapid information retrieval, thereby enhancing instructors' ability to monitor attendance trends and manage classroom administration with minimal cognitive load.

teaching schedule using a structured card-based layout in which each card specifies the subject, time, room, and day. By presenting timetable elements in a discretized and consistently formatted arrangement, the interface supports rapid visual parsing and reduces the cognitive effort required to manage multiple teaching commitments. This structured presentation is particularly important in academic environments where instructors oversee overlapping courses and sessions, as it enhances situational awareness and minimizes the risk of scheduling conflicts.

course (e.g., *Future Technology*, as illustrated in Figure 7), presenting weekly attendance percentages alongside student identifiers, group classification, and records of attended sessions. The tabulated structure enables systematic examination of individual and cohort-level attendance trends, facilitating timely detection of irregular participation patterns. Such structured visibility is essential for evidence-based monitoring of student engagement and for supporting instructional and administrative decision-making processes.

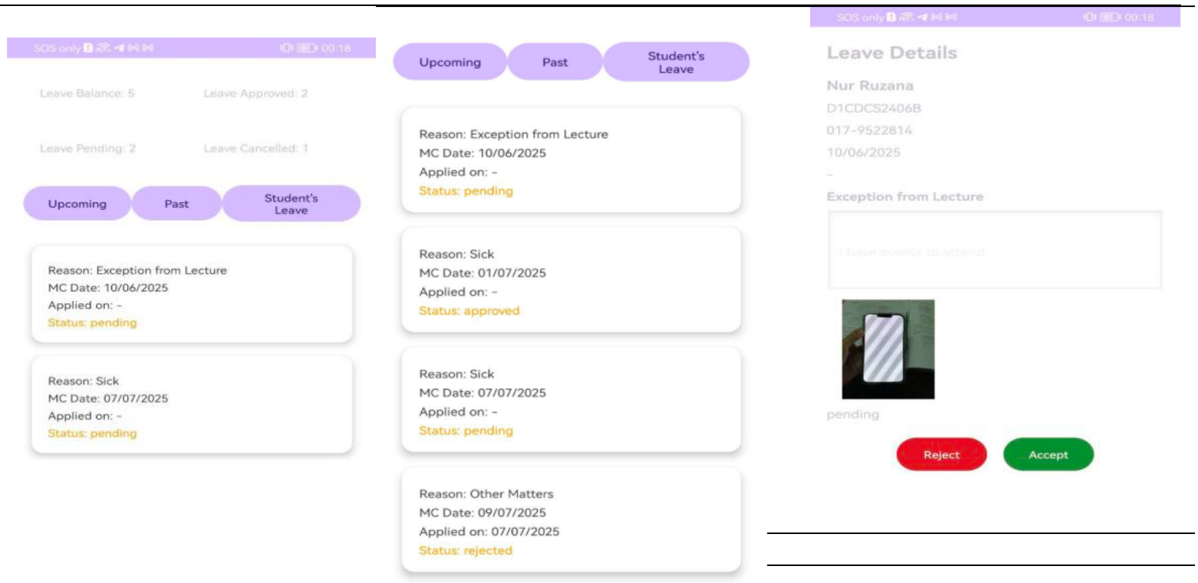

Figure 8: Student's Leave

The Teacher Interface as shown in Figure 8 allows instructors to review and manage student attendance and leave requests. The Student Leave section has Upcoming, Past, and Student Leave tabs, showing the status of each application—pending, approved, or rejected. Key details like Leave Balance and counts of Approved, Pending, and Cancelled requests are displayed at the top. Clicking an entry shows full Leave Information, including student name, group, contact, leave date, reason, justification, and any uploaded proof (e.g., medical certificates). Teachers can approve or reject requests at the bottom. The interface is user-friendly, interactive, and ensures transparent, traceable management of student leave.

From the above analysis, it indicates that the technology substantially enhances classroom management. The easy design allows students to conveniently record attendance, view timetables, and submit medical certificates, while teachers can successfully monitor attendance, manage leave requests, and track class performance. CLASS TECH enhances classroom administrative operations with GPS-based verification, organised dashboards, and interactive elements, ensuring correctness, transparency and accountability.

B Usability Metrics and Implications

To provide a clearer view of how users responded to each usability item, the individual SUS components were analysed and summarized in a structured format. Table 1 presents the distribution of responses for all five SUS items, including the number of students who selected "Strongly Agree" and "Agree," as well as the corresponding mean score for each item. This breakdown highlights the consistently high ratings across all usability dimensions, offering empirical support for the overall SUS score and reinforcing the system's strong performance in terms of efficiency, clarity, accuracy, and user satisfaction. The SUS evaluation yielded consistently high ratings across all items. Table 2 shows the distribution of responses and mean scores for each usability dimension.

Table 2: SUS Item-Level Distribution and Mean Scores

SUS Item	Strongly Agree (5)	Agree (4)	Mean Score (1–5)
Q1: Ease of Marking Attendance	40	10	4.8
Q2: Accuracy of Location Detection	40	10	4.8
Q3: Clarity of Attendance History	25	25	4.5
Q4: Preference Over u-Future	45	5	4.9
Q5: Overall Satisfaction	40	10	4.8

The overall SUS score was 95.2, placing TECH-CLASS in the "Best Imaginable Usability" category according to Bangor, Kortum, and Miller's (2009) adjective rating scale. The standard deviation of 0.32 across SUS responses indicates low variability, showing that participants were highly consistent in their evaluations. No neutral or negative responses were recorded, suggesting uniformly positive acceptance. TECH-CLASS demonstrated higher usability relative to the current institutional system, u-Future system (mean = 4.9) is particularly noteworthy. This is likely due to the system's automated geofence-based verification, which addresses key weaknesses of u-Future—namely remote check-ins, system latency, and manual lecturer confirmation. These results align with earlier findings that location-bound attendance systems outperform login-based methods in authenticity and convenience.

The results also demonstrate that TECH-CLASS offers significant improvements over existing attendance mechanisms. In contrast to u-Future—which permits attendance to be marked off-site—the geofencing approach ensures location-verified authenticity, directly addressing concerns raised in prior digital attendance studies. The absence of attendance fabrication throughout the pilot phase provides strong evidence of the system's effectiveness under real academic conditions. Furthermore, the system's high SUS score and low variability are consistent with usability research showing that mobile interfaces with minimal user input, automated task initiation, and clear feedback loops tend to achieve superior usability outcomes. The stable performance across diverse devices also indicates that the selected geofence radius, combined with Google's adaptive filtering, is suitable for classroom environments, despite known GPS fluctuations in indoor settings.

Overall, the pilot deployment and usability evaluation confirm that TECH-CLASS is a highly usable, accurate, and operationally effective attendance solution. The geofencing mechanism and strong user acceptance position it as a practical improvement over traditional and existing institutional systems. These findings support its potential for broader deployment across additional faculties and campuses.

5 Conclusion and Future Work

This study introduced the design, development, and assessment of TECH-CLASS, a geofencing-based attendance system aimed at enhancing the reliability of attendance verification in higher education. The system earned an outstanding SUS score of 95.2%, signifying exceptional usability, and the pilot deployment demonstrated its constant validation of physical presence while minimizing potential for fraudulent attendance. However, numerous constraints must be acknowledged. System performance is very susceptible to GPS variability, especially in indoor settings where structural and signal-related limitations diminish accuracy. Despite geofence smoothing mitigating this heterogeneity, sporadic detection delays were seen across several device models. The existing technology is exclusively compatible with Android, which constrains its broader applicability, and the pilot was executed in a limited number of schools, so restricting generalizability.

These constraints affect the scalability across the institution. Wider implementation necessitates meticulous setting of classroom geofences to prevent overlap, server optimization to accommodate increased traffic, and consistent upkeep of room-location data. The successful adoption hinges on staff training and well-defined institutional policies regarding data privacy and device permissions. Future research should broaden assessment to include more faculties and campuses, integrate hybrid indoor location methodologies (e.g., BLE beacons, Wi-Fi fingerprinting, sensor fusion), and enhance compatibility with iOS devices. Longitudinal research investigating the system's impact on attendance patterns and administrative processes would elucidate its long-term worth. Addressing these areas will allow TECH-CLASS to develop into a scalable and dependable institutional solution consistent with smart-campus goals.

Conflict of Interest Statement

The authors should declare any potential conflicts of interest that may influence the research, authorship, or publication of this manuscript.

Author Contributions

Ainul Azila Che Fauzi led the study conceptualization, supervised the project, validated the system design, and contributed to manuscript writing and final revisions. Nur Ruzana developed the system, collected data, conducted usability testing, performed methodological design and analysis, and prepared the initial manuscript draft. Asiah Mat and Noor Ashafiqa reviewed the work, provided expert feedback, and contributed domain-specific insights. Auni Fauzi supported the review process and provided additional expertise related to system design and evaluation.

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