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Article

Smart Attendance for Faculty Monitoring System Using the Bluetooth Low Energy: Design and Implementation

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Abstract: Student attendance serves many other important purposes aside from monitoring. In certain universities, the attendance of students in a course is also used as one of the requirements for students to be allowed to sit for the final examination. Traditionally, among most Malaysian Institutions of Higher Learning (IHL), attendance recording is usually done using pen and paper, or uses simple web-based system that is time consuming and difficult for faculty periodic monitoring. To address the identified drawbacks, this research aims to develop a Smart Attendance for Faculty Monitoring System using the Bluetooth Low Energy (BLE) technology to assist faculty in recording, managing and monitoring students' attendance and class schedules effectively. The system is developed for Android-based devices using an agile methodology consists of iteration and incremental approaches. Thus, to evaluate the effectiveness of the system, a survey was conducted on 140 respondents involving lecturers and students of Kolej Universiti Poly-Tech MARA (KUPTM). Respondents were selected using purposive sampling. The descriptive analysis showed that 87.9% of the respondents strongly agreed that the system is effective in assisting lecturers to record attendance, manage class schedules and student attendance as well as to assist faculty in monitoring students' absenteeism.

Keywords: smart attendance system; attendance monitoring system; students' absenteeism; Bluetooth Low Energy technology; beacon-based application

1. Introduction

Effective attendance recording and management play an important role in today's world whether in industries or educational institutions. Attendance is one of the work ethics valued by employers and it is also one of the factors that influence the performance of students [1]. Students can gain valuable information from lecturers by attending classes, which can increase students' competencies. The importance of class attendance is emphasized as it not only influences students' grades but also their characteristics and behaviors [2]. Interestingly both students and some educational researchers seem somewhat skeptical of the importance of class attendance albeit empirical evidence which shows students with poor attendance records have poor academic performance [3]. In some universities, students who do not attend classes end up performing poorly in their final examination, as their final examination marks will be reduced by an average of 1.89% [4]. In addition, class attendance can be used as an indicator for taking preventive and corrective measures to improve student success [5]. Therefore, attendance monitoring is an important element for faculty to identify problems at an early stage and provide appropriate support to students to improve their performance.

In recent years, Internet of Things (IoT) technology has made a significant impact in the development of innovative systems that have been investigated by many researchers in various domains. Many attempts have been made by researchers to address the weaknesses of traditional systems by developing automated systems using this latest technology. Therefore, this research aims to propose an effective attendance taking process integrated with BLE

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technology using IoT applications to assist faculty to monitor student absenteeism via web-based and mobile applications.

2. Literature Review and Problem Statement

Most educational institutions and industries in developing countries still use paper-based attendance methods to maintain their attendance records [6, 7]. In Malaysia, most universities still use the traditional attendance taking method to record physical class attendance [8]. But, in recent years, some of them have use a simple web-based system for lecturers to manually record attendance data and store the data into a database. However, there are some difficulties faced by lecturers using traditional methods such as inefficient attendance taking process, tedious monitoring student absenteeism, high risk of data loss, and tendency to allow students to sign attendance on behalf of absent peers [9]. Studies have shown that the traditional methods are inefficient as it required more class time, difficult for faculties periodic monitoring and the possibility of misuse by students, especially in classes involving large group of students [5], and is time consuming and requires human interference, hence, it can be prone to human error and fraud [10]. Therefore, there is a critical need to adopt an automated attendance management system to assist lecturers to record, manage and monitor students' absenteeism effectively.

The global COVID-19 pandemic has further affected the education and industry sectors drastically. Industries and educational institutions were forced to close to prevent the spread of the disease. As a contribution to prevent the spreading of the disease, a contactless class attendance system was proposed to fulfill the current needs. For example, the development of a contactless temperature measuring and web-based attendance monitoring system using Node MCU, MLX90614 Infrared Thermometer, RFID Reader and Ultrasonic Sensor to reduce possibilities of COVID-19 infection presents much opportunities to improve the attendance recording process [11]. As new technologies evolve rapidly, there are various types of automated attendance systems to fulfill the current needs and requirements such as software-based systems and hardware-based solutions using barcode, magnetic stripe, RFID-based technology [5, 12], BLE technology [9, 18, 21] and biometric (fingerprint and face-recognition) solutions [6, 13, 14, 15].

Various technologies have been developed and emerged recently, to provide an automatic approach to attendance monitoring and management systems. The most critical step in these innovative systems is the data gathering process, and data processing model [1]. Many of well-known technologies have been used for this purpose such as Radio-Frequency Identification (RFID), Near-Field Communication (NFC), Bluetooth [9, 18, 21], barcode reader, magnetic stripe and biometric techniques including face recognition, signatures, fingerprint, voice recognition and irises [6, 13, 14, 15]. With these technologies, the process of recording of attendance data becomes easier, fast and accurate [12].

The aforementioned software-based system focused on the Short Message Service (SMS) notification to monitor student absenteeism based on the percentage of attendance allowed by the university [16]. The system will send SMS notifications automatically to the parents and students in order to assist the Academic Affairs Division (ADD) to manage the warning letters issued by the lecturer. Nevertheless, lecturers are still need to key-in the data of the absent students manually to the system, hence, it is time-consuming and incur cost of the SMS services. As in other software-based systems, a semi-automated Android-based system was developed at minimal cost using a QR code that contains all attendance-related information [7]. Android is a mobile operating system designed primarily for touchscreen mobile devices with a modified version of the Linux kernel and other open source software. In confirming of student attendance, the code must be scanned by the Android device and the information will be stored and updated in an online database.

However, there are some drawbacks to using QR codes, barcodes, and magnetic stripe charges for hardware-based solutions, such as a long registration time, error prone, low accuracy and data sources, artificial identification, problems which are similar to traditional manual management and individual staff statistics for attendance management records [17]. Furthermore, the aforementioned solutions are not eco-friendly. Therefore, a RFID-based Attendance Management System (AMS) and web-based application to manage student's attendance and class schedules effectively [17] incorporating a Bluetooth Low Energy-based

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student positioning framework for automatically recording student attendance in classrooms is proposed [18].

In this study, the technology proposed are based on the BLE technology coupled with the application of IoT and cloud technology to run and monitor the attendance in real time. Bluetooth is a wireless technology standard used to transfer data at short distance and is also known as "Bluetooth Smart" which is a subset of the classic lightweight Bluetooth class that has been introduced as part of the core Bluetooth 4.0 specification. BLE aims to provide greatly reduced power consumption and cost while maintaining a similar communication range [8]. Beacons are small BLE radio transmitters that have given mobile applications the ability to understand position based on micro-local scales and provide proximity content to location-based receivers [9]. Beacon devices are placed in fixed locations (e.g., classrooms, lecture hall, etc.) or can be brought by the lecturer. Whenever there is a class, students' smartphones can detect the beacon thus allowing attendance to be taken. The range of BLE devices can be adjusted, thus, the device can transmit, and it can be connected to an infinite number of devices or smartphones [18]. This device will be placed in the classroom where students will check in to confirm their attendance via Bluetooth. Students will be able to verify their personal information via the mobile app and lecturers will be able to easily observe the number of attendees for their classes and the information of participating students anytime and anywhere.

3. The Objective of the Study

This objective of this study is to develop an Android-based smart attendance for faculty monitoring system using the Bluetooth Low Energy (BLE) technology to address weaknesses identified in traditional attendance taking processes. The system consists of web-based and mobile applications to assist faculty in recording, managing, and monitoring student absences and class schedules effectively. A survey was conducted on 140 respondents involving lecturers and students of Kolej Universiti Poly-Tech MARA (KUPTM) Kuala Lumpur to evaluate the system to address the aforementioned objective.

4. Methodology and Development

The system development uses combination of various software and programming tools. The web-based platform is developed by utilizing Vue as the development software. Whereas the mobile platform uses React Native and UI Kitten mobile frameworks. The server back-end frameworks uses Apollo server which is spec-compliant with GraphQL server. The system uses MongoDB and Redis as the database while Redis is used as the database which cater the in-memory data structure store, cache, and message broker.

Figure 1 illustrates the backend and frontend structure of the development process. The backend development provides endpoint access for frontend to request data from database. Web and mobile frontend request data using endpoint applying the Application Programming Interfaces (API) concepts to get response from backend. This way will provide a great deal of flexibility and improved connectivity between data and systems.

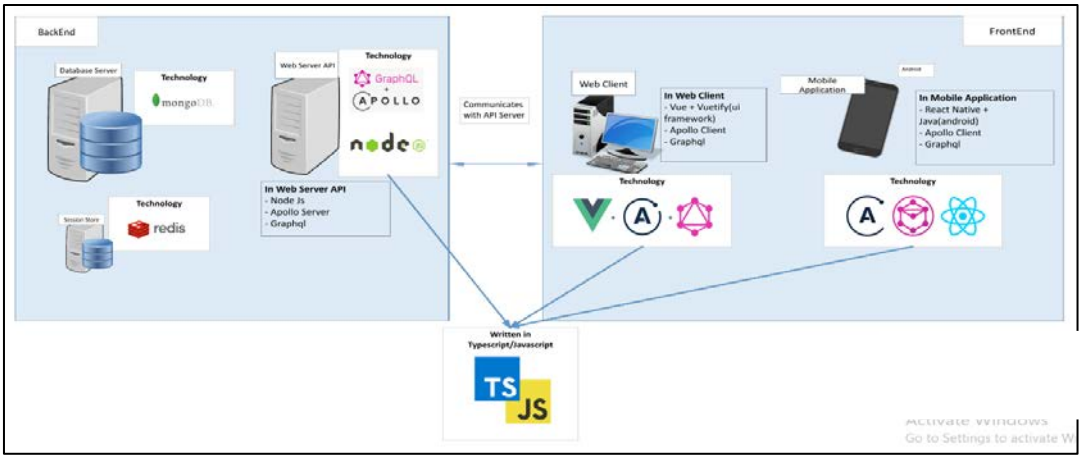

Figure 1. Development specification.

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Agile methodology is used as a system development lifecycle for this research. The agile methodology uses an iterative and incremental approach in developing a software as shown in Figure 2. Agile approaches dissolve tasks into lesser versions, or segments. This method do not directly require long-term planning. Plans are clearly defined in advance regarding the number of iterations, the length and the range of each iteration. This approach can save significant development time as users can see the product for the first time through the rework process. It is an excellent way for developers to validate their understanding of the specifications and ensure that the solutions proposed are consistent with organization expectations. Each iteration is considered to be a short "frame" period in the agile development model, which usually lasts from one to four weeks. Splitting the entire project into smaller pieces helps reduce project uncertainty and reduce the overall project completion time requirement. Each iteration involves a team working through a full software development life cycle including planning, requirement analysis, design, coding, and testing before a work product is shown to the client. Agile model consist of six phases; requirement gathering, design the requirements, construction or iteration, testing or quality assurance, deployment and feedback.

Requirement gathering is the first phase which involve the definition of the project scope and specifications. This phase is the most crucial phase to ensure the next development process is smooth and clear. Technical and economic feasibility are also determined to clarify the time and effort needed for the development of the project plan. Next phase is designing the requirement. This phase involve specifications design such as designing use case diagram, user flow diagram and class diagram. These diagrams are useful to view the function of new features and demonstrate how it would relate to the current system. After completed design the requirements, construction or iterations process will begin to work towards delivering a working product on the project. The software will be enhanced in various stages. Therefore, it includes simple and minimal functionality. Testing or quality assurance phase checks the consistency of the material in this cycle and searches for the error. A few agile test method will be used as the testing or quality assurance. The final phase is deployment and feedback. The product is published and deploy in real environment of the user during this process. The real environment normally will faced a lots of problems and incompatibility issues. From here, feedback is gain through the experiment of user experiences on the system.

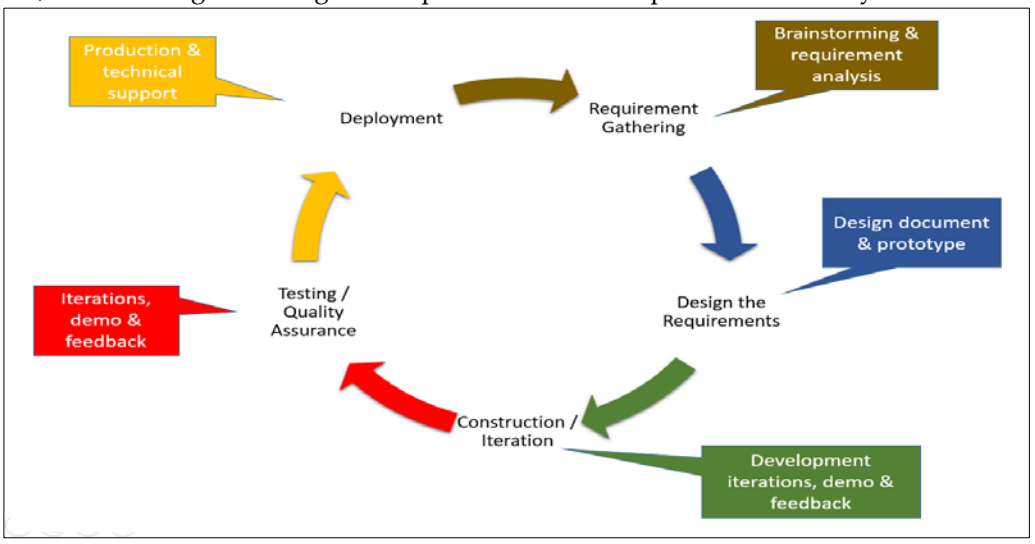

Figure 2. Agile Methodology Development Life Cycle.

5. Interface Design

This section discusses the interface design of the research paper. The system aimed to provide an effective attendance-taking process and monitoring management. It uses BLE technology integrating with the Internet of Things (IoT) applications to assist lecturers in performing automated attendance monitoring and management system. The focus of this section is divided into five main tasks (modules) of the interface design including Task 1: Managing class schedules; Task 2: Taking student attendance; Task 3: Managing student attendance; Task 4: Monitoring students' absenteeism; and Task 5: Sending students' absenteeism notifications.

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Task 1: Managing class schedules

Managing class schedules module focuses on organizing lecturers' and students' timetable within the application. The system allows lecturer to upload the class information file into the system as shown in Figure 3. The class information file should be in xls or xlsm format that contains course information, time, venue, and list of students. The system will generate the schedule for the user to view. If the user is a lecturer, the schedule can be viewed in both platforms, i.e. web-based and mobile. Whereas, for students, the schedule is viewed in mobile application platform only. Figure 4 and Figure 5 show the schedule page in web-based and mobile application platform respectively. Moreover, this module also allows the lecturer to add replacement class for replacement classes. The replacement classes slot can be viewed and edited in the schedule as shown in Figure 6 and Figure 7.

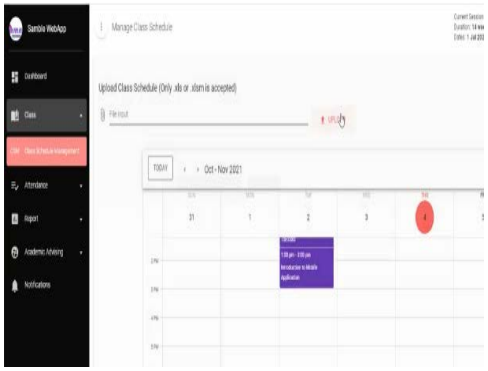

Figure 3. Lecturer can upload .xls or .xlsm file to generate schedule

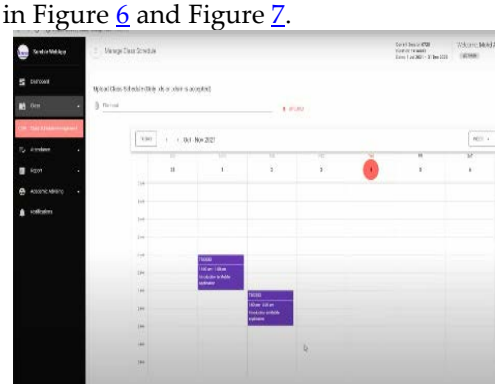

Figure 4. Class schedules in web-based platform

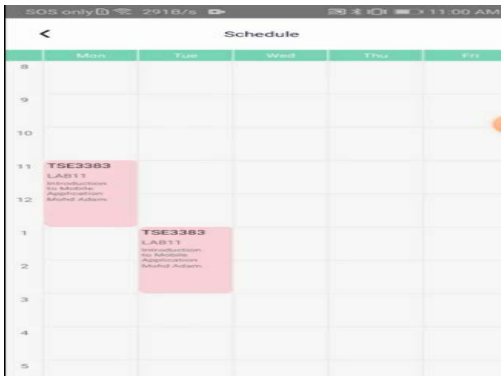

Figure 5. Schedule view in mobile application platform

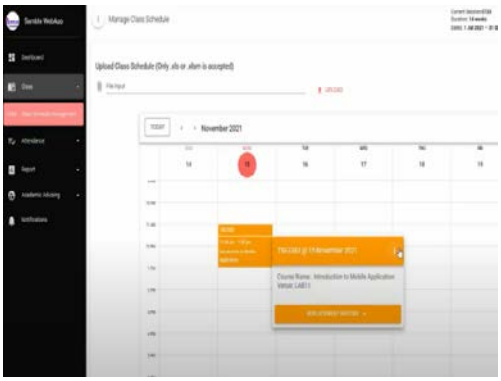

Figure 6. Lecturer can view replacement class history

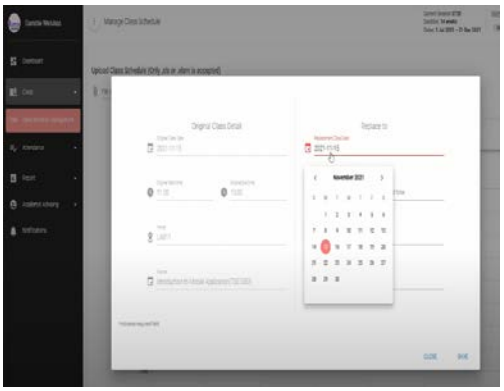

Figure 7. Lecturer can add and edit replacement class

Task 2: Taking student attendance

The system can record student attendance automatically using proximity detection by integrating with the BLE beacon. A lecturer can activate the system to take attendance automatically. After the student has logged into the apps, his/her attendance is automatically rec-

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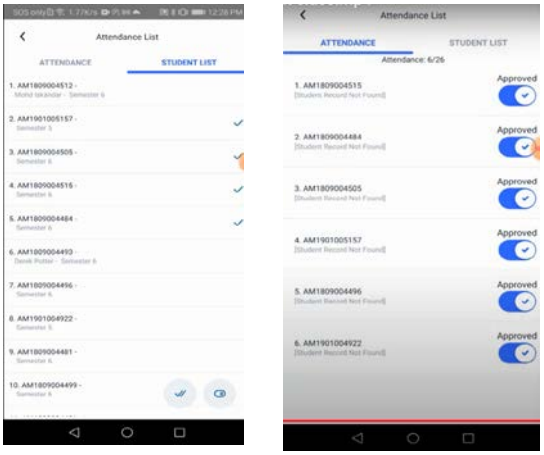
orded upon activation of his/her smartphone's Bluetooth whilst in the classroom. The lecturer needs to validate the attendance after class session by activating the check button. If a student forgets to bring a smartphone or has a smartphone problem during class, the lecturer can help to record the attendance manually. Figure 8 shows the interface of students' attendance taking in the apps.



(a) (b)

Figure 8. Manage students' attendance in apps

Task 3: Managing student attendance

The lecturer also can update manually students' attendance in case of any technical issues that occur during attendance taken by the beacon. The lecturer can also view students' list for the taught courses and attendance can be updated manually. Finally, the lecturer can view the list of students for his/her class and can manage the class attendance easily as shown in Figure 9.

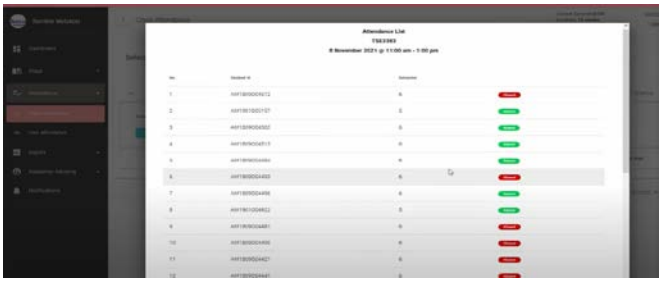


Figure 9. Lists of summary records of student attendance

Task 4: Monitoring students' absenteeism

The system provide many ways to monitor students' absenteeism record. Firstly, the lecturer can view the analytical graph reports of the attendees, absentees, and attendance rate in the dashboard page of the web-based platform as shown in Figure 10. Secondly, the lecturer can view and manage the students' attendance record for all courses that he or she taught for the semester. The system can list summary records of student absenteeism for monitoring purpose. Thirdly, the system will notify the lecturer to automatically send warning letters to students, other lecturers, parents and mentors based on permissible percentage (7%, 14% and 21%).

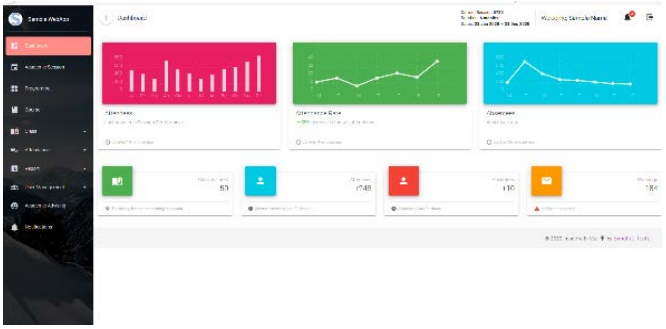


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Figure 10. Dashboard page with analytical graphs for students' absenteeism reports

Task 5: Sending students' absenteeism notifications

The system and apps provide notification features which alert the lecturer on students who are absent from class based on permissible percentage discussed earlier. The notification is send via in-apps alert and email. The system notifies the lecturer to inform that students' warning letters have been sent to his/her email. Moreover, the system can also notify mentor by email, if the respective mentee receives a first or second warning letter or a warning letter that bars the student from taking the examination. Finally, the system can also notify parents by email (refer Figure 11).

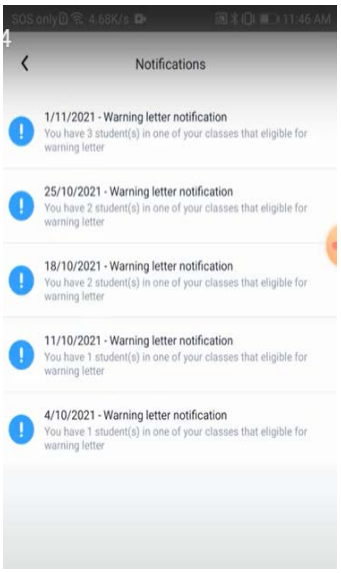

Figure 11. In-app warning letter notification

6. Discussion of results

In this expletory study, a questionnaire was developed to gather responses from the lecturers and students. The questionnaire for lecturers consisted of 25 items that assessed five tasks namely managing class schedules, taking student attendance, managing student attendance, monitoring students' absenteeism and sending students' absenteeism notifications. In addition, the questionnaire for students consists of an additional task which focuses on the perception of students on the system. Furthermore, the system was evaluated based on the functionality and usability test. Each item was assessed using a 10-point Likert scale with a range from (1) strongly disagree to (10) strongly agree as per the recommendation by this paper [19]. The questionnaires were distributed to 32 lecturers and 108 students of Kolej Universiti Poly-Tech MARA (KUPTM) using purposive sampling and the statistical method. KUPTM is one of the biggest private educational institutions with more than 12,500 full time students at 7 campuses across Malaysia.

Table 1. Demographic characteristics.

Item	Lecturer		Student	
	Frequency	Percentage	Frequency	Percentage
Faculty				
FBASS	6	18.8	39	36.1
FCOM	16	50.0	25	23.1
FEHA	10	31.3	44	40.7
Gender				
Male	4	12.5	33	30.6
Female	28	87.5	75	69.4
Position			**Programme Level**	
Lecturer	21	65.6	Diploma	7	6.5

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Senior lecturer	11	34.4	Bachelor's Degree	91	84.3
			Professional	10	9.3
Year of Services			**Semester**		
5 years or below	6	18.8	1 – 2	11	10.2
6 - 10 years	9	28.1	3 – 4	63	58.4
11 - 15 years	12	37.5	5 – 6	22	20.3
16 - 20 years	2	6.3	7 – 8	12	11.1
More than 20 years	3	9.4			

Table 1 shows the demographic characteristics of the respondents which are divided into lecturers and students. Most lecturers who participated in the study was from the Faculty of Computing and Multimedia (FCOM) which contributed 50% of the data. While most students who participated in the survey were from the Faculty of Education, Humanities and Arts (40.7%). In addition, 87.5% were female lecturers and 69.4% were female students. By position, 65.6% were lecturers and 34.4% were senior lecturers. Among the respondents, there are lecturers who have served at KUPTM for 11 to 15 years (37.5%), while only 6.3% have years of service between 16 to 20 years. The largest group of students came from semesters 3 and 4 which was 58.4% of the sample.

Table 2. Reliability Statistics.

Tasks	Number of items	Cronbach's Alpha	Mean	Variance
Lecturers	25	0.972	9.15	1.24
Students	28	0.992	8.68	2.44

Table 2 shows the value of Cronbach's alpha, mean and variance of the overall instruments based on lecturers' and students' tasks. Cronbach's alpha values of 97.2% and 99.2% for the questionnaire items for the two groups indicate good statistical reliability. Any component with a Cronbach's alpha value of 0.7 or higher has a reliable measure of internal consistency [20].

Table 3. Mean and standard deviation based on tasks.

Tasks	Lecturer		Student	
	Mean	Standard deviation	Mean	Standard deviation
Tasks for students	Not applicable		8.601	1.449
Task 1: Managing class schedules	9.200	0.859	8.734	1.491
Task 2: Taking student attendance	9.083	0.917	8.701	1.431
Task 3: Managing student attendance	9.138	0.851	8.707	1.477
Task 4: Monitoring students' absenteeism	9.117	0.998	8.584	1.438
Task 5: Sending students' absenteeism notifications	9.200	1.050	8.676	1.446

Table 3 summarizes the mean and standard deviation for each task for both groups of respondents. From the lecturer's perception, manage class schedules (Task 1) and sending students' absenteeism notifications (Task 5) showed the highest mean compared to other tasks of 9.20 out of 10 with standard deviations of 0.86 and 1.05, respectively. This can be interpreted that the system can assist lecturers in managing class schedules as well as sending student absenteeism notifications. Task 2 indicated slightly lower mean values than the other tasks, but still within a highly agreed range (Mean = 9.08, SD = 0.92). For Task 3, managing student attendance, lecturers tended to strongly agreed that this system could be used to manage student attendance (Mean = 9.14, SD = 0.85). Similar results are shown in Task 4, monitoring students' absenteeism showing a mean of 9.12 and a standard deviation of 0.99. The same results are also shown from the students' perception. Although the mean results showed slightly lower than the lecturer's mean, the values still almost strongly agreed with

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a mean of 8.68 and a standard deviation of 1.41. Thus, it can be concluded that both lecturers and students are strongly agreed that the system can assist lecturers to record attendance, manage class schedules and student attendance as well as to assist faculty in monitoring students' absenteeism effectively by providing automatic notifications (in-app & via email).

7. Conclusions and Recommendation

Findings of the survey showed positive feedback from the respondents. The system provides automatic attendance recording by interacting with the BLE beacons and it is agreed by the respondents in assisting lecturers and students in managing attendance. In addition, the system promotes a contactless attendance-taking process to prevent students from contracting infectious diseases, especially COVID-19. Furthermore, this research is significant for faculty monitoring system, where the notifications via application (in-app and forced notifications) and via email is sending automatically to the respective individuals such as parents, subject lecturers and academic advisors when the percentage of student absenteeism reached the allowable percentage set by the educational institution. The application of the system has improved the overall quality of the attendance recording process as quality is not a static condition and must be evaluated and improved on a regular basis [22].

As a result, the findings suggest that this system can assist lecturers to record attendance, manage class schedules and student attendance as well as assist faculty in monitoring students' absenteeism effectively. However, there are limitations in this system which can only support Android-based devices. This shortcoming can be addressed by other researchers. In addition, a qualitative study involving interviews and observations of students and lecturers should be conducted using a modified version of Technology Acceptance Model (TAM) to assess their perceptions with regards to the system's usefulness, satisfaction and behavioral intention to use towards technology adoption and actual system use.

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