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Development and implementation of real-time staff performance monitoring and evaluation system based on Global Positioning System (GPS)

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Abstract

This work presents the development and implementation of a Real-Time Staff Performance Monitoring and Evaluation System (RT-SPMES) using Global Positioning System (GPS) technology. In line with the dynamism of the workplace, due to rapid changes in technology, existing staff performance appraisal systems have fallen short of expectations due to their manual nature. Hence, the need arises for a more robust approach to monitoring and evaluating employee work performance. To achieve this, this work carried out an exhaustive review of existing performance evaluation methods within the academic and a conceptual architecture was developed. A real-time monitoring and evaluation system was developed, using PHP programming language, Hyper Text Markup Language and Cascading Styles Sheet. The system is hosted on Azure Cloud infrastructure. Through sufficient testing of the developed system developed in this work, it was asserted effectively monitors employee performance in real-time, paving the way for an objective appraisal process devoid of bias and manipulation.

Keywords: Staff performance; GPS; Monitoring; System; Technology; Programming Language

1. Introduction

The growth in human resources has made manual handling of human activities very strenuous. Accurate assessment of staff activities in tertiary institutions is very pertinent in order to achieve academic and non-academic excellence. The manual approach poses a lot of issues such as human errors, mismanagement of vital documents, negligence of duty, sense services, prone to data disorganization, delays in profile updates, prejudiced decisions, delays in delivery of services, result submission, absenteeism from lectures and other impending issues that hinder the excellence of tertiary institutions. Traditional methods of performance assessment often prove to be time-consuming, subjective, and insufficient in providing real-time insights into employee activities. In response to these challenges, the convergence of cutting-edge technology, particularly Global Positioning System (GPS) technology, with performance management has given rise to a transformative solution: the Real-Time Staff Performance Monitoring and Evaluation System (RT-SPMES).

The advent of GPS technology, primarily known for its role in geolocation and navigation, has opened up new possibilities for monitoring and assessing staff activities with unprecedented precision and accuracy. By harnessing the power of GPS, organizations can gain real-time visibility into the movements and actions of their staff members, regardless of whether they are located within a physical office, in the field, or even working remotely. This technological innovation has revolutionized staff performance management by providing organizations with the means to make informed decisions, optimize resource allocation, enhance security, and ultimately improve overall efficiency.

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The advantages of engaging a real-time staff performance monitoring and evaluation system (RT-SPMES), as regards data management in tertiary institutions range from faster information procedure, and greater accuracy in information management schemes to enhance inter-staff communications. RT-SPMES will serve as a powerful tool in prompting staff into anticipated actions in their areas of jurisdiction and thereby improve productivity in the quest for academic excellence. As a monitoring arrangement, it will help the school management to harness staff competencies and hence develop staff proficiencies rather than just promotion and remuneration drives.

2. Review existing literature

According to [1], the essence of evaluating employees' performance in any tertiary institution is to realize the goals of the institution by measuring the contribution of each employee. It is of great significance to consider the development of performance appraisal as an important work agenda of enterprises and take it as an important part of management [2]. However, the most important single purpose served by performance appraisals is to let employees know where they stand. However, in the same way that it is difficult for individuals to develop a way of evaluating themselves, it is also difficult for organizations and their employees to develop a perfect way of evaluating the performances of their personnel [3].

With recent technology, employers are able to track locations through GPS apps on employees' smartphones. This is an advancement to the age-long monitoring of employees through GPS sensors embedded in their vehicles [4]. [5] Noted that despite the organizational benefits of this Electronic Performance Monitoring, these systems can have adverse effects on employee satisfaction, organizational commitment, fairness perceptions, and employee behaviour due to privacy concerns. Despite these privacy concerns which may lead to lower job satisfaction it is reported that comprehensible reasons for monitoring communicated by the manager to the employees may result in increased satisfaction [6].

A study by [7] involving questionnaire responses from randomly selected 352 respondents showed that web-based appraisal systems improved employees' perception of rater competence, hence more trust in the appraisal system. [8] Also corroborated the postulation by a study, that electronic employee performance monitoring has a positive impact on employee achievement. All these present evidence of the need for a rapid shift, from traditional to GPS/Cloud-based appraisal systems.

3. Materials

The following software tools and services were utilized in the development of the real-time staff monitoring and evaluation system: MySQL Server, PHP Programming Language, Hyper Text Markup Language (HTML), Cascading Styles Sheet (CSS), Visual Studio Code (VS code), Microsoft Information Interchange Server (IIS), Microsoft Azure cloud platform, Docker, Kubernetes, Git/Github.

In addition, the following hardware tools played vital roles in the realization of the system developed in this work: Core i5 Notebook Computer, Desktop Computer System, Two Smart Phones, and Azure Disk Storage.

3.1. Methods

The system developed in this work rates employees based on the following key performance indicators:

proposed appraisal system will evaluate the staff on the following criteria: Attendance and punctuality to classes, Regularity to school, Timeliness of result submission, seminars and projects, Publications in Journals, conferences papers and attendance to workshops and membership to professional bodies and industry certifications.

3.1.1. Attendance to class:

- This proposed system will monitor Attendance to class using two criteria: Punctuality to class and Duration of lectures, using Geo Positioning System in the following manner;
- Each academic staff will be assigned an ID that will be used for authentication into their dashboards.
- Each semester's course allocation will be uploaded to the cloud system.
- The courses allocated to each lecturer and the time schedules for each course will be displayed on their dashboards.
- Every student will be able to log into the system using their ERP credentials.
- The lecturer will log into his dashboard and tick the attendance checkbox that will be provided.

Attendance will be taken at the beginning and at the end of the lecture session. The system will read the GPS data of the lecturer's device. A minimum of one-third of the population of students is expected to log in at the same time to a centralized lecture attendance platform, select the course title and tick "lecture started" checkbox. It is noteworthy to state that the students will only be able to validate attendance after the lecturer has indicated his presence by performing step 5 above. The system will also read the GPS data of each student's device. Only students whose GPS data corresponds to that of the lecturer within a proximity of 10 metres will be able to validate the lecturer's attendance.

At the end of the class, steps 5, 7 and 8 are repeated, but this time, the students will tick "lecture ended". This process will enable the system to calculate the duration of the lecture session.

The system analyzes the Attendance data gathered to determine the following: Punctuality of the lecturer to the class (50 points). Duration of the lecture session (50 points). The system calculates the Attendance score of the lecturer for that course and the information derived is stored in the database.

The attendance score is calculated as follows:

3.1.2. Punctuality (50 points):

The duration of each lecture session is 120 minutes. The evaluation scale will be implemented as follows:

Table 1 Punctuality to class rating

Punctuality	**Points**
0 - 15 minutes into the scheduled time	50 (100%)
16 - 30 minutes into the scheduled time	37.5 (75%)
31 - 60 minutes into the scheduled time	25 (50%)
61 - 90 minutes into the scheduled time	12.5 (25%)
91 - 120 minutes into the scheduled time	2.5 (5%)

3.1.3. Duration of Lecture Session (50 points)

The score of the lecturer is calculated based on how long the lecture lasted as follows:

Duration of class = Lecture end time - Lecture start time

Table 2 Duration of lecture rating

Lecture duration		**Points**
91 - 120 minutes	(1hr 46 mins - 2hrs)	50 (100%)
61 - 90 minutes	(1hr 1min - 1hr 45 mins)	35 (70%)
31 - 60 minutes	(31 mins - 1hr)	17.5 (35)
1 - 30 minutes		5 (10%)

The score for the lecturer for each class will be calculated as the algebraic sum of the punctuality score and the duration of the class score. The calculated score is stored in the database.

At the end of the appraisal year, the system analyses all the attendance data stored in the database and scores the lecturer as follows:

The total score obtained for the semester is calculated as follows:

Attendance score per lecture (Sl) = punctuality score per lecture (Sp) + duration score per lecture (Sd)

i.e., Sl = Sp + Sd ... equation 3.1

The sum of attendance scores per semester (S_s) = Summation of all attendance scores obtained.

i.e., $S_s = \sum Sl$ ... equation 3.2

Maximum Attendance Score Obtainable per lecture (S_m) = (Max Punctuality score + Max Duration score)

Hence, $S_m = 50 + 50 = 100$.

Maximum Attendance Score Obtainable per Semester (S_{mo}) = Maximum Attendance Score Obtainable per lecture (S_m) * number of classes in the semester (N_s).

$S_{mo} = S_m * N_s$ ... equation 3.3
Since $S_m = 100$

$S_{mo} = 100 * N_s$

Total Score Obtained by the lecturer for the semester (S_t) = $\frac{\text{Summation of attendance scores for the semester}}{\text{Maximum Score Obtainable per Semester}} 100$

$St = Ss/ S_{mo} * 100$ …… equation 3.4

If the staff is assigned more than one course, we need to calculate the scores for each course and finally aggregate the scores obtained from each of the courses.

This can be calculated as follows:

Appraisal score For Attendance (S_a) = $\frac{\text{Sum of scores obtained from each course}}{\text{Number of courses allocated}}$ … equation 3.4

The value of S_a is in percentage. This value will form part of the overall appraisal evaluation.

3.2. Regularity to school

The system developed in this work utilizes GPS Technology to capture this appraisal criteria. Each academic staff is required to log into his dashboard upon arrival to school on every working day. The system automatically reads the GPS data of the device with which they logged in and compares it with the Geo Information System map of the Institution stored in the cloud. If the device's GPS coordinates correspond with any location within the institution's map, attendance is automatically recorded for the staff for the day. Attendance will be recorded only once per day.

At the end of the Academic year, Regularity score is calculated as:

Regularity Score (S_r) = $\frac{\text{Total number of times present}}{\text{Total number of working days within the appraisal year}} \times 100$... equation 3.5

The value of S_r is in percentage. This value will form part of the overall appraisal evaluation.

3.3. Submission of results

Table 3 Timeliness of result submission rating

Time Frame	Score
< 3 weeks after exams	100%
4 – 5 weeks after exams	70%
6 – 7 weeks after exams	50%
8 – 10 weeks after exams	20%
Exceeding deadline	0%

Examination timelines will be provided at the beginning of each session during the publication of the Academic Calendar, for the system to use in monitoring the submission process.

In a situation whereby a lecturer handles more than one course, and/or seminars and projects, he/she will be evaluated on all the expected submissions, and his final score calculated as follows:

$$\text{Effective score obtained from all submissions } (S_s) = \frac{\text{Sum of scores obtained from all submissions}}{\text{Maximum score obtainable from all submissions}} \times 100 \quad \text{equation 3.6}$$

$$(S_s) = \frac{\text{Sum of scores obtained from all submissions}}{\text{Total number of submissions} \times \text{max score per submission}} \times 100 \ldots \quad \text{equation 3.7}$$

From above, max score per submission = 100, hence,

$$S_s = \frac{\text{sum of scores}}{\text{Total number of submissions}} \times 100 \ldots \quad \text{equation 3.8}$$

$$S_s = \frac{\text{sum of scores}}{\text{Total number of submissions}} \quad \text{equation3.9}$$

The value of S_s is in percentage and will form part of the overall appraisal score. Presented below is the distribution of the appraisal score among the aforementioned variables.

Attendance to class = 25%

Regularity to school = 20%

Result Submission timeline = 25%

Paper publications and membership to professional bodies = 30%

Appraisal Score = Attendance to class score (S_a) + Regularity to school core (S_r) + Result Submission score (S_s) + Paper publication score (Sp).

Since each of the variables is expressed in percentage, we need to reduce each so that each variable represents the distribution stated above.

Hence,

Appraisal Score = $0.25*S_a + 0.20*S_r + 0.25* S_s + 0.30*Sp$ ... equation 3.10

3.4. Development of the system

Figure 1 shows the High-Level Model (HLM) of the proposed system, a top-down design specification of those modules and sub-modules identified for the Real-time staff monitoring and evaluation system needs to read the GPS location of the staff during daily clocking and each time the lecturer clicks on start lecture. It needs this data to verify that the staff is within the geo-fence for the lecture sessions. It is also necessary for validating daily attendance. The communication between the staff mobile device and the web server is done through Hypertext Transfer Protocol (HTTP), and every transmitted data is represented in JSON (JavaScript Object Notation) format.

The back-end application is structured to follow the single dependency principle, giving priority to security, scalability, testability and code maintainability. This involved separating the client-facing controller classes from the business logic of the service classes and also the database-facing repository interfaces. Each controller and service class are implementations of the corresponding interface, ensuring that the application's core functionality is hidden from the outside world.

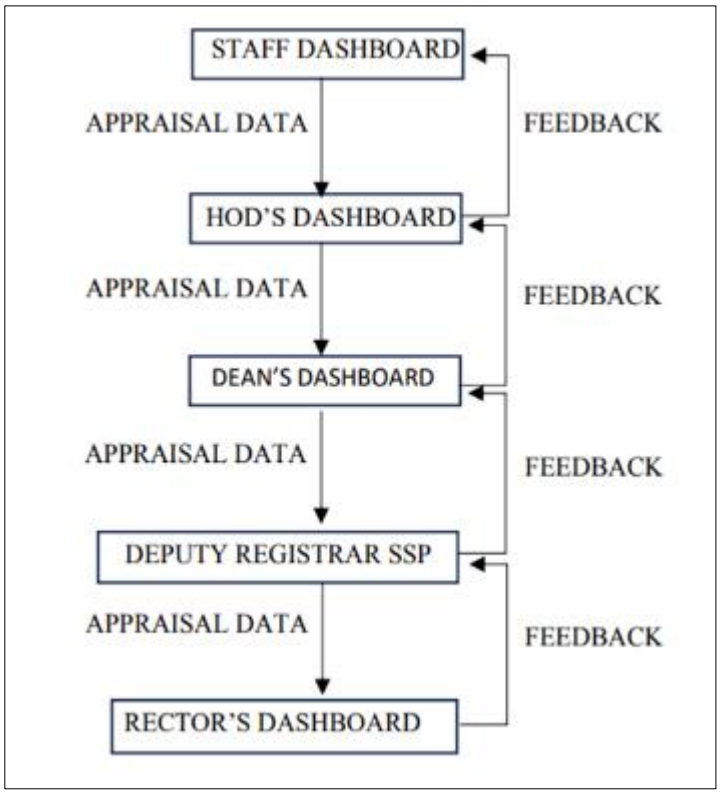

Figure 1 High-Level Model of the Proposed System

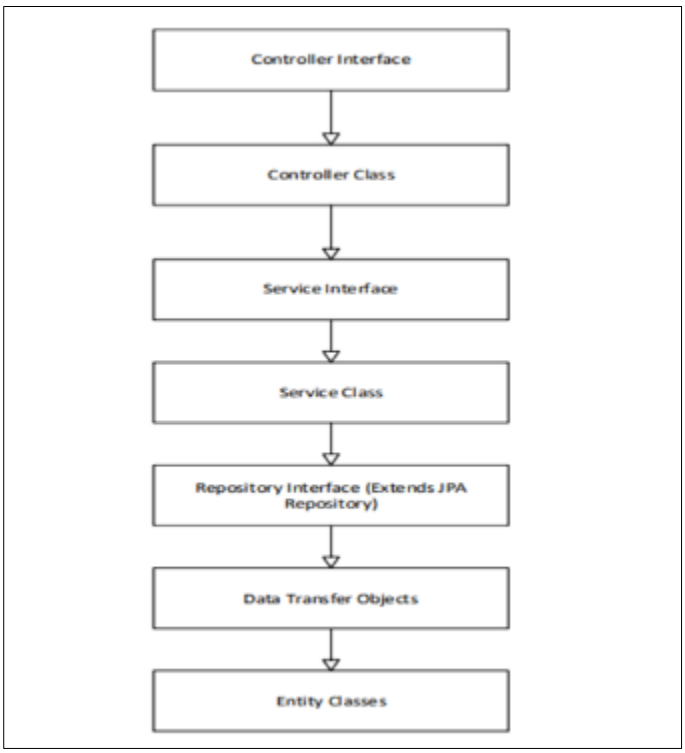

Figure 2 Structure and application of Source Code

The entity classes represent the database tables, each entity corresponding to a table. The fields of the entities translate to columns on the tables, while each object of the entity constructed forms a row in the table.

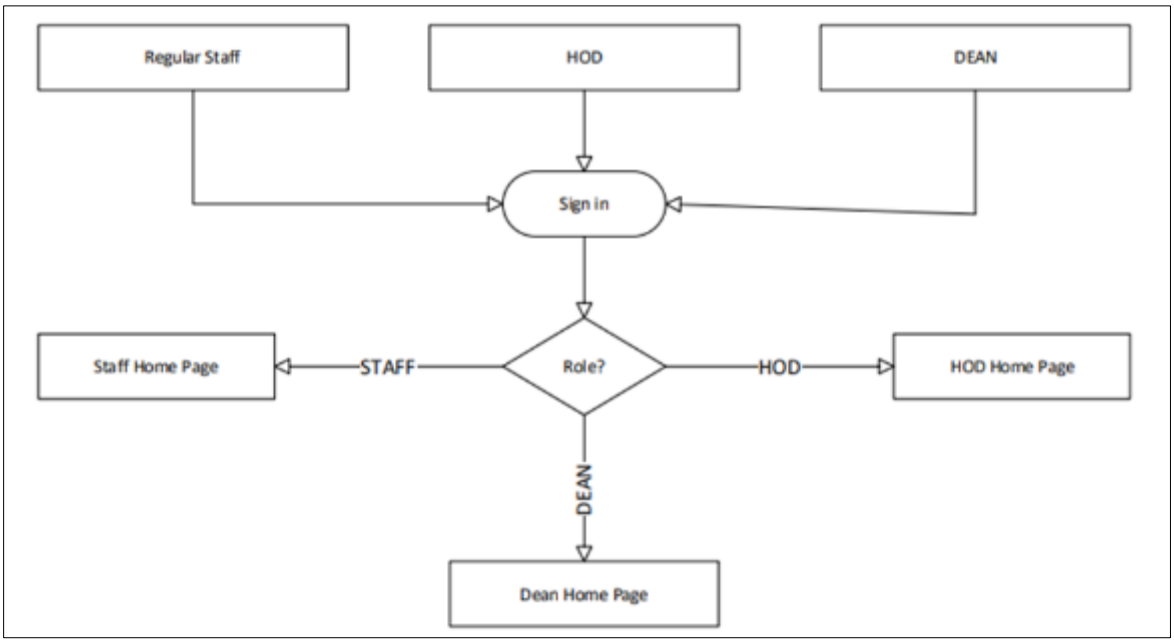

Figure 3 Client-side Access Control Policy

Role-based access level control policy was put in place on the front-end (client) side to ensure a seamless authentication process. The application queries the HTTP response from the authentication request for the role of the authenticated user, and hence, decides on which screen to navigate the user to. This robust Authentication System will be implemented to protect unauthorized access to the system. This will also ensure that each academic staff has unique authentication details and hence no staff will be able to access the dashboard of another staff. The figure below depicts a Data Flow Diagram of the user interaction with the web interface from authentication to activities within the staff dashboard.

4. Results and discussion

4.1. Location permission

Figure 4 shows that the systems successfully request for user location permission as expected, the user is expected to grant this permission. Figure 5 show how the system notifies the staff when they try to access the system from outside the set perimeters of the institution, and figure 6 shows the real-time location information of the staff with its latitude and longitude components.

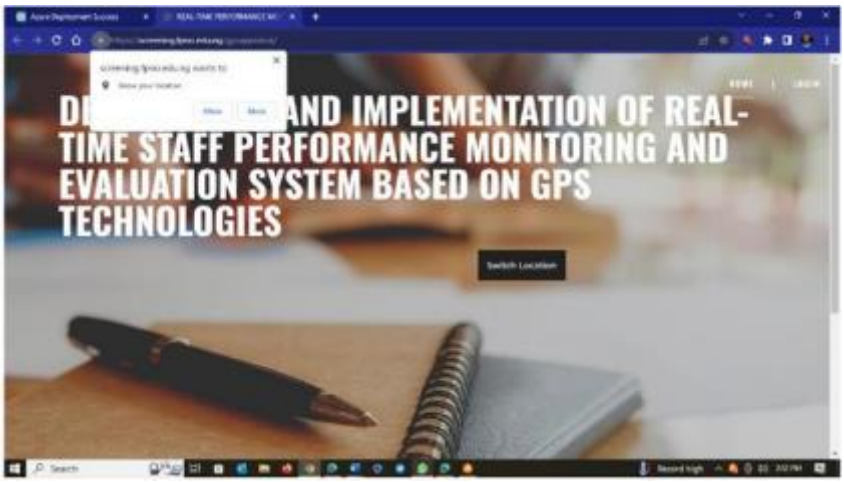

Figure 4 The Landing page showing location permission request.

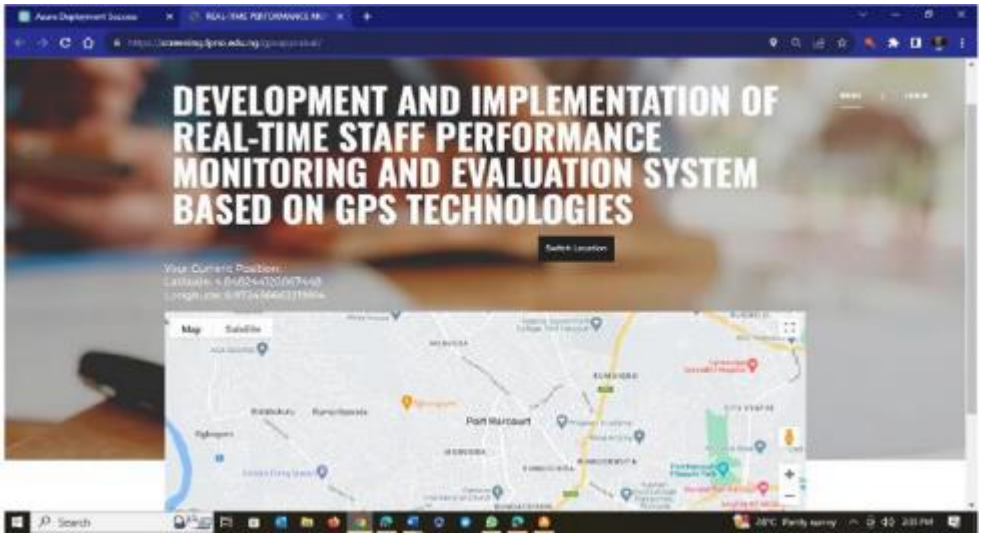

Figure 5 The Landing page showing that the staff is not within the perimeter of the institution

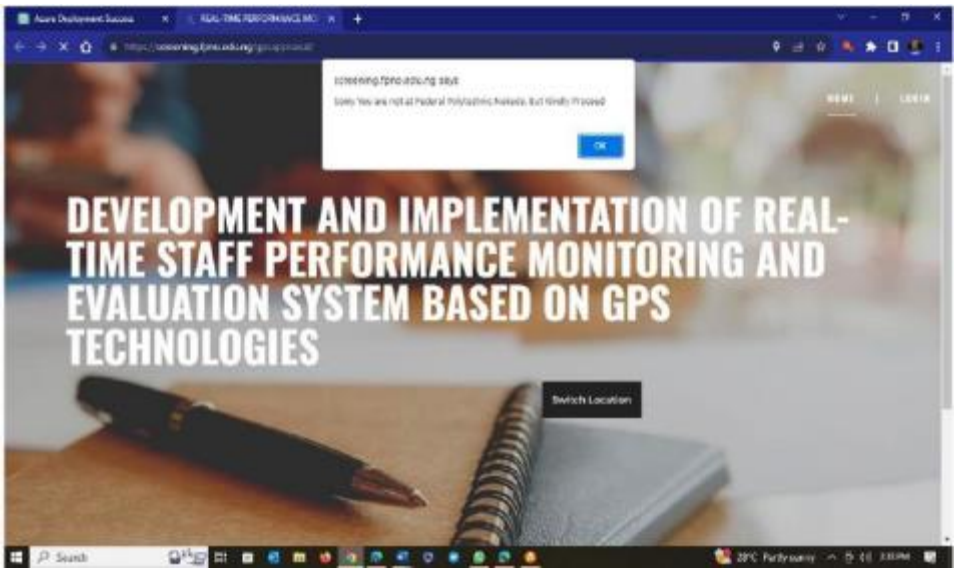

Figure 6 The Landing page showing the real-time location coordinates of the staff.

4.2. Staff dashboard

The staff dashboard is the landing page for regular staff after successful authentication. It contains links to the different actions that a member of staff can take. This includes link to biodata form, class attendance, upload of conference papers, industry certifications, journal papers etc, appraisal score acceptance and rejection, among other things.

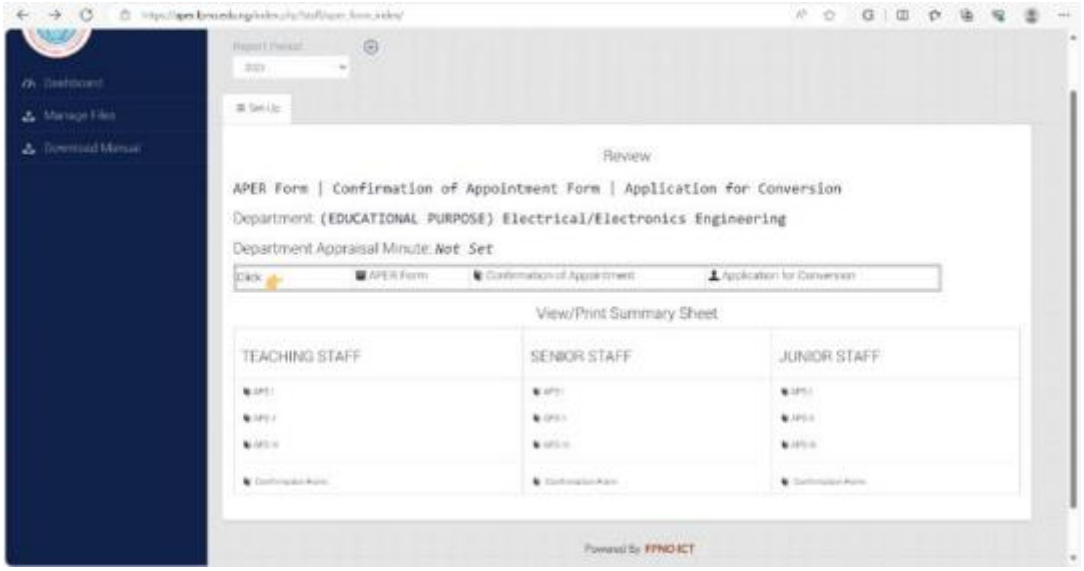

Figure 7 Staff Dashboard

4.3. HOD'S and dean's dashboard

As shown in Figure 8, the HOD has the privilege of viewing the details of each staff's appraisal form. This is to enable him to make an objective assessment of the data provided by the staff. To do this, he clicks "Aper Form" at the left pane of the web page. This presents the comprehensive list of the appraisal form of the staff under review to him as shown below.

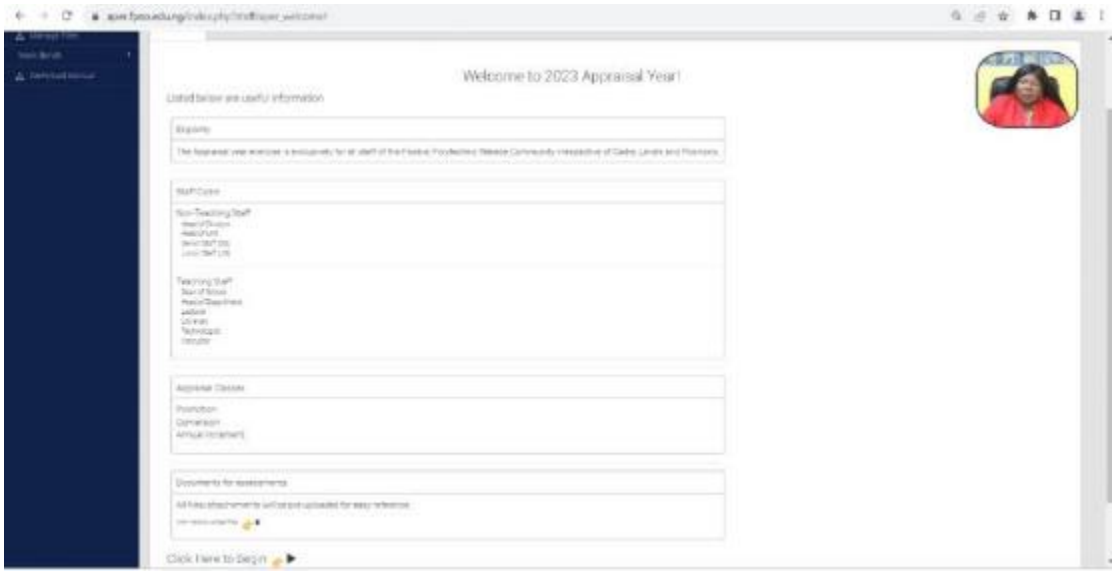

Figure 8 HOD's dashboard

To view the comprehensive appraisal form for each staff, the HOD clicks "Review". This is illustrated in Figure 9. A sample screenshot of the comprehensive appraisal status form is shown in Figure 10.

After the location permission is granted by the staff, the system reads the Geo location data and if you are outside the geo-fence of the institution, a pop-up is shown to the staff, stating that he is outside the perimeters of the institution. This brings to the knowledge of the staff that his attendance clocking cannot be recorded from that location. This justifies the ability of the system to generate an accurate attendance record of all staff. The same notification is also thrown when the user refuses to grant permission for location data. The staff must close this pop-up to be able to continue. If, however the staff is within the perimeters of the of the institution, no pop-up is thrown and the staff is instantly permitted to click the "Sign in" button.

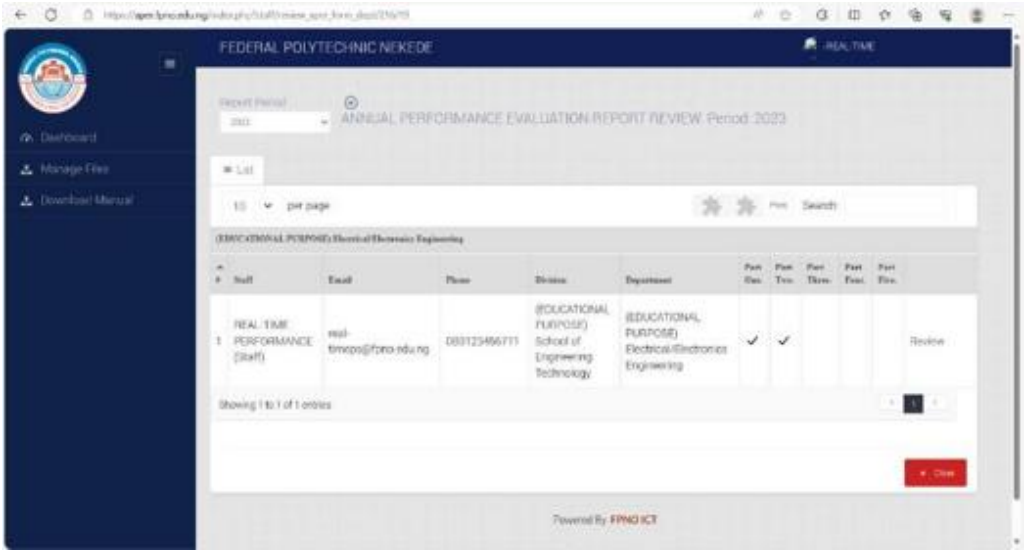

Figure 9 HOD's view of staffs' appraisal forms

The system continually aggregates and cumulates the staff's appraisal score and stores it in the database. Each time a staff uploads a new document, a notification is sent to the HOD. When the HOD validates the document, the staff's score is updated with the accrued score which is based on the policy discussed in chapter three. Similarly, the score for attendance to classes accumulates each time the staff indicates his presence in scheduled lecture sessions and the same is affirmed by the required number of students as specified in the appraisal policy.

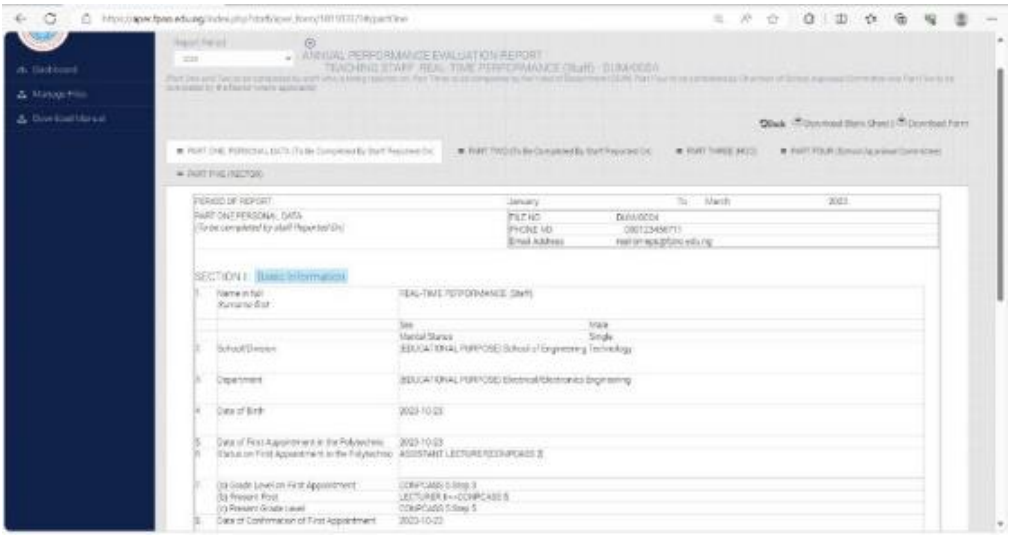

Figure 10 Comprehensive staff appraisal form as seen by HOD and Dean

Every staff is expected to log into their dashboard upon arrival at the institution. The system then automatically documents the GPS location and time of time of arrival of such staff. It is noteworthy to state that only authentication from within the institution's geo fence is regarded as valid. Upon successful authentication, the system compares the staff's Geo location with the coordinates of the institution and if valid, the score is updated in the database. More so, the staff is notified via a pop-up if authentication happens outside the perimeter of the institution. Since Results are submitted directly to the ERP portal of the institution, this real-time staff performance monitoring and evaluation system was designed to retrieve the result submission data from the institution's ERP portal through an exposed API.

5. Conclusion

By developing a holistic appraisal policy, ensuring that all critical key performance indicators were considered in the evaluation of staff, for accurate appraisal and the successful development of software implementation of the appraisal

framework, using PHP, MySQL, and HTML/CSS, resulting in a fully functional cloud-based software system, this work developed a unique and comprehensive performance metrics that consider multiple facets of academic staff roles, including teaching, research, administrative duties, and student interactions.

The innovative integration of GPS technology into the academic staff performance evaluation process, this work introduces a novel dimension to the assessment of academic staff activities, moving beyond traditional methods.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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