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Optimization of Access Control in Private Educational Institutions: An Approach with Geolocation and Biometrics Using Mobile-D

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Abstract. This paper addresses the application of the Mobile-D methodology in an educational setting, motivated by the need for efficient software to comprehensively manage faculty access registration. The lack of adequate technological solutions has limited the optimization of this process, generating inefficiencies in both time and cost. The main objective was to evaluate the effectiveness of Mobile-D in improving faculty access procedures, with particular emphasis on reducing registration times and decreasing associated administrative costs. To address this problem, a pure experimental and quantitative approach was employed, analyzing the impact of Mobile-D. The study population included all access processes carried out by faculty members, with a sample of 30 cases used for testing. Technologies such as Firebase, a NoSQL database manager, and the OpenCV library, used to develop a facial detection algorithm, were integrated. The results demonstrated significant improvements in operational efficiency, confirming the potential of Mobile-D to transform educational processes. A considerable reduction in both time and costs was observed. However, practical challenges also emerged, such as the need to optimize facial recognition through pretrained models and to explore automatic geolocation to enhance the effectiveness of technology.

Keywords. Mobile-D methodology, operational efficiency, educational processes, facial recognition, geolocation.

1 Introduction

Currently, many educational institutions in the country still manage faculty access control manually. This traditional approach is limited and inefficient, as it relies on processes prone to human error and consumes valuable time in the preparation of monthly reports, whose accuracy is critical for payroll calculations.

The main issue with manual systems lies in their lack of accessibility and the dispersion of information across multiple formats, making it difficult to consolidate reliable data on compliance with schedules and, consequently, restricting the ability of authorities to make sound organizational decisions.

In this regard, Rashid and Strakova [1] proposed a system based on generative artificial intelligence that integrates computer vision and geolocation techniques to optimize remote work environments. Similarly, Victoria Virgil [2] developed a facial recognition system supported by biometric AI, capable of identifying individuals by comparing facial features with databases, applied in areas such as security, surveillance, human-computer interaction, and marketing, though subject to criticism for its ethical implications. In a different context, Thiel [3] examined the integration of biometric technologies in centralized population data systems, highlighting the institutional tensions and negotiations observed through ethnographic fieldwork. Likewise, Abuhamad and collaborators [4] explored continuous authentication strategies in mobile devices through behavioral biometrics captured by embedded sensors, emphasizing approaches based on motion patterns, keystroke dynamics, touch gestures, voice, and multimodal methods. Finally, Jansen, Sánchez, and Dencik [5] analyzed the use of voice biometrics in Europe, identifying it as the third most relevant biometric database for Interpol, and underscoring its implications for justice and surveillance.

Complementarily, Zainul and colleagues [6] proposed an innovative solution for workplace management by integrating facial recognition, geofencing, and blockchain in a cross-platform mobile application, which enhanced system accuracy, security, and transparency. Along similar lines, Lee and his research team [7] developed an autonomous access control system based on facial recognition, employing the LBP-AdaBoost framework for detection and a modified Gabor-LBP model for recognition, in order to overcome limitations caused by lighting variations. Likewise, Ukamaka and his research group [8] designed a biometric attendance system supported by facial recognition, developed in Android with Kotlin and TensorFlow, which automated attendance control and improved accuracy, efficiency, and security. Finally, Babatunde and his coauthors [9] implemented a school attendance management system combining geofencing and facial recognition through Google and Firebase technologies, achieving process automation and increased reliability in attendance recording.

In addition, Ahmed and Hussain [10] proposed an authentication scheme for mobile environments based on fingerprints, implemented in Android smartphones through a challenge–response process, whose performance demonstrated improvements in usability and security. Similarly, Hadžimehanović and his team [11] developed a facial recognition–based access control system oriented toward attendance automation and intruder detection, supported by MongoDB storage, which enhanced institutional management and security in educational settings. Pujol and collaborators [12] designed a facial recognition system supported by the HOG descriptor with added entropy, aimed at preventing spoofing attempts, achieving significant advances in accuracy and robustness against standard databases.

Along the same lines, Talha and his colleagues [13] presented a mobile biometric attendance system integrating cloud-based databases offering an efficient, low-cost, and accessible alternative for educational institutions. On another front, Kowshika and his research group [14] proposed a security model for ATMs that combines access cards with facial recognition using convolutional neural networks, increasing protection against fraudulent activities. The study conducted by Ocampo and his research team [17] analyzed the usefulness of a mobile application as a support and complementary tool for teaching processes in educational institutions. The research demonstrated that such technological resources can be effectively integrated in comparison to traditional or current methods. Finally, [31] conducted a review of 92 papers on the application of computer vision and augmented reality to support the mobility of people with visual disabilities, highlighting recommendations relevant to the development of future technological solutions related to geolocation and biometric control.

The review of prior studies reveals a consensus regarding the need to migrate from manual and fragmented systems to automated, biometric, and AI-based solutions capable of ensuring accuracy, security, and efficiency in access management. Although various studies have demonstrated

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progress in the integration of facial recognition, geolocation, blockchain, behavioral biometrics, and cloud storage, their application in the educational domain remains limited and, in many cases, experimental.

This gap contrasts with the problems diagnosed in national educational institutions, where manual practices persist, directly affecting the transparency of records, the reliability of reports, and the strategic decision-making process.

In this sense, it is necessary to develop proposals that adapt and integrate recent technological innovations to the specific context of educational institutions, in order to optimize access management, strengthen administrative processes, and contribute to organizational security. Thus, this research is justified as it addresses a real and critical issue while seeking to provide a viable and contextualized solution, supported by modern approaches to biometric control and geolocation.

The objective of this research is to develop and evaluate a mobile application that integrates geolocation and biometric control in order to optimize access and attendance management of faculty members in a Peruvian educational institution. The proposal aims to enhance security, accuracy, and efficiency in identification and verification processes, responding to the need for modernization and operational optimization demanded by the educational sector.

Regarding the structure of this paper, it is organized into six main sections. The second presents the contextual analysis and technologies that underpin the study, while the third describes the methodological approaches applied to ensure rigorous scientific development. The fourth section details the implementation of the solution, supported by the Mobile-D methodology.

The experimental results and their comparison with prior studies are presented in the fifth section, highlighting similarities and differentiating contributions. Finally, the sixth section presents the conclusions, where the findings are synthesized, the scope of the project is discussed, and recommendations for future research are proposed.

2 Theoretical Background

2.1 Geolocation and Biometric Control

The integration of geolocation with biometric systems constitutes an advanced solution to strengthen institutional management and security mechanisms across various contexts. In the educational domain, this combination enables the optimization of access control, attendance verification, and space protection, ensuring more reliable and efficient processes. A study by Rashid and Strakova [1] demonstrated that the convergence of generative artificial intelligence, biometric sensors, and geolocation in immersive environments significantly improves personnel management and interactions with control systems.

Complementarily, Zainul and other authors [6] highlight that the incorporation of advanced technologies—such as geolocation, facial recognition, and blockchain—into workforce management systems provides substantial benefits in terms of accuracy, security, and transparency. Collectively, this evidence confirms that the combined application of geolocation and biometrics not only addresses current needs for control and security in educational institutions but also capitalizes on recent technological advances to deliver more comprehensive, scalable, and robust solutions.

2.2 Personnel Access Process

Within the framework of institutional management, personnel authentication and access control processes have become critical components to ensure both security and operational efficiency in organizations of different sizes and sectors. The evolution of these processes has been driven by the need to reduce fraud risks, optimize resource utilization, and improve time management. According to Hadžimehanović and his colleagues [11], manual access control systems present substantial limitations, reflected in recurring errors, low efficiency, and security vulnerabilities.

In response, automation emerges as a mechanism capable of increasing accuracy, reducing failures, and improving institutional

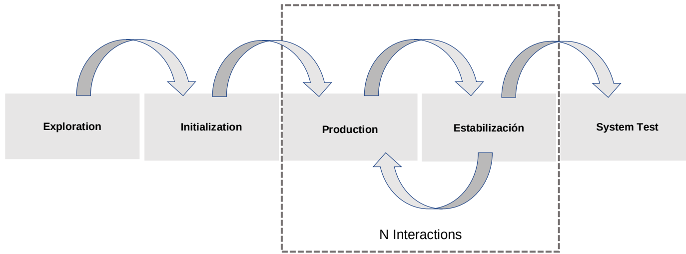

Fig. 1. Mobile-D Methodology

Table 1. Operationalization of the Dependent Variable

Indicator	Index	Unit of Measurement	Unit of Observation
Access Registration Time	[300 – 420]	Seconds	Manual review
Report Generation Time	[30 – 45]	Minutes	Manual review
Teacher Absenteeism Rate	[0 – 30]	Percentage	Manual review
Report Issuance Costs	[20 – 35]	Soles	Manual review
Teacher Satisfaction Level	Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree	Likert scale	Survey

management. In a similar line, Talha and his research team [13] emphasize that attendance management has progressively transitioned from manual schemes to technological solutions, driven by the lack of accuracy and reliability of traditional methods. In this sense, the shift toward automated systems responds to the need to overcome the limitations of conventional processes, offering faster, safer, and more reliable alternatives.

Incorporation of advanced technologies into access control allows for the establishment of more robust management models, aligned with contemporary standards of security and operational efficiency.

3 Research Method

This section clearly describes the methodology employed, covering the process from data collection to data analysis, in order to ensure the validity and reliability of the results.

The methodological approach adopted seeks to guarantee that the findings reflect the stated objectives and contribute to the body of knowledge on geolocation and biometric control in educational institutions, while also ensuring replicability and academic relevance.

3.1 Mobile-D Methodology

Mobile-D is an agile methodology designed for the development of mobile applications, originating in Finland in 2004. Its approach is based on iterative cycles and agile phases that allow for rapid adaptability, particularly in small teams, fostering both efficiency and flexibility throughout the development process (see Figure 1).

In the **Exploration** phase, key stakeholders are identified, expectations and scope are defined, and the development team is established. The **Initialization** phase comprises the definition of the architectural model, the development of use cases, and the preliminary design of the user interface. The **Production** phase encompasses the deployment of the application, organized into one planning day, one launch day, and several days of iterative development. During the **Stabilization** phase, components are integrated and verified to ensure system consistency. Finally, in the **Testing** phase, the robustness and functionality of the application are validated, correcting errors according to client requirements before its final release.

3.2 Applied Research Methodology

This section describes the methodological design adopted, detailing the techniques employed, the analyses performed, and the criteria considered, with the aim of clarifying the approach followed in the study and ensuring the validity of the results.

3.2.1 Operationalization of Variables

Table 1 presents the operationalization of the indicators corresponding to the dependent variable: Faculty Access Process.

3.2.2 Research Design

The study is framed within a pure experimental design, establishing two clearly differentiated groups: the Experimental Group (Ge), in which the mobile system will be applied, and the Control Group (Gc), which will not receive such application. The experimental stimulus (X) will be implemented exclusively in the Ge, with the purpose of addressing the issues identified in the faculty access process. The evaluation will be carried out through post-test indicators (01 for the Ge and 02 for the Gc), which will allow for direct comparisons and precise determination of the intervention's impact.

RGe	X	O_1
RGc	--	O_2

3.2.3 Population and Sample

The study focuses on faculty access processes in private and public primary and secondary educational institutions in Spanish-speaking countries. Since it is not possible to determine the total number of such processes, the population is considered indeterminate. For the purposes of the research, a sample of 30 access processes was defined, corresponding to the Institución Educativa Particular María Montessori. The choice of this sample size is supported by the applicability of Student's t-test, which is suitable for samples of 30 elements or fewer and allows for the comparison of means between two independent and normally distributed populations. This justification is consistent with the statement by Pande in The Six Sigma Way (McGraw-Hill, 2004, pp. 135–136).

3.2.4 Data Collection Procedure

Two complementary data collection procedures were applied in the research. First, systematic or structured direct observation, which consisted of the organized and controlled recording of specific events or behaviors related to the access process, using previously designed observation sheets. Second, indirect observation was employed, understood as documentary review and analysis, aimed at gathering information from institutional records and other relevant documents. As in the previous case, the information was recorded in observation sheets, thus ensuring uniformity, traceability, and reliability in the management of collected data.

3.2.5 Hypothesis Statement

In this study, hypotheses were formulated to contrast the critical processes associated with faculty access. These are:

H_1: If Geolocation and Biometric Control are used, applying the Mobile-D methodology, then the access registration time for the Faculty Access Process at Institución Educativa Particular María Montessori will be reduced.

H_2: If Geolocation and Biometric Control are used, developed with the Mobile-D methodology, then the report issuance costs in the Faculty Access Process at Institución Educativa Particular María Montessori will be reduced.

H_3: If Geolocation and Biometric Control are used, applying the Mobile-D methodology, then the teacher absenteeism rate in the Faculty Access Process at Institución Educativa Particular María Montessori will decrease.

H_4: If Geolocation and Biometric Control are used, applying the Mobile-D methodology, then the time required for report generation in the Faculty Access Process at Institución Educativa Particular María Montessori will decrease.

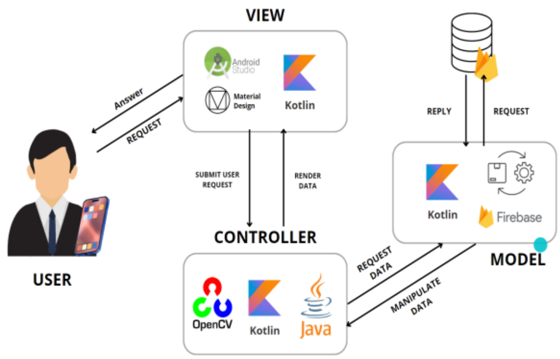

Fig. 2. Software Architecture

Table 2. Tools for System Development

Stakeholder	Role
Android Studio	IDE environment
Kotlin	Programming language
Java	Programming language
OpenCV	Image processing library
Firebase	No-SQL Database Manager

Table 3. List of System Requirements

Code	Detail of the Requirement
RQF01	The system must register new users based on their email and password.
RQF02	The system must validate if the user is already registered in the system.
RQF03	It is essential that the system verify the user's current location.
RQF04	It is essential that the system, based on location, validates whether the user is within the institutional campus to be able to register their attendance, in addition to checking through the biometrics of their face if it matches the user who has logged in.
RQF05	It is important that the system also records the teacher's departure times, applying the same geolocation and biometric control validations.
RQF06	The system must calculate the hours worked by each teacher per day.
RQF07	The system will generate a report in PDF.
RQF08	The system must allow viewing the user's basic information, as well as allowing its editing.
RQNF01	The system must be made up of the representative colors of the institution.
RQNF02	The system must be developed for Android mobile environments.
RQNF03	The scalability of the system in the future must be prioritized.
RQNF04	The system must work with a datbase in the cloud (Firebase)

H_5: If Geolocation and Biometric Control are used, applying the Mobile-D methodology, then the faculty satisfaction level in the Faculty Access Process at Institución Educativa Particular María Montessori will increase.

To test the hypotheses, solutions were designed to directly evaluate the indicators defined in the study. Each indicator was associated with specific measurement procedures, enabling objective comparisons between the experimental and control groups.

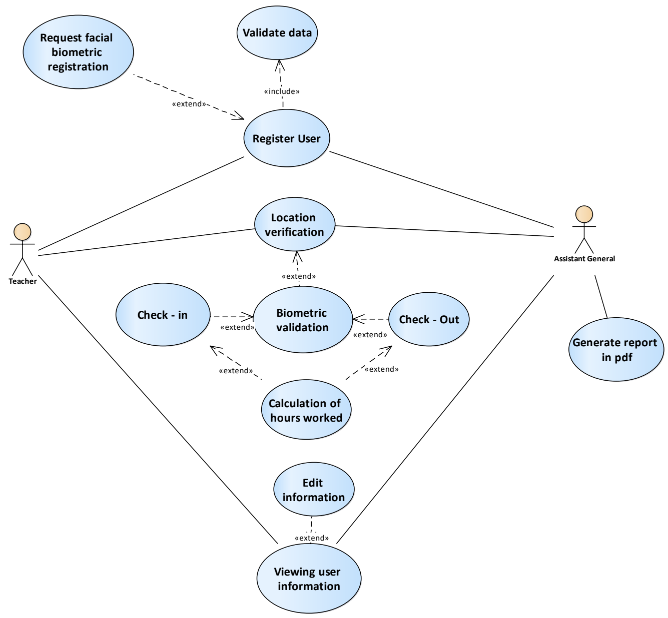

Fig. 3. General Use Case Diagram

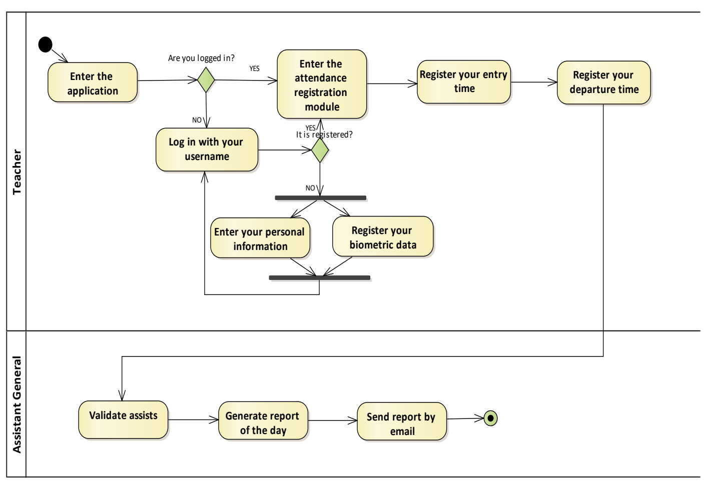

Fig. 4. System Activity Diagram

μ_1 = Population Mean (H1, H2, H3, H4) for the post-tests of the Control Group (Gc),

μ_2 = Population Mean (H1, H2, H3, H4) for the post-tests of the Experimental Group (Ge),

where: $H_o = \mu_1 \leq \mu_2$ y $H_a = \mu_1 > \mu_2.$

On the other hand:

μ_1 = Population Mean (H_5) for the post-tests of the Control Group (Gc)

μ_2 = Population Mean (H_5) for the post-tests of the Experimental Group (Ge)

where: $H_o = \mu_1 \geq \mu_2$ y $H_a = \mu_1 < \mu_2.$

Descriptive and inferential statistics will be applied for hypothesis analysis and testing. In the

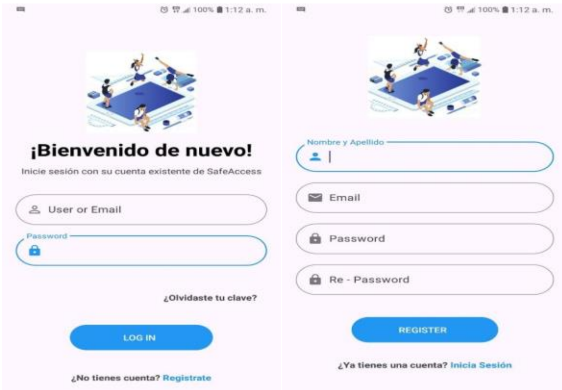

Fig. 5. UI Login and Register

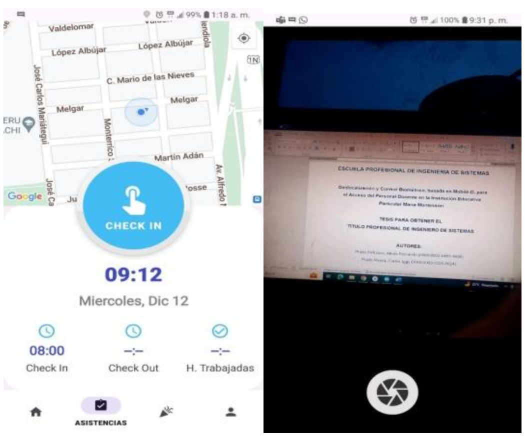

Fig. 6. UI Attendance and Biometrics

descriptive stage, graphical representation of frequency distributions will be employed, along with the calculation of measures of central tendency and dispersion. In the inferential stage, Student's t-test will be used on randomly selected samples, provided the dependent variable meets the assumption of normality. Otherwise, non-parametric tests will be applied, specifically the Mann–Whitney U test, in order to compare sample means and ensure the validity of the results.

4 Case Study

For the development of the case, the Mobile-D methodology was applied, structured into five execution phases that enable an agile and organized process.

4.1 Exploration and Scope Specification

In this stage, the scope of the project was defined, aimed at establishing indicators to measure the improvement of the faculty access process. The criteria considered include: access registration time, costs associated with report issuance, time required for report generation, faculty satisfaction level, and absenteeism rate. These aspects constitute key parameters for evaluating the efficiency, effectiveness, and impact of the proposed system on the optimization of the overall process.

4.2 Initialization

In this phase, the system architecture was defined and the tools required for software development were identified, along with the system's functional and non-functional requirements.

4.2.1 System Architecture

The proposed architecture reflects the internal structure of the software and the interaction between its main components. The Model–View–Controller (MVC) pattern is adopted, which separates business logic, user interface, and data management, thus ensuring a modular, scalable, and maintainable design. Figure 2 shows the overall composition.The user interacts with the mobile application (View), developed in Android Studio with Kotlin and Material Design. The Controller manages user requests using Kotlin, Java, and the OpenCV library for biometric processing, while the Model is responsible for data manipulation and storage in Firebase. This approach facilitates the integration of geolocation and biometric control within a reliable and secure environment.

4.2.2 Development Environment

The development environment comprises the set of tools and technologies employed for building the mobile application.

Table 2 presents a detailed description of each resource used, specifying its function and

ISSN 2007-9737

Table 4. Post-test results for Gc and Ge

I1: Access Registration Time (sec.)		I2: Report Generation Time (min.)		I3: Teacher Absenteeism Rate (%)		I4: Report Issuance Costs (S/.)		I5: Teacher Satisfaction Level	
Post-Test Gc	Post-Test Ge	Post-Test Gc	Post-Test Ge	Post-Test Gc	Post-Test Ge	Post-Test Gc	Post-Test Ge	Post-Test Gc	Post-Test Ge
288	148	33	10	4.17	0.00	24	10	Neither Agree nor Disagree	Agree
270	220	37	8	25.00	8.33	30	1	Agree	Strongly Agree
273	177	41	5	16.67	16.67	31	4	Neither Agree nor Disagree	Strongly Agree
262	140	43	5	8.33	4.17	28	5	Neither Agree nor Disagree	Agree
240	177	41	9	12.50	8.33	27	4	Agree	Strongly Agree
300	165	38	6	25.00	12.50	33	7	Neither Agree nor Disagree	Strongly Agree
240	180	33	9	29.17	12.50	26	2	Agree	Strongly Agree
287	234	31	5	4.17	4.17	34	14	Neither Agree nor Disagree	Strongly Agree
291	277	37	8	20.83	16.67	27	8	Neither Agree nor Disagree	Strongly Agree
240	155	37	3	20.83	20.83	34	7	Agree	Strongly Agree
230	170	38	5	25.00	8.33	21	2	Disagree	Strongly Agree
245	112	39	9	20.83	20.83	28	10	Neither Agree nor Disagree	Strongly Agree
260	180	36	6	29.17	12.50	22	15	Disagree	Strongly Agree
270	240	35	7	16.67	12.50	32	3	Neither Agree nor Disagree	Strongly Agree
278	226	33	3	20.83	16.67	29	5	Neither Agree nor Disagree	Strongly Agree
286	238	34	8	16.67	8.33	27	2	Neither Agree nor Disagree	Strongly Agree
240	180	35	7	0.00	0.00	28	13	Neither Agree nor Disagree	Agree
300	240	36	6	4.17	4.17	33	5	Disagree	Strongly Agree
240	180	34	9	20.83	12.50	31	7	Disagree	Agree
288	196	37	3	16.67	4.17	23	2	Neither Agree nor Disagree	Agree
240	210	38	7	8.33	0.00	25	8	Disagree	Strongly Agree
222	178	34	4	29.17	12.50	22	3	Neither Agree nor Disagree	Strongly Agree
276	174	33	9	12.50	8.33	27	6	Neither Agree nor Disagree	Agree
250	240	32	3	25.00	12.50	32	9	Neither Agree nor Disagree	Strongly Agree
269	203	31	6	16.67	8.33	24	6	Neither Agree nor Disagree	Agree
268	241	42	7	16.67	4.17	31	4	Neither Agree nor Disagree	Strongly Agree
267	204	34	6	12.50	8.33	26	1	Agree	Strongly Agree
259	233	42	4	8.33	4.17	20	15	Agree	Agree
291	180	37	6	12.50	8.33	31	13	Neither Agree nor Disagree	Strongly Agree
260	233	43	5	8.33	0.00	20	7	Agree	Agree

relevance within the implementation process. This systematization ensures methodological transparency and facilitates the replicability of the project in future studies or similar applications.

4.2.3 System Requirements

After selecting the development tools, meetings were held with the stakeholders to define the

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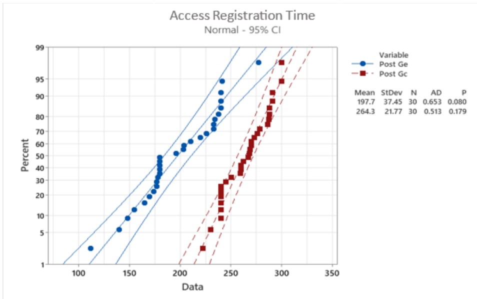

Fig. 7. Normality Test for Indicator I1

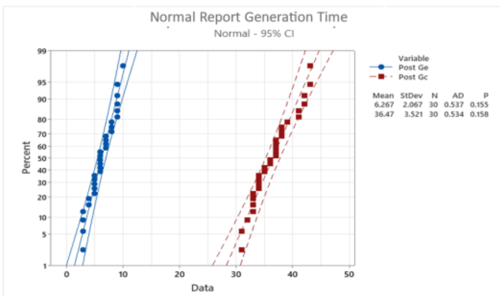

Fig. 8. Normality Test for Indicator I2

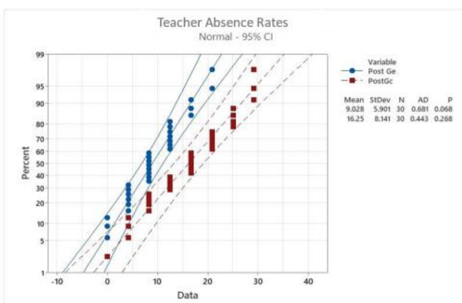

Fig. 9. Normality Test for Indicator I3

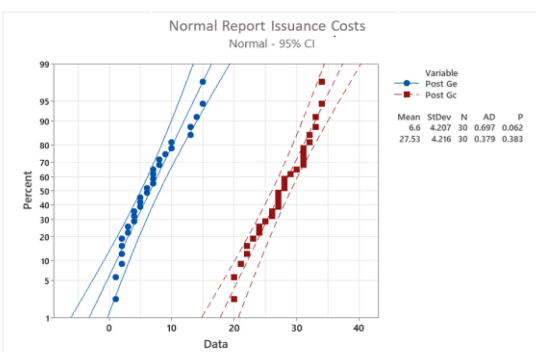

Fig. 10. Normality Test for Indicator I4

system requirements. These correspond to the functions and features demanded by the client in accordance with institutional needs. The list includes both Functional Requirements (RQF), which describe the essential operations of the application, and Non-Functional Requirements (RQNF), which establish attributes of quality, usability, and scalability. Table 3 summarizes the set of requirements defined for the system.

The project documentation included the identification of the main use cases and the detailed definition of the process flow associated with faculty access. This stage made it possible to structurally represent the interactions between users and the system, specifying the actions, validations, and expected outcomes.

– General Use Case Diagram.

Figure 3 illustrates the General Use Case Diagram, which summarizes the main functionalities of the proposed system. It highlights the biometric registration process, user authentication, location verification, and the generation of reports, as well as complementary functionalities such as editing and viewing user information. This diagram provides a clear view of the scope of the system and its interaction with users.

– Activity Diagram.

Figure 4 presents the System Activity Diagram, which details the dynamic behavior of the system from user login to report generation. It specifies the sequence of actions, decision points, and validations required to complete the processes of check-in, check-out, and attendance reporting. This representation makes it possible to identify the workflow logic and to ensure that all user-system interactions are consistent and efficient.

4.3 Production

During this phase, prototypes of the system views were developed, aimed at graphically representing the interaction between the user and the application. The application includes a login screen that allows faculty members to access the system using email and password, complemented by a registration form for new users, which enables the storage of their basic data in the institutional database (Figure 5).

The attendance control screens integrate real-time geographic location with the recording of working hours, while the facial biometric validation module ensures user authentication through face recognition (Figure 6).

4.4 Stabilization

In the stabilization stage, the aim is to integrate and harmonize the different subsystems or modules developed, in order to guarantee their joint operation.

However, in the present project, no team-based integration was necessary, since the development was carried out individually, which made it possible to maintain a coherent and unified structure throughout the entire process.

4.5 System Testing

In the final stage, tests were conducted to validate the correct functioning of the software. Pilot tests were applied to verify the system’s effectiveness under real usage conditions and, at the same time, to identify potential limitations or errors.

The results obtained in this phase were decisive for making the necessary adjustments before delivering a first functional product to the client.

5 Results and Discussion

This section presents the findings obtained after the implementation of the mobile system based on geolocation and biometric control, comparing the results of the Experimental Group (Ge) and the Control Group (Gc).

The indicators defined in the study are analyzed, evaluating their impact through descriptive and inferential statistical techniques.

Furthermore, the results are discussed in relation to the research objectives and previous literature, in order to determine the effectiveness of the proposal and its contributions to the faculty access process in educational institutions.

5.1 Experimental Results: Reduction of I1, I2, I3, I4 and Increase of I5

Table 4 presents the data obtained after the application of the tests corresponding to the research indicators. These results correspond to the post-tests carried out both in the control group and the experimental group, and were fully collected through observation sheets, ensuring the validity and reliability of the records.

For the quantitative analysis of the indicators, the following formulas were used:

– Access Registration Time (ART):

$$ART = TR + TE + 10s. \quad (1)$$

– Report Generation Time (RGT):

$$PRGT = TV + TD + 5\ min. \quad (2)$$

– Absenteeism Rate (AR):

$$AR = \left(\frac{AI}{TA}\right) \times\ 100. \quad (3)$$

– Report Issuance Costs (RIC):

$$RIC = GUO + GA + GI. \quad (4)$$

5.2 Normality Test

Normality tests were performed on the post-test results corresponding to each indicator, with the purpose of determining whether the data fit a normal distribution and, consequently, defining the applicability of parametric or non-parametric tests in the inferential analysis. The results obtained are presented in Figures 7, 8, 9, and 10.

For I1: Access Registration Time.

For I2: Report Generation Time.

For I3: Faculty Absenteeism Rate

For I4: Report Issuance Costs

In summary, the results show that for all indicators, both in the Control Group (Gc) and the Experimental Group (Ge), the p-values exceeded the established significance level ($\alpha = 0.05$). Consequently, it is concluded that the data fit a normal distribution, thereby validating the use of parametric tests in the inferential analysis.

Table 5. Results of descriptive statistics

Sample	N	Mean	StDev	AD	p-value
I1: Post-Test (Gc)	30	264.3	21.77	0.513	0.179
I1: Post-Test (Ge)		197.7	37.45	0.653	0.080
I2: Post-Test (Gc)	30	36.47	3.521	0.534	0.158
I2: Post-Test (Ge)		6.267	2.067	0.537	0.155
I3: Post-Test (Gc)	30	16.25	8.141	0.443	0.268
I3: Post-Test (Ge)		9.028	5.901	0.681	0.068
I4: Post-Test (Gc)	30	27.53	4.216	0.379	0.383
I4: Post-Test (Ge)		6.6	4.207	0.697	0.062

Table 6. Summary of indicator values

Sample	N	95% Confidence Interval for the Mean	Kurtosis	Skewness	Q3
I1: Post-Test (Ge)	30	183.72 – 211.68 seg.	-0.347571	-0.070787	233.25
I2: Post-Test (Ge)	30	5.4949 - 7.0384 min.	-0.959208	-0.006957	8.00
I3: Post-Test (Ge)	30	6.8243% - 11.2313%	-0.538567	0.231222	12.5
I4: Post-Test (Ge)	30	5.0292 y 8.1708 S/.	-0.510338	0.652001	9.25

5.3 Discussion of Results: Effect on Faculty Access Control

Within this section, both a descriptive analysis and an inferential analysis of the values obtained in the study are carried out, with the aim of interpreting the impact derived from the data collection.

5.3.1 Using Descriptive Statistics

A descriptive analysis of the samples was performed in order to identify the main trends and characterize the results obtained in the post-tests of the Control Group (Gc) and the Experimental Group (Ge).

Table 5 presents the values of mean, standard deviation (StDev), Anderson–Darling test (AD), and p-value, confirming in all cases the normality of the data ($p > 0.05$).

Complementarily, Table 6 presents the 95% confidence intervals for the means of each indicator of the Experimental Group (Ge), together with the values of kurtosis, skewness, and the third quartile (Q3).

For Indicator I1: Access Registration Time

The Control Group (Gc) presents a mean of 264.3 sec. (StDev 21.77), compared to 197.7 sec. (StDev 37.45) in the Experimental Group (Ge), with $p > 0.05$ confirming normality.

The confidence interval (183.72–211.68) demonstrates consistency in the reduction, with slight skewness (–0.07) and kurtosis close to normal (–0.34). The Q3 value of 233.25 supports that most records remain below the average of the Control Group.

The results of this study are consistent with previous research that reported substantial improvements in registration times through biometric and facial recognition technologies. For example, Tenuche et al. [15] reported a 9.2% reduction in registration times through a biometric student attendance system based on fingerprints.

Similarly, Badmus et al. [16] optimized the registration process by 7.3 minutes using an intelligent biometric management system with fingerprints and RFID. Likewise, Viswanathan et al. [18] achieved a 15% reduction in institutional registration times using facial recognition technology. In the same line, Adamu [19] obtained a 75% reduction in registration times by integrating fingerprint and iris biometrics. Finally, Yang and Han [23] demonstrated that a facial recognition attendance system with real-time video processing reduced registration times by up to 60% compared to manual methods.

The reduction in registration time validates the efficiency of the mobile system compared to the traditional method. Its adoption in other sectors with large-scale entry processes (healthcare, manufacturing, retail) could significantly decrease operational times. At an international level, this result suggests the applicability of the model in institutions with high volumes of personnel and during critical access control periods.

For Indicator I2: Report Generation Time

The Experimental Group (Ge) achieved a mean of 6.27 min. (StDev 2.07), considerably lower than the Control Group (Gc) with 36.47 min. (StDev 3.52), with $p > 0.05$ ensuring normality. The confidence interval (5.49–7.03) confirms the reduction, with skewness close to zero (–0.006) and negative kurtosis (–0.95), indicating a flatter distribution. The Q3 value of 8 min. demonstrates stability in the improvement of processing times.

These findings are closely aligned with previous research that also reported significant reductions in report generation times. For example, Akinduyite's research group [32], in their work *Development of Mobile and Desktop Applications for a Fingerprint-Based Attendance Management System*, showed that their proposed system reduced total time requirements by up to fivefold compared to manual reporting. Similarly, Kurniawan and Alviana [21], in *The Effectiveness of Smart Workinary for Attendance Data Delivery and the Paperless Information System*, reported a 30% reduction in reporting times. In the same line, Adamu [19], using a fingerprint and iris biometric attendance system, achieved a 75% reduction in reporting time. Finally, Balkhi [22], in *Development of an Intelligent Attendance System Using Near-Field Communication*, documented a 31% reduction in report generation times.

The shortening of report generation time strengthens administrative responsiveness. This benefit can be extrapolated to sectors where decision-making depends on fast reporting (banking, logistics). Moreover, it projects future improvements through real-time data integration in institutions within countries with high levels of digitalization in education.

For Indicator I3: Absenteeism Rate

The Experimental Group (Ge) presented a mean of 9.03% (StDev 5.90), reduced compared to the Control Group (Gc) at 16.25% (StDev 8.14), with $p > 0.05$ indicating normality. The confidence interval (6.82–11.23) confirms stability, while positive skewness (0.23) reflects a slight inclination toward higher values. Negative kurtosis (–0.53) indicates a flatter distribution, and a Q3 of 12.5% confirms dispersion control.

The results of this research demonstrate a more significant reduction in absenteeism compared to previous studies. For example, Mir et al. [22], in *The Benefits of Implementing a Biometric Attendance System*, reported only an 8% reduction in work absenteeism, a figure considerably lower than that achieved in this study. Similarly, Yang and Han [23], in *Real-Time Video Processing-Based Facial Recognition Attendance System*, obtained a 13% reduction in student absenteeism. By contrast, Dowden et al. [27], in *The Chronic Absenteeism Evaluation Project in Rural India*, reduced absenteeism by 56.2% by identifying and addressing structural causes. Likewise, Nang, Quang, and Liu [25], through a Deep CNN with self-attention for speaker identification, reported a 55% reduction in absenteeism rates. Finally, Alabdulatif [24], in *A Novel and Robust Multi-Factor Authentication Method Based on Geolocation*, documented a 16% reduction in initial absenteeism rates.

The reduction in absenteeism rates supports the impact of the system on teacher punctuality. This finding can be transferred to companies facing labor absenteeism issues to improve productivity. In geographic contexts with low levels of on-site supervision, the integration of biometrics and geolocation could become a standard mechanism of control.

For Indicator I4: Report Issuance Costs

The Experimental Group (Ge) achieved a mean of 6.6 soles (StDev 4.20), compared to 27.53 soles (StDev 4.21) in the Control Group (Gc), with

Table 7. Hypothesis Testing for Parametric Indicators

Sample	n	Ho	t-value	p-value
I1: Post-Test (Gc) I1: Post-Test (Ge)	30	μ1 ≤ μ2	8.43	0.000
I2: Post-Test (Gc) I2: Post-Test (Ge)	30	μ1 ≤ μ2	40.52	0.000
I3: Post-Test (Gc) I3: Post-Test (Ge)	30	μ1 ≤ μ2	3.93	0.000
I4: Post-Test (Gc) I4: Post-Test (Ge)	30	μ1 ≤ μ2	19.25	0.000
I5: Post-Test (Gc) I5: Post-Test (Ge)	30	μ1 ≥ μ2	496.5	0.000

normality validated ($p > 0.05$). The confidence interval (5.03–8.17) demonstrates reduction, while positive skewness (0.65) indicates a tendency toward higher costs in some cases. Negative kurtosis (–0.51) suggests less concentration around the mean, and the Q3 value of 9.25 confirms sustainable limits.

The literature review identifies studies showing significant reductions in attendance management costs, although with heterogeneous results compared to those obtained in the present research. For instance, Adeniran [29], in *Development of an Intelligent Attendance System Using Near-Field Communication*, reported a 20% cost reduction, considerably lower than the outcome achieved here.

In contrast, Ekowati [30] recorded a 92.5% reduction in attendance reporting costs, while Kurniawan [21] reported a 74.5% decrease in costs associated with access data reporting queries. Similarly, Pang [20] demonstrated that their implementation optimized both costs and operational times. Finally, Viswanathan [18], using a web-based system, achieved an 83% reduction in reporting costs, confirming the effectiveness of digital technologies in resource optimization.

The reduction in costs implies direct and sustained savings for institutional management. This result can be applied to other sectors with recurrent expenses in reporting (banking, auditing). Its international application demonstrates feasibility in institutions seeking economic efficiency and operational cost reduction.

5.3.2 Inferential Statistics: Hypothesis Testing

In this phase, hypothesis tests were conducted to evaluate the impact of the system on the five defined indicators. Table 7 presents the results of the parametric contrasts applied to indicators I1 through I4, while Table 8 displays the values obtained for indicator I5, analyzed using a non-parametric test.

For Access Registration Time (I1):

With n=30, the null hypothesis (μ1 ≤ μ2) was rejected, obtaining a t-value of 8.43 and a p-value of 0.000 (<0.05). This demonstrates significant differences between the Control Group (Gc) and the Experimental Group (Ge). The results confirm that the system statistically reduced registration time.

Viswanathan et al. [18] reported favorable outcomes when implementing a facial recognition system based on video processing, which significantly reduced registration times compared to traditional manual methods. The optimization of registration time validates the system's contribution in educational contexts requiring agile access. This improvement can be extrapolated to healthcare and transportation sectors where entry flow is critical. Moreover, its adoption in countries with high population density could enhance operational efficiency.

For Report Generation Time (I2):

With n=30, the null hypothesis (μ1 ≤ μ2) was also rejected, obtaining a t-value of 40.52 and a p-value of 0.000. This reflects a highly significant effect of the system in reducing reporting times. The contrast confirms that the difference between groups is not attributable to chance.

Adamu [19] reported substantial progress by integrating fingerprint and iris biometric technologies, significantly reducing the time required for institutional reporting. The sharp reduction in reporting times supports the applicability of the tool in administrative management. This result can be transferred to business areas that depend on periodic reports, such as auditing and logistics. Furthermore, in regions where paperwork delays processes, digitalization provides immediate impact.

For Absenteeism Rate (I3):

With n=30, the null hypothesis ($\mu 1 \leq \mu 2$) was rejected, obtaining a t-value of 3.93 and a p-value of 0.000. The result confirms that the Experimental Group (Ge) presented a significant reduction in absenteeism compared to the Control Group (Gc). The parametric test demonstrates the system's effectiveness in this aspect.

Nang, Quang, and Liu [25] highlighted that the use of Deep CNN architectures contributed to reducing absenteeism among staff. The reduction of absenteeism supports continuity in the educational process. This benefit can be replicated in companies to mitigate labor absenteeism. Similarly, in rural areas or contexts with limited on-site supervision, the integration of biometrics and geolocation strengthens attendance monitoring.

For Report Issuance Costs (I4):

With n=30, the null hypothesis ($\mu 1 \leq \mu 2$) was rejected, obtaining a t-value of 19.25 and a p-value of 0.000. This confirms that costs in the Experimental Group (Ge) were significantly lower than those of the Control Group (Gc). The parametric contrast demonstrates sustained savings generated by the system.

Viswanathan [18] concluded that the application of biometric technologies significantly reduced the costs associated with report generation. The cost reduction has a direct effect on institutional financial sustainability. This finding can be extended to sectors with intensive reporting needs, such as banking and insurance. Moreover, in international contexts, it reinforces the feasibility of implementing low-cost solutions to enhance administrative efficiency.

For Teacher Satisfaction Level (I5):

With n=30, the null hypothesis ($\mu 1 \geq \mu 2$) was rejected both in the parametric test (W-value = 496.5; p-value = 0.000) and in the non-parametric test (w-value = 496.5; p-value = 0.000). These extremely high values, with absolute significance, show that the system clearly and robustly increased teacher satisfaction.

Table 8. Hypothesis Testing for the Non-Parametric Indicator

Sample	n	Ho	W-value	p-value
I5: Post-Test (Gc) I5: Post-Test (Ge)	30	$\mu 1 \geq \mu 2$	496.5	0.000

Ekowati [30] demonstrated that the use of fingerprint biometric technologies improved job satisfaction levels. The increase in teacher satisfaction strengthens the acceptance of the tool and its integration into organizational culture. This effect can also be applied in universities and companies seeking to improve employee experience. Furthermore, in other regions or time periods, the combination of biometrics and geolocation could consolidate a more positive work environment.

6 Conclusions and Future Research

The study demonstrated that the implementation of a mobile system based on geolocation and biometrics, developed with the Mobile-D methodology, successfully optimized the indicators. First, regarding Indicator I1, the reduction in access registration time not only represents an operational improvement but also a structural change in institutional management. By achieving significantly lower means in the experimental group, the effectiveness of a model that prioritizes speed and control is consolidated, mitigating the issues of slowness and human error inherent to manual methods.

In relation to Indicator I2, the findings reflect a substantial improvement in report generation, where the experimental group reduced the time by more than fivefold compared to the control group. This result has direct implications for administrative efficiency and projects benefits in areas with immediate reporting demands, such as auditing and logistics.

With respect to Indicator I3, the significant reduction in absenteeism reinforces the system's positive impact on academic continuity. By enabling stricter and more reliable supervision, the technology contributes to strengthening punctuality and compliance among teachers. This

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effect can also be extrapolated to other sectors facing similar challenges in attendance management and personnel control.

Likewise, for Indicator I4, the reduction in reporting costs validates the economic feasibility of the proposal. The savings achieved in the experimental group demonstrate that the initial investment in technology can translate into sustained reductions in operating expenses, generating a positive return in the short and medium term.

Transversally, the integration of results from the four analyzed indicators reveals that combining geolocation and biometric control constitutes an effective and replicable strategy. The system not only optimizes time and costs but also improves data reliability, thereby strengthening institutional decision-making in the educational field. In summary, this paper provides an empirical framework supporting the relevance of modernizing processes through mobile solutions, demonstrating that the Mobile-D methodology can serve as a key tool in the digitalization of educational institutions.

It is recommended to extend the study to multicentric scenarios, assessing the system's effectiveness in institutions across different geographic contexts and educational levels. Finally, future research lines could focus on measuring longitudinal impacts, considering not only operational efficiency but also effects on organizational culture and work climate.

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