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Research Article

Reliability and Accuracy of Fingerprint Biometrics by the End-Users: Basis for Strategic Policy Formulation

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Abstract
Fingerprint biometrics plays a vital role in security and identity management within higher education institutions, especially for attendance tracking and access control of personnel. Although it has been widely adopted, doubts still exist about its accuracy and reliability. This research examines the reliability and accuracy of fingerprint biometrics as perceived by end-users, providing a basis for strategic policy formulation. This research used a descriptive-comparative research design and quantitative research method, utilizing both descriptive and inferential statistical methods for analyzing the data. The study included 146 participants selected through stratified random sampling. The research found that fingerprint biometrics are usually reliable and accurate. However, factors such as device quality, software delay, and power interruption-related concerns can affect how well they work. Based on these findings, the researcher proposes the installation of a good backup power system to help prevent downtime during power interruption, maintain regular software updates and consistent implementation of the fingerprint biometric system for all user groups, and provide continuous institutional encouragement for its utilization as the primary tool for identification and attendance tracking.
Keywords: Fingerprint Biometrics, Reliability, Accuracy, End-Users, Strategic Policy Formulation.

Introduction

With the digital age, strong and reliable security solutions are essential, particularly in the domain of individual privacy and data protection. Fingerprint biometrics has grown to become a significant method in this sector, bringing with it a unique combination of security and convenience. With biometric solutions more deeply embedded in everyday use, from cell phone unlocks to safeguarding sensitive financial transactions, their reliability and effectiveness need more scrutiny.

Fingerprint biometrics relies on variations in the patterns of valleys and ridges on an individual's fingers. These patterns, in theory, are unique to each individual, and fingerprints have long been an attractive option for verification. Yet the implementation of fingerprint recognition systems presents grave doubts regarding their reliability, precision, and susceptibility.

This study aims to evaluate the dependability and integrity of fingerprint biometrics in providing privacy and protection in numerous applications. It surveys the operation of such systems, looking at things from outside, the potential for human errors, and the constantly evolving technical toolkit required to crack the fingerprint dependability puzzle. The study also looks into the real-world applications of fingerprint biometrics across various industries, noting their strengths as well as weaknesses.

Literature Review

According to Lamin *et al.,* (2021), recording students' attendance has been a significant concern at Kolej Universiti Poly-Tech Mara. However, monitoring attendance manually is a cumbersome issue for lecturers, as students tend to manipulate attendance by signing each other's attendance. It has been found that fingerprint biometrics can monitor attendance systematically and efficiently. This study aims to verify the students' attendance using fingerprint biometrics. The evolutionary prototyping model was used to develop the students' attendance system. Students must use a thumbprint using the fingerprint device installed in the

classroom to record their attendance. The fingerprint device captured their fingerprint images, which were then registered to the server for attendance. The implementation of fingerprint biometrics has helped lecturers monitor student attendance more systematically, efficiently, and ethically. Using the system embedded with biometrics, reporting on absenteeism is genuine and straightforward. Lecturers need to print out and take the necessary action. Therefore, fingerprint biometrics is valuable and helpful in keeping track of and managing the attendance of the students.

According to Malik (2024), biometric authentication is a fast-growing, novel technology that makes the identity verification process secure and user-friendly with unique physiological and behavioral indicators. Integrating machine learning and artificial intelligence has made these systems more accurate and reliable. Hence, they can be used on mobile devices, banks, and border control since biometric authentication systems are beneficial; however, many risks exist, including privacy, data breaches, spoofing attacks, and regulatory issues. While these risks are unavoidable as more and more organizations are embracing biometric systems, it is only right that data protection is strong, that legal frameworks are abided by, and that the practice is ethical.

According to Rahman (2021), the present is a revolutionary time of information and computer technology. Most of the work in daily life depends on computer applications. Traditional student attendance includes all the hassles of roll calling and the time-consuming process of students and teachers conducting classes in an institute. This time-consuming process is very dull for the students and teachers. Thus, a new and innovative approach is required to handle this issue. It motivates us to design a reliable system for student attendance. Biometric authentication systems are widely used for the unique identification of humans, like students, and mainly for the verification and identification of individuals.

According to Blancaflor *et al.,* (2024), integrating biometric technology for personal identification is of growing interest and an area of concern. Nevertheless, emerging technological integration emerges as a subject of academic interest and the evolving global market, with the Philippines being no exception. AI's growing misuse and development remain a threat to falsifying biometric data. While such technology is potentially destructive to an entity, embracing how tech will continue to evolve while preparing and mitigating the risks is ideal for thriving as an institution.

According to Saul *et al.,* (2023), the traditional method of taking attendance using paper sheets is prone to errors like impersonation, loss, or theft. To solve this issue, automatic attendance systems utilizing identification technology such as barcode badges, electronic tags, magnetic stripe cards, and biometrics have been implemented. Fingerprint identification depends on the uniqueness of fingerprints and consists of comparing two friction ridge impressions on human fingers or toes to ascertain whether they come from the same person.

According to Dela Peña *et al.,* (2024), biometric verification is becoming more common in airports to improve security and efficiency. While it offers significant benefits like accurate identification and easier passenger screening, it raises concerns about privacy and data security. The research looked into the use of biometric systems in Philippine airports, focusing on security benefits and privacy protection. A mixed-methods approach was used, which included passenger surveys, interviews with key stakeholders, and case studies of airports that use biometric technology.

Theoretical Framework

The theoretical framework of this study integrates several interrelated theories-Pattern Recognition Theory, Diffusion of Innovation Theory, Social Exchange Theory, Technological Determinism Theory, and the Unified Theory of Acceptance and Use of Technology (UTAUT)-to assess the reliability and acceptance of fingerprint biometrics.

The pattern recognition theory posits that every observed item is stored as a "template" in long-term memory, allowing incoming sensory data to be compared against these templates to ensure accurate identification. This theory supports the idea that fingerprint biometrics function through a similar mechanism, where unique fingerprint patterns are matched against stored templates to confirm identity (de Paiva, 2009).

The diffusion of innovation theory explains how new technologies, such as biometric systems, are adopted and spread among individuals and organizations. In the context of fingerprint biometrics, it considers factors

like perceived benefits, compatibility with existing systems, complexity, and trialability, which collectively influence the level of acceptance and rate of adoption among users (Rogers, 1962).

Meanwhile, the social exchange theory provides insight into the decision-making process behind the implementation and acceptance of fingerprint biometrics. It emphasizes how individuals and organizations weigh perceived risks, such as privacy concerns, against perceived benefits, like enhanced security and efficiency. This balance between cost and reward determines trust and willingness to adopt biometric technologies (Cook and Rice, 2006).

The technological determinism theory suggests that technological advancements significantly shape human thought, behavior, and societal structures. Applied to fingerprint biometrics, this theory underscores how emerging technologies can transform security practices, institutional policies, and social interactions by influencing how individuals relate to and depend on technology (McLuhan, 1962).

Lastly, the unified theory of acceptance and use of technology (UTAUT) provides a comprehensive framework for understanding technology adoption. It identifies key determinants-performance expectancy, effort expectancy, social influence, and facilitating conditions-that affect users' behavioral intentions and actual technology usage. This theory helps explain how various factors contribute to the acceptance and continued use of fingerprint biometric systems (Ayaz and Yanartaş, 2020).

Together, these theories create a multidimensional foundation for examining both the technical reliability and the human acceptance of fingerprint biometric systems, emphasizing the interaction between technological capability, user perception, and societal adaptation.

Conceptual Framework

This study is guided by the input-process-output-outcome (IPOO) model, which serves as the conceptual foundation for systematically assessing and improving the fingerprint biometric system. The IPOO model ensures that every stage of the research-from data collection to outcome formulation-follows a structured and logical progression, aligning with the objectives of evaluating system reliability and user satisfaction.

In the input phase, three primary components are examined: the end-users' assessment of the fingerprint biometric system, their satisfaction level, and the challenges they encounter in its use. The analysis focuses on three core aspects-promptness of data, consistency of records and recordings, and durability-which collectively determine the system's effectiveness and efficiency from the users' perspective. Furthermore, the study evaluates the end-users' satisfaction level, categorized into two groups: teaching personnel and non-teaching personnel, to provide a comparative understanding of their experiences with the system.

The process phase involves the systematic procedures undertaken to collect, manage, and analyze the data. A structured survey questionnaire is utilized to gather information from the identified respondents. The collected data undergo statistical treatment to ensure objectivity, accuracy, and validity of the findings. This phase also includes data analysis and interpretation, identifying key trends, patterns, and relationships. Moreover, comparative analysis is performed between the two user groups to determine whether significant differences exist in their levels of satisfaction and perception of the system's performance.

The output phase translates the analyzed data into practical and actionable outcomes. These include the development of a strategic action plan, policy recommendations, and training programs designed to address the challenges identified and enhance the fingerprint biometric system's overall performance. These outputs aim to strengthen both the system's reliability and the users' satisfaction by providing evidence-based solutions.

Finally, the outcome phase represents the long-term impact of the study's implementation. Expected outcomes include improved user satisfaction, enhanced system reliability and accuracy, and the formulation of informed strategic policies and implementations. These outcomes highlight the potential of user-centered analysis to guide technological and organizational improvements in biometric systems.

Overall, the IPOO framework ensures that each stage of the study builds on the previous one, creating a coherent flow from input to outcome. This structured approach facilitates the generation of well-informed, sustainable solutions aimed at optimizing the performance, reliability, and acceptance of fingerprint biometric systems within institutional settings.

Significance of the Study

The findings of this study are expected to provide valuable, multi-sectoral contributions centered on enhancing the reliability, security, and ethical adoption of fingerprint biometric systems. For public institutions, the research offers actionable insights for the government to improve the accuracy of national identification systems (like PhilSys) and guides law enforcement in balancing effective security with individual privacy protection. In the private sector, the study supports businesses in minimizing identity fraud and financial losses, while providing technology developers with empirical data crucial for refining algorithmic precision and reducing authentication errors. Critically, the results offer policymakers evidence-based guidance for establishing regulatory frameworks, standards, and privacy protections. Ultimately, this research enriches academic discourse by providing localized, empirical findings and promotes greater confidence and trust in technology-driven identification systems among the general public.

Objectives of the Study

General Objective

This study aims to assess the reliability and accuracy of fingerprint biometrics as perceived by the end-users in higher education institutions.

Specific Objectives

- Specifically, the study seeks to: Assess the reliability and accuracy of the fingerprint biometric system in terms of:
  - Promptness of data
  - Consistency of records and recordings
  - Durability

- Determine whether there is a significant difference in the assessment of end-users on the reliability and accuracy of the fingerprint biometric system when grouped according to:
  - Higher education institutions teaching personnel
  - Higher education institutions non-teaching personnel

- Evaluate the level of satisfaction of end-users with the reliability and accuracy of the fingerprint biometric system in terms of:
  - Promptness of data
  - Consistency of records and recordings
  - Durability

- Identify whether there is a significant difference in the level of satisfaction of end-users with the reliability and accuracy of the fingerprint biometric system in terms of:
  - Promptness of data
  - Consistency of records and recordings
  - Durability

- Determine the challenges encountered by end-users in the utilization of the fingerprint biometric system in terms of:
  - Promptness of data
  - Consistency of records and recordings
  - Durability

Methodology

This study employed a quantitative, descriptive-comparative research design to assess the reliability and accuracy of fingerprint biometrics as perceived by end-users. The research was conducted in two Higher Education Institutions (HEIs) in Tarlac City, Philippines, that utilize biometrics for staff attendance and access control. The target population comprised teaching and non-teaching personnel (aged 25 years and older) who use the system, from which a total sample size of 146 respondents was selected using stratified random sampling. Data were collected using a self-structured questionnaire with a 4-point Likert scale; the instrument was validated by experts and confirmed for high internal consistency via Cronbach's alpha. Data analysis utilized descriptive statistics (median) to determine user assessment and satisfaction levels, while the Mann-Whitney U Test (chosen due to confirmed non-normality) was employed to determine the significant difference in assessment and satisfaction between the independent groups of teaching and non-teaching personnel.

Results and Discussions

Table 1. End-users' assessment of the reliability and accuracy of the use of fingerprint biometrics in terms of promptness of data.

Promptness of data	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) The fingerprint biometrics device quickly processes my fingerprint without any delay.	4.00	SA	4.00	SA	4.00	SA
2) The fingerprint biometrics device verification is faster compared to manual methods such as Bundy clocks.	3.00	A	4.00	SA	4.00	SA
3) I don't experience long queues because the fingerprint biometrics device scans fast.	4.00	SA	4.00	SA	4.00	SA
4) I don't have to wait a long time for the fingerprint biometrics device to respond after scanning my fingerprint.	4.00	SA	4.00	SA	4.00	SA
5) I receive quick confirmation that my fingerprint has been accepted.	4.00	SA	4.00	SA	4.00	SA
6) The fingerprint biometrics device works well even in different weather or environmental conditions.	4.00	SA	4.00	SA	4.00	SA
7) The fingerprint biometrics device works quickly even during peak hours.	4.00	SA	4.00	SA	4.00	SA
8) The fingerprint biometrics device verifies my fingerprint quickly even when multiple users scan consecutively.	3.00	A	4.00	SA	4.00	SA
9) It only takes a few seconds to scan my fingerprint.	4.00	SA	4.00	SA	4.00	SA
Overall	3.78	SA	4.00	SA	4.00	SA
Legend: Strongly disagree (1.00-1.99), Disagree (2-2.99), Agree (3-3.49), Strongly agree (3.50-4)						

Table 1 presents the end-users' assessment of the reliability and accuracy of fingerprint biometrics in terms of promptness of data. The responses were collected from higher education institutions' teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' assessment of the reliability and accuracy of using fingerprint biometrics for both teaching and non-teaching personnel in terms of promptness of data from item 1 to item 9 is 4.00, interpreted as "Strongly Agree".

The median overall score of 4.00 for all items shows that respondents strongly agree that fingerprint biometrics are reliable and accurate regarding the promptness of data. For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 3.78, interpreted as "Strongly Agree." Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the overall median garnered 4.00, interpreted also as "Strongly Agree." These indicate that the users from both teaching and non-teaching personnel have a high confidence level in the fingerprint biometrics' ability to process data promptly and efficiently.

The overall median result is consistent with earlier research results. Gabuya *et al.,* (2022) established that the Biometric Attendance Monitoring System (BAM) used in CTU-Tuburan Campus tremendously increased time efficiency over traditional processes. This substantiates the current study's discovery that users think that the biometric system is quicker and more accurate when processing attendance than the manual method.

Likewise, Maggay (2017) found that the use of a biometric attendance monitoring system (BAMS) at Cagayan State University–Lasam Campus minimizes the queuing time and improves the logging experience of the employees, which is the same in the present study, where end-users highly agreed with their assessment that the system provides prompt data. In addition, Jain *et al.,* (2016) pointed out through their biometric study review that technology innovation had significantly improved the performance and speed of fingerprint recognition systems to capture real-time verification even in the presence of high user activity.

These findings, in addition to the findings in this study, further establish the application of biometric systems as a very effective and efficient approach to attendance monitoring and access management in institutions.

Table 2. End-users' assessment of the reliability and accuracy of the use of fingerprint biometrics in terms of consistency of records and recordings.

Consistency of records and recordings	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) The fingerprint biometrics device always clocks my attendance without fail.	4.00	SA	4.00	SA	4.00	SA
2) The fingerprint biometrics device correctly identifies my fingerprint every time I use it and efficiently accommodates multiple fingers per user (e.g., the right thumb and left thumb of the teacher/instructor are registered in one device).	4.00	SA	4.00	SA	4.00	SA
3) The system logs match my actual log-in and log-out.	4.00	SA	4.00	SA	4.00	SA
4) The fingerprint biometrics device can scan my fingerprint even if there is a power interruption.	1.00	SD	1.00	SD	1.00	SD
5) I've never encountered a situation where the system mixed up my fingerprint with another person's.	4.00	SA	4.00	SA	4.00	SA
6) My attendance is recorded reliably even when I make use of different biometric scanners at work.	4.00	SA	4.00	SA	4.00	SA
7) The fingerprint biometrics match my profile without error.	4.00	SA	4.00	SA	4.00	SA
8) The fingerprint biometrics device provides the same correct output even if I swipe my fingerprint multiple times.	4.00	SA	4.00	SA	4.00	SA
9) I can rely on the fingerprint system to maintain my attendance records accurately and consistently in the long term.	4.00	SA	4.00	SA	4.00	SA
Overall	3.67	SA	3.67	SA	3.67	SA
Legend: Strongly disagree (1.00-1.99), Disagree (2-2.99), Agree (3-3.49), Strongly agree (3.50-4)						

Table 2 presents the end-users' assessment of the reliability and accuracy of fingerprint biometrics in terms of consistency of records and recordings. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' assessment of the reliability and accuracy of the use of fingerprint biometrics for both teaching personnel and non-teaching personnel in terms of consistency of records and recordings from item 1 to item 9 (except item 4) is 4.00, interpreted as "Strongly Agree".

The median overall score of 4.00 for all items shows that respondents strongly agree that fingerprint biometrics are reliable and accurate in terms of consistency of records and recordings. However, item 4 has the lowest median rating of 1.00 by both groups, which is interpreted as "Strongly Disagree". This indicates the lack of capacity of fingerprint biometrics to scan when there is a power interruption in the locale. Apart from the exception of power-related concern, the consistent median value of 4.00 across most items indicates that end-users tend to find the system reliable and accurate in the consistency of records and recordings. For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 3.67, interpreted as "Strongly Agree".

Moreover, for the overall median of Items 1 to 9 from non-teaching personnel, the overall median also garnered 3.67, interpreted as "Strongly Agree". It indicates that both teaching and non-teaching personnel have a very low assessment for item 4, but apart from it, these results reflect that the user has a high level of confidence in the fingerprint biometrics' ability to process data promptly and efficiently, record consistently, reliably, and accurately. This also aligns with the study of Thakur and Vyas (2019), that biometrics are more sophisticated, advanced, and highly sensitive than ever before. They are used to protect businesses and citizens. Above all, biometrics work on the biological qualities of a person that cannot be duplicated.

Table 3. End-users' assessment of the reliability and accuracy of the use of fingerprint biometrics in terms of durability.

Durability	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) The fingerprint biometrics device works well even for long hours of use.	4.00	SA	4.00	SA	4.00	SA
2) The fingerprint biometrics device works well under extreme conditions (e.g., temperature, humidity).	4.00	SA	4.00	SA	4.00	SA
3) Physical wear and tear on the scanner are minimal even with continuous use.	4.00	SA	3.00	A	4.00	SA
4) The general design and structure of the biometric system contribute to its long-term durability.	4.00	SA	4.00	SA	4.00	SA
5) I've witnessed the device last for years without significant damage or repair.	4.00	SA	3.00	A	4.00	SA
6) The fingerprint biometric device withstands frequent pressing and scanning.	4.00	SA	4.00	SA	4.00	SA
7) The system components, such as the screen and sensor pad, remain intact and functional over time.	4.00	SA	4.00	SA	4.00	SA
8) The fingerprint biometrics device is durable enough to be utilized in schools or other busy areas.	4.00	SA	4.00	SA	4.00	SA
9) I have never seen the fingerprint biometrics device overheat while in use.	4.00	SA	4.00	SA	4.00	SA
Overall	4.00	SA	3.78	SA	4.00	SA
Legend: Strongly disagree (1.00-1.99), Disagree (2-2.99), Agree (3-3.49), Strongly agree (3.50-4)						

Table 3 presents the end-users' assessment of the reliability and accuracy of fingerprint biometrics in terms of durability. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' assessment of the reliability and accuracy of the use of fingerprint biometrics for both teaching personnel and non-teaching personnel in terms of durability from item 1 to item 9 is 4.00, interpreted as "Strongly Agree".

The median overall score of 4.00 for all items shows that respondents strongly agree that fingerprint biometrics are reliable and accurate in terms of durability. For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 4.00, interpreted as "Strongly Agree". Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the median garnered 3.78, interpreted also as "Strongly Agree". These indicate that respondents from both teaching and non-teaching personnel agree that the components associated with the hardware and software of the fingerprint biometrics are perceived to be exceptionally reliable and well-built, and can withstand different weather and environmental conditions. As users view fingerprint biometrics as long-lasting and ever-reliable through time, their adoption rate and continuous use of the technology become higher (Greenhalgh, 2020).

Table 4. Difference in the assessment of the end-users on the reliability and accuracy of the use of fingerprint biometrics according to group.

Mann-Whitney U test				
		U statistic	**p**	**Interpretation**
Promptness of data	Mann-Whitney U	2402	0.447	No significant difference
Consistency of records and recordings	Mann-Whitney U	2354	0.341	No significant difference
Durability	Mann-Whitney U	2454	0.58	No significant difference

Table 4 presents the significant differences in the assessment of the end-users on the reliability and accuracy of the use of fingerprint biometrics according to the group. The responses were collected from higher education institution teaching personnel and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The Mann-Whitney U Test is used to determine whether there are significant differences in the assessments of end-users between teaching personnel and non-teaching

personnel. For the promptness of data, the computed U-value is 2402, and the p-value is 0.447. For the consistency of records and recordings, the U-value is 2354, and the p-value is 0.341. And for durability, the computed U-value is 2452, and the p-value is 0.58.

For the promptness of data, the computed U-value is 2402 with a p-value of 0.447. Since the p-value is greater than 0.05, the result indicates that the difference is not statistically significant; thus, it fails to reject the null hypothesis $H_0$1. This means that there is no significant difference between the two groups of respondents in their assessment of the reliability and accuracy of fingerprint biometrics in terms of the promptness of data. Likewise, for the consistency of records and recordings, the computed U-value is 2354 with the p-value of 0.341.

Again, since the p-value is greater than 0.05, the result indicates that the difference is not statistically significant; thus, it fails to reject the null hypothesis $H_0$1. This also means that there is no significant difference between the two groups of respondents in their assessment of the reliability and accuracy of fingerprint biometrics in terms of consistency of records and recordings.

And lastly, for durability, the computed U-value is 2452 with a p-value of 0.58. Since the p-value is greater than 0.05, the result indicates that the difference is not statistically significant; thus, it fails to reject the null hypothesis $H_0$1. This means that there is no significant difference between the two groups of respondents in their assessment of the reliability and accuracy of fingerprint biometrics in terms of durability.

These results indicate that both teaching and non-teaching personnel have the same agreement about the promptness, consistency, and durability of fingerprint biometrics. The fact that there are no statistically significant differences in all the variables indicates that the fingerprint biometric system is viewed equally across employee groups. The result of having the same agreement of assessment in the two groups is aligned by the study conducted by Maggay (2017). In her study on fully customized Biometric Attendance Monitoring System (BAMS) design and development at Cagayan State University–Lasam Campus, the system's functionality facilitated users of varied administrative and instructional positions to effectively input, manipulate, and retrieve data. This convenience and simplicity of use between different types of users translated to better work values that facilitated good governance.

Likewise, in the current study, teaching and non-teaching personnel both showed a similar level of satisfaction and confidence in the system's dependability, demonstrating that technology is able to address diverse user groups' needs and facilitate efficient, precise attendance tracking irrespective of their roles. Similarly, the outcome is also supported by the study conducted by Gabuya (2022).

Gabuya highlighted that biometric systems have continually maintained employee punctuality and offered proper attendance records. The convenience of daily application of the system and the potential for users with a few difficulties indicate high levels of satisfaction expressed in the present study. This adds credence to the reliability of fingerprint biometrics as a speedy and stable tool for following attendance.

Table 5 presents the end-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of promptness of data. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' level of satisfaction with the reliability and accuracy of using fingerprint biometrics for both teaching and non-teaching personnel in terms of promptness of data from item 1 to item 9 is 4.00, interpreted as "Very Satisfied".

The median total score of 4.00 shows that respondents are very satisfied with the fingerprint biometrics being reliable and accurate regarding the promptness of data. For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 4.00, interpreted as "Very Satisfied". Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the median garnered 3.89, interpreted also as "Very Satisfied". These indicate that the users from both teaching and non-teaching personnel have a high level of satisfaction with the fingerprint biometrics' ability to process data promptly and efficiently.

The satisfaction of respondents with the fingerprint biometrics being prompt is in agreement with the literature of Rivera (2021). Taking and maintaining the attendance of employees manually on a regular basis is a big activity that requires time. For this reason, an effective system was designed. The system was

designed and developed primarily to improve the monitoring of employees' attendance and leave management through the use of biometric technology. It records the data of the employees, handles leave management, tracks employee attendance, and encourages participation through fingerprint recognition. The outcome shows that through the usage of the biometrics system, employees' attendance has improved.

Table 5. End-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of promptness of data.

Promptness of data	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) I am satisfied with how the fingerprint biometrics device quickly processes my fingerprint without any delay.	4.00	VS	4.00	VS	4.00	VS
2) I am satisfied with the use of a fingerprint biometrics device rather than manual methods because it is faster.	4.00	VS	4.00	VS	4.00	VS
3) I am satisfied with the fingerprint biometrics verification because it is faster and I don't have to wait for a long queue.	4.00	VS	4.00	VS	4.00	VS
4) I am satisfied with how quickly the fingerprint biometrics device responds after scanning my fingerprint.	4.00	VS	4.00	VS	4.00	VS
5) I am satisfied with how quickly I received the information that my fingerprint has been accepted.	4.00	VS	4.00	VS	4.00	VS
6) I am satisfied with the fingerprint biometrics device because it works well even in different weather or environmental conditions.	4.00	VS	4.00	VS	4.00	VS
7) I am satisfied with the use of fingerprint biometrics devices because it works quickly even during peak hours.	4.00	VS	4.00	VS	4.00	VS
8) I am satisfied with how fast the system verifies my fingerprint even when multiple users scan consecutively.	4.00	VS	3.00	S	4.00	VS
9) I am satisfied with the time it takes for my attendance to be recorded.	4.00	VS	4.00	VS	4.00	VS
Overall	4.00	VS	3.89	VS	4.00	VS
Legend: Very dissatisfied (1.00-1.99), Dissatisfied (2-2.99), Satisfied (3-3.49), Very satisfied (3.50-4)						

Table 6 presents the end-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of consistency of records and recordings. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics for both teaching personnel and non-teaching personnel in terms of consistency of records and recordings from item 1 to item 9 (except item 4) is 4.00, interpreted as "Very Satisfied".

The median overall score of 4.00 for all items shows that respondents are highly satisfied that fingerprint biometrics are reliable and accurate in terms of consistency of records and recordings. However, item 4 had the lowest median rating of 1.00 by both groups, which is interpreted as "Very Dissatisfied". This indicates the lack of capacity of fingerprint biometrics to scan when there is a power interruption in the locale. Apart from the exception of power-related concern, the consistent median value of 4.00 (VS) across most items indicates that end-users are very satisfied with the consistency of records and recordings provided with fingerprint biometrics.

For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 3.67, interpreted as "Very Satisfied". Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the overall median also garnered 3.67, interpreted as "Very Satisfied". These still indicate that the

users from both teaching and non-teaching personnel have a high level of satisfaction in the fingerprint biometrics' ability to process data promptly and efficiently, record consistently, reliably, and accurately.

Table 6. End-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of consistency of records and recordings.

Consistency of records and recordings	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) I am satisfied with the use of the fingerprint biometrics device which always clocks my attendance consistently.	4.00	VS	4.00	VS	4.00	VS
2) I am satisfied that the fingerprint biometrics device correctly identifies my fingerprint every time I use it and efficiently accommodates multiple fingers per user.	4.00	VS	4.00	VS	4.00	VS
3) I am satisfied that the system logs match my actual log-in and log-out.	4.00	VS	4.00	VS	4.00	VS
4) I am satisfied with the fingerprint biometrics device's capacity to scan my fingerprint even if there is a power interruption.	1.00	VD	1.00	VD	1.00	VD
5) I am satisfied with how the system distinguishes my fingerprint from other users with similar patterns.	4.00	VS	4.00	VS	4.00	VS
6) I am satisfied with the system's capacity to record data consistently across many devices or terminals.	4.00	VS	4.00	VS	4.00	VS
7) I am satisfied that my fingerprint logs always record the precise times that I scanned, without the need for manual corrections.	4.00	VS	4.00	VS	4.00	VS
8) I am satisfied with the use of the fingerprint biometrics device for providing correct output even if I swipe my fingerprint multiple times.	4.00	VS	4.00	VS	4.00	VS
9) I am satisfied with the system's capacity to accurately maintain my attendance records.	4.00	VS	4.00	VS	4.00	VS
Overall	3.67	VS	3.67	VS	3.67	VS
Legend: Very dissatisfied (1.00-1.99), Dissatisfied (2-2.99), Satisfied (3-3.49), Very satisfied (3.50-4)						

Table 7 end-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of durability. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the end-users' level of satisfaction with the reliability and accuracy of using fingerprint biometrics for both teaching and non-teaching personnel in terms of durability from item 1 to item 9 is 4.00, interpreted as "Very Satisfied".

The median overall score of 4.00 for all items shows that respondents are highly satisfied with the fingerprint biometrics being reliable and accurate in terms of durability. The median value of 4 for most items indicates a uniform positive level of satisfaction perceived by end-users in terms of durability of the fingerprint biometrics, supporting the expectation of the end-users with the durability of fingerprint biometrics, even for continuous usage for over a year. This consistency indicates a stable user experience irrespective of the rated feature.

Median reinforces the central tendency of responses, with the majority of the items interpreted as 4, verifying the consistency of positive satisfaction by end-users. For the overall median of item 1 to 9 responses from teaching personnel, the overall median reflects 4.00, interpreted as "Very Satisfied".

Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the median garnered 3.89, interpreted also as "Very Satisfied". These indicate that the end-users from teaching and non-teaching personnel are highly satisfied with the fingerprint biometrics' durability, built nature, and capacity to withstand different weather and environmental conditions.

Table 7. End-users' level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of durability.

Durability	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) I am satisfied with how long the fingerprint biometrics device performs well without failure even for prolonged use.	4.00	VS	4.00	VS	4.00	VS
2) I am satisfied with the capacity of the fingerprint biometrics device to work well even under extreme conditions (e.g., temperature, humidity).	4.00	VS	4.00	VS	4.00	VS
3) The fingerprint biometric system maintains functional performance even with repeated use.	4.00	VS	4.00	VS	4.00	VS
4) I am satisfied with the physical durability of the device.	4.00	VS	4.00	VS	4.00	VS
5) I am satisfied with the device lasting for years without significant damage or repair.	4.00	VS	3.00	S	4.00	VS
6) I am satisfied with the fingerprint biometrics device's capacity to withstand frequent pressing and scanning.	4.00	VS	4.00	VS	4.00	VS
7) I am satisfied with the durability of the screen and sensor pad which remains intact and functional over time.	4.00	VS	4.00	VS	4.00	VS
8) I am satisfied with the software's stability.	4.00	VS	4.00	VS	4.00	VS
9) I am satisfied with the fingerprint biometrics device's not overheating.	4.00	VS	4.00	VS	4.00	VS
Overall	4.00	VS	3.89	VS	4.00	VS
Legend: Very dissatisfied (1.00-1.99), Dissatisfied (2-2.99), Satisfied (3-3.49), Very satisfied (3.50-4)						

Table 8. Differences in the level of satisfaction of the end-users with the reliability and accuracy of fingerprint biometrics.

Mann-Whitney U test				
		U statistic	**p**	**Interpretation**
Promptness of data	Mann-Whitney U	976	0.104	No significant difference
Consistency of records and recordings	Mann-Whitney U	2405	0.596	No significant difference
Durability	Mann-Whitney U	398	0.004	With significant difference

Table 8 presents the significant differences in the level of satisfaction of the end-users on the reliability and accuracy of the use of fingerprint biometrics in terms of promptness of data, consistency of records and recordings, and durability. The responses were collected from higher education institution teaching personnel and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The Mann-Whitney U Test is used to determine whether there are significant differences in the level of satisfaction of the end-users on the reliability and accuracy of the use of fingerprint biometrics in terms of promptness of data, consistency of records and recordings, and durability.

For the promptness of data, the computed U-value is 976, and the p-value is 0.104. For the consistency of records and recordings, the U-value is 2405, and the p-value is 0.596. And for the durability, the computed U-value is 398, and the p-value is 0.004. For the promptness of data, the computed U-value is 976 with a p-value of 0.104. Since the p-value is greater than 0.05, the result indicates that the difference is not statistically significant; thus, it fails to reject the null hypothesis $H_0$2. This means that there is no significant difference between the two groups of respondents in their level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of the promptness of data.

Likewise, for the consistency of records and recordings, the computed U-value is 2405 with a p-value of 0.596. Again, since the p-value is greater than 0.05, the result indicates that the difference is not statistically significant; thus, it fails to reject the null hypothesis $H_0$3. This also means that there is no significant

difference between the two groups of respondents in their level of satisfaction with the reliability and accuracy of the use of fingerprint biometrics in terms of consistency of records and recordings. Lastly, for durability, the computed U-value is 398 with a p-value of 0.004. Since the p-value is less than 0.05, the result indicates that the difference is statistically significant; thus, it rejects the null hypothesis $H_0$4. This means that there is a significant difference between the two groups of respondents in their level of satisfaction with the reliability and accuracy of the fingerprint biometrics in terms of durability.

These results indicate that both teaching and non-teaching personnel have the same level of satisfaction with the promptness of data and consistency of records and recordings. However, in terms of durability, there is a perceived significant difference in the level of satisfaction between the two groups. In terms of promptness of data and consistency of records and recordings, this result is supported by the research of Syed *et al.,* (2024), which indicated that familiarity and frequent exposure can create the satisfaction of end-users with the use of biometric systems. Aligning with this result, teaching personnel, as they tend to have higher digital literacy because of the different digital platforms they are using, can build positive attitudes toward technology, therefore reporting higher satisfaction. Non-teaching personnel, on the other hand, may have less varied environmental or logistical contexts, which could affect their perception of durability.

Table 9. Challenges encountered by end-users in the utilization of fingerprint biometrics in terms of promptness of data.

Promptness of data	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) The system sometimes takes too long to respond.	1.00	NC	1.00	NC	1.00	NC
2) The manual method is much faster than the fingerprint biometrics device.	1.00	NC	1.00	NC	1.00	NC
3) There is often a queue due to the system's slow response time.	1.00	NC	1.00	NC	1.00	NC
4) I have to wait a long time for the fingerprint biometrics device to respond after scanning my fingerprint.	1.00	NC	1.00	NC	1.00	NC
5) Confirmation takes several minutes before it confirms that my fingerprint has been accepted.	1.00	NC	2.00	SC	1.00	NC
6) The fingerprint biometric device lags or freezes depending on weather or environmental conditions.	1.00	NC	1.00	NC	1.00	NC
7) The fingerprint biometrics device is lagging during peak hours.	1.00	NC	1.00	NC	1.00	NC
8) I often have to scan multiple times before the system recognizes my fingerprint.	1.00	NC	1.00	NC	1.00	NC
9) It takes several minutes to scan my fingerprint.	1.00	NC	1.00	NC	1.00	NC
Overall	1.00	NC	1.11	NC	1.00	NC
Legend: Not challenging (1.00-1.99), Slightly challenging (2-2.99), Challenging (3-3.49), Very challenging (3.50-4)						

Table 9 presents the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of promptness of data. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of promptness of data is 1.00, interpreted as "Not Challenging".

The median total score of 1.00 shows that respondents are not encountering challenges in the utilization of fingerprint biometrics in terms of the promptness of data. For the overall median of item 1 to 9 responses from teaching personnel, the overall median is 1.00, interpreted as "Not Challenging".

Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the median garnered 1.11, interpreted also as "Not Challenging". These indicate that the end-users, teaching and non-teaching personnel, have a low level of challenges encountered in the fingerprint biometrics' ability to process data promptly and efficiently.

Table 10. Challenges encountered by end-users in the utilization of fingerprint biometrics in terms of consistency of records and recordings.

Consistency of records and recordings	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) There are instances of incorrect or missing records.	1.00	NC	1.00	NC	1.00	NC
2) The system occasionally fails to recognize my fingerprint.	1.00	NC	2.00	SC	1.00	NC
3) The system does not match my actual log-in and log-out.	1.00	NC	2.00	SC	1.00	NC
4) My fingerprint cannot be scanned during a power interruption.	4.00	VC	3.00	C	4.00	VC
5) My fingerprint is sometimes recognized as someone else's fingerprint.	1.00	NC	2.00	SC	1.00	NC
6) My attendance is not recorded reliably when I make use of different biometric scanners at work.	2.00	SC	1.00	NC	1.00	NC
7) I am always correcting my log manually due to the fingerprint not recording the precise time I scanned.	1.00	NC	1.00	NC	1.00	NC
8) I need to swipe my fingerprint multiple times because the fingerprint biometrics device does not provide the same correct output.	1.00	NC	2.00	SC	1.00	NC
9) Manual registers are much better than fingerprint biometrics.	1.00	NC	1.00	NC	1.00	NC
Overall	1.44	NC	1.67	NC	1.33	NC
Legend: Not challenging (1.00-1.99), Slightly challenging (2-2.99), Challenging (3-3.49), Very challenging (3.50-4)						

Table 10 presents the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of consistency of records and recordings. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The majority of the overall median for the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of consistency of records and recordings is 1.00, interpreted as "Not Challenging".

The median total score of 1.00, except for item no. 4, shows that respondents are not encountering challenges in utilizing fingerprint biometrics in terms of consistency of records and recordings. The value of median as 1 (except for item 4) for the majority of items supports the impression of low challenges and indicates an overall consensus among the end-users that they are not experiencing or encountering challenges with the consistency of records and recordings of fingerprint biometrics. For the overall median of item 1 to 9 responses from teaching personnel, the overall median is 1.44, interpreted as "Not Challenging".

Moreover, for the overall median of items 1 to 9 from non-teaching personnel, the median garnered 1.67, interpreted also as "Not Challenging". These indicate that the respondents from teaching and non-teaching personnel face problems scanning their fingerprints during a power interruption. This is in line with the present study, where end-users barely experienced any inconvenience regarding the consistency of fingerprint biometrics. In addition, Wayman (2001) emphasized that low rates of problems reported by users commonly signify high algorithmic consistency of fingerprint biometrics. This correlation supports the findings of our study that the fingerprint biometric system being evaluated works with a great degree of accuracy and consistency of records and recordings, adding to the technology's overall user satisfaction and efficiency.

Table 11 presents the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of durability. The responses were collected from higher education institutions teaching and non-teaching personnel who use fingerprint biometrics for attendance tracking and access control. The overall median for the challenges encountered by end-users in the utilization of fingerprint biometrics in terms of durability is 1.00, interpreted as "Not Challenging".

The median total score of 1.00 shows that respondents are not encountering or experiencing challenges in fingerprint biometrics in terms of durability. For the overall median of item 1 to 9 responses from teaching personnel, the overall median is 1.00, interpreted as "Not Challenging". And for the overall median of items 1 to 9 from non-teaching personnel, the overall median garnered 1.67, interpreted also as "Not Challenging". These indicate that the end-users from both teaching and non-teaching personnel have a low level of challenges encountered in the fingerprint biometrics' durability, built nature, and capacity to withstand different weather and environmental conditions.

The strong consensus of the respondents on the durability of fingerprint biometrics is corroborated by research conducted by Maltoni *et al.,* (2009). In their definitive work Handbook of Fingerprint Recognition, they underscore that sensor material quality, frequency of maintenance, and resistance to the environment play major roles in the durability of a biometric system. The significant level of disagreement for challenges encountered on most items in the table confirms this norm, indicating a level of resilience and durability on the part of the fingerprint biometrics.

Unar *et al.,* (2014) similarly confirm these findings by drawing attention to the fact that the stability of biometric systems, specifically sensor life and endurance against wear and tear, can drive user satisfaction consistency directly. In fingerprint recognition systems, long-lasting sensors can endure many enrollments and verifications without losing much in performance. This mirrors this study's stable low median values, indicating few hardware-related issues with end-users.

Table 11. Challenges encountered by end-users in the utilization of fingerprint biometrics in terms of durability.

Durability	**Teaching personnel**		**Non-teaching personnel**		**Overall**	
	Median	**Int.**	**Median**	**Int.**	**Median**	**Int.**
1) The device often malfunctions or crashes when used for long hours.	1.00	NC	2.00	SC	1.00	NC
2) The biometric system positioned outdoors fails to function properly under certain environmental conditions (e.g., temperature, humidity).	1.00	NC	2.00	SC	1.00	NC
3) The fingerprint scanner wears out easily after an extended period of use.	1.00	NC	2.00	SC	1.00	NC
4) The internal and external parts of biometric systems have to be replaced or upgraded frequently due to poor durability.	1.00	NC	1.00	NC	1.00	NC
5) Fingerprint devices do not last for years.	1.00	NC	2.00	SC	1.00	NC
6) The biometric device does not withstand frequent pressing and scanning.	1.00	NC	2.00	SC	1.00	NC
7) The system components, such as the screen and sensor pad, need to be replaced frequently.	1.00	NC	2.00	SC	1.00	NC
8) The fingerprint biometrics device is not durable enough to be utilized in schools or other busy areas.	1.00	NC	1.00	NC	1.00	NC
9) The fingerprint biometrics device overheats with prolonged use.	1.00	NC	1.00	NC	1.00	NC
Overall	1.00	NC	1.67	NC	1.00	NC
Legend: Not challenging (1.00-1.99), Slightly challenging (2-2.99), Challenging (3-3.49), Very challenging (3.50-4)						

Conclusion and Recommendations

The study concludes that fingerprint biometrics are a highly reliable and accurate solution for identity verification and attendance tracking in Higher Education Institutions (HEIs). End-users reported extreme satisfaction with the system's promptness, consistency, and durability. This positive perception was uniform across both teaching and non-teaching personnel, with no statistically significant difference in their overall assessment, confirming the technology's consistent performance across diverse user groups.

The primary challenge and limitation noted is the system's inability to operate during power interruptions, which is the only significant factor undermining its overall reliability. These findings validate that fingerprint biometrics meet expectations as an effective and trustworthy security and administrative tool.

Based on these findings, the following recommendations were made:

- ☞ Install reliable backup power systems, such as UPS or alternate power sources, to ensure the continuous operation of fingerprint biometric systems during power interruptions.
- ☞ Maintain consistent implementation of the fingerprint biometric system for all user groups, as it adequately meets the needs of both teaching and non-teaching personnel.
- ☞ Institutions continue to utilize and support biometric systems as the exclusive device for identification verification and attendance tracking.
- ☞ Continue using the fingerprint biometric system and resolve the durability issues of non-teaching personnel through reorientation or training on effective device use and maintenance.
- ☞ Resolve its downtime in case of power interruption by incorporating a backup power supply, such as a UPS, or alternate power sources.

Declarations

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