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IoT-Based E-Voting System Using Fingerprint Biometrics for School Elections

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Abstract. This study proposes an Internet of Things (IoT)-based e-voting system to address the limitations of traditional paper-based student council elections, which are prone to errors, inefficiency, and data manipulation. The system is developed using the ADDIE model for Research and Development (R&D), incorporating a Laravel-based administrative dashboard, a Flutter-based mobile voting interface, and a biometric authentication device built with an ESP32 microcontroller and JM-101B fingerprint sensor. Evaluation involved 20 participants who completed six functional test scenarios, achieving a 100% success rate across 120 instances. Usability testing revealed a notable comfort difference, with 30% comfort on mobile phones and 90% on tablets. Performance testing showed a fingerprint scan time of 669.6 ms and a vote submission latency of 437.1 ms, indicating good system responsiveness. The results suggest the system improves security, transparency, and efficiency in the election process. However, the study is limited by a small sample size and evaluation within a single institution. Future work could explore cloud integration, multi-school deployment, and additional authentication methods to enhance scalability and support broader adoption.

Keywords: E-voting, Internet of Things, Fingerprint Authentication, R&D, ADDIE

1. INTRODUCTION

The Intra School Student Organization (OSIS) plays an important role in secondary education by providing opportunities for students to learn organizational management, collaboration, and leadership skills[1]. The Student Council President holds a central role in coordinating student activities and ensuring that the organization's objectives are achieved effectively[2]. However, many schools still conduct student council elections using conventional paper-based procedures, which involve distributing paper ballots and manually counting votes. This method introduces several drawbacks, including susceptibility to data loss, environmental waste, and limited scalability within modern digital learning environments[3], [4]. These conditions highlight the need for a more secure and efficient computerized voting mechanism.

Previous studies have attempted to address the limitations of manual voting through various e-voting implementations. Study [1] proposed a web-based e-voting system using the prototype method with an 84.17% feasibility score, while study [3] applied the Unified Modeling Language (UML) approach to improve efficiency, participation, and data-processing speed. Study [4] introduced a mobile-based voting application that achieved 100% functionality feasibility, and study [5] combined gesture recognition with blockchain technology to enhance accessibility and security, achieving very high accuracy rates with 100% precision and 99% recall. Study [6] evaluated e-voting adoption factors using the HOT-Fit model and found that technical issues such as server downtime and low participation affected implementation success.

Despite these advancements, a critical research gap remains: most existing e-voting solutions do not integrate reliable voter authentication mechanisms. Web based and mobile based systems rely largely on username password or code based validation, which are vulnerable to credential sharing and duplicate voting. Meanwhile, gesture-recognition methods show promise but are highly sensitive to lighting variations, making them impractical for real-world school environments where illumination conditions vary significantly[7]. These limitations emphasize the need for a more robust and tamper resistant authentication solution.

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To address this gap, the present study proposes an e-voting system integrating IoT-based fingerprint biometric authentication. The system combines Laravel for web-based administrative management, Flutter for mobile-based voting, and an IoT fingerprint verification module to ensure that only verified students can cast their votes. Biometric identification provides a stronger security paradigm by binding each vote to a unique physiological characteristic, reducing the risk of impersonation, double voting, and unauthorized system access[8].

This research advances the state of the art by providing a hybrid architecture that unifies web, mobile, and IoT platforms while incorporating fingerprint biometrics an approach that offers stronger reliability than gesture based systems and higher security than conventional code based verification. Accordingly, the objective of this study is to design, develop, and evaluate an IoT-integrated e-voting system that enhances the security, transparency, and validity of student council elections in secondary education environments.

2. METHODS

This study was conducted using a Research and Development (R&D) approach and implemented the ADDIE development model to analyze issues in the conventional voting system at SMA Negeri 1 Ulujami, Pemalang Regency, as shown in Figure 1. The selection of the R&D method and the ADDIE model was based on the need for a systematic, structured, and iterative development process, enabling each stage from needs analysis, system workflow design, integration with IoT devices, and the implementation of the system within the school environment, followed by functional evaluation to be carried out comprehensively and measurably [9]. Through this approach, the research was able to design an e-voting solution that aligns with the identified problems and ensures that the resulting prototype can be properly tested and validated.

The research utilized data obtained from 20 students, which included their Student Identification Number (NIS), full name, and class information, as shown in Table 1. In addition, the ballot design used in the traditional voting process served as a reference for developing the digital voting page interface, allowing it to closely resemble the actual conditions within the school environment, as shown in Figure 2. The data were collected directly by the researcher through a field visit to SMA Negeri 1 Ulujami, Pemalang Regency. The data collection process was carried out through an interview with the Student Affairs Teacher, Mr. Grita Diding Sugiarto, S.Pd., on May 7, 2025, from 09:30 to 11:40 AM (WIB). The interview was conducted in a question-and-answer format to obtain detailed information about the students' identities used as voter data in the system as well as to gather insights into the ballot design, which served as the basis for creating the e-voting application's interface.

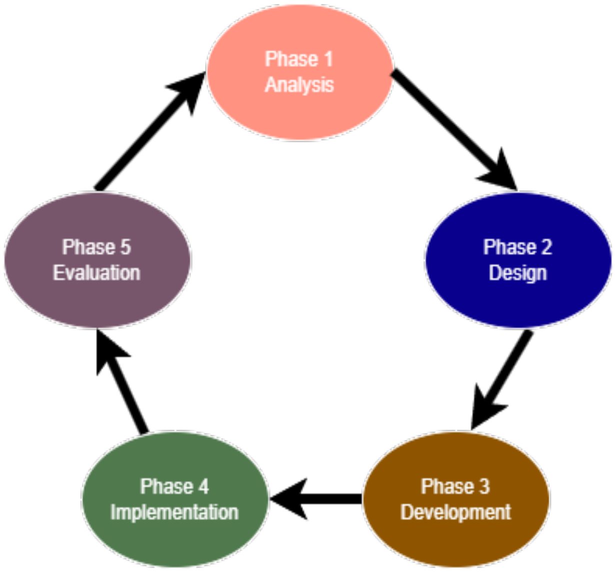

Figure 1. Research and Development (R&D) process using the ADDIE model as the development framework.

Table 1. Research Data

No	Nis	Name	Class
1	9266	Abdi Nugraha	X.I
2	9267	Abi Naim	X.I
3	9268	Aisyah Anggreani	X.I
4	9269	Al Fauzan Khairul Anwar	X.I
5	9270	Alinda Maretania	X.I
6	9271	Andika Eka Prasetya	X.I
7	9272	Anggun Kirei Kemuning Senja	X.I
8	9273	Cahaya Anisa	X.I
9	9274	Catur Adi Yogo Utomo	X.I
10	9275	Chaya Bellia Putri	X.I

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No	Nis	Name	Class
11	9276	Danang Erik Setiawan	X.I
12	9277	Dwi Lutfiana Afriyani	X.I
13	9278	Erza Maulana	X.I
14	9279	Fatimah Nisyah Zahra	X.I
15	9280	Fifi Anggraeni	X.I
16	9281	Ghevira Anisa Kholish	X.I
17	9282	Hafizh Husni	X.I
18	9283	Halliza Melyani	X.I
19	9284	Kartika Afrilia	X.I
20	9285	Kayla Enggar Lestari	X.I

Figure 2. Ballot Design Data

This study began with an analysis of the existing voting system to identify its shortcomings and limitations, followed by the design of a new system proposed as a solution. The analysis stage was conducted to understand the workflow of the manual system previously used, where the voting process was carried out conventionally[10]. The election committee would first prepare paper ballots, and students would select their preferred candidate by punching the paper ballot. After voting, the ballots were placed into a ballot box, and finally, the committee conducted a manual vote count from the collected ballots.

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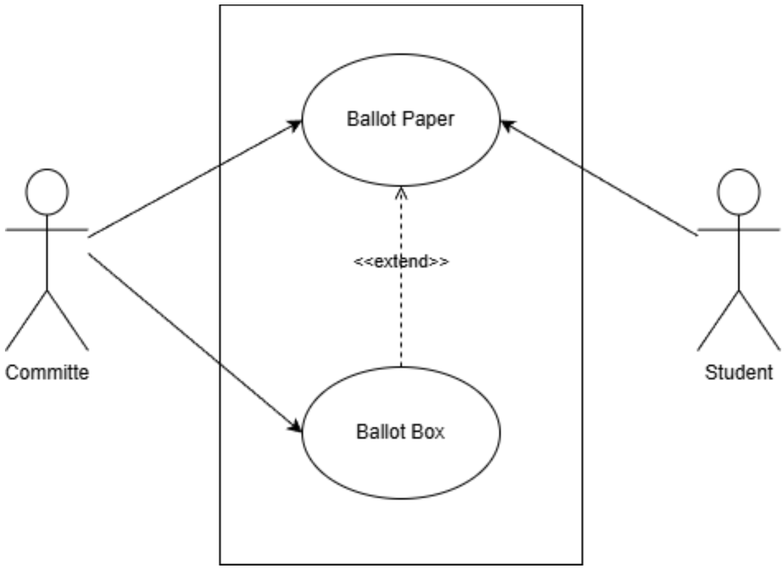

Figure 3. UseCase of the Existing Voting System

To address the limitations of this manual process, this study designed a digital e-voting system that offers greater efficiency and security. In the proposed system, the committee prepares digital ballots instead of physical ones. Before casting a vote, students verify their identity using fingerprint authentication, and once verified, they can vote through a digital ballot interface. The recorded votes are then automatically stored in the database and counted in real time, enhancing the efficiency, accuracy, and security of the election process.

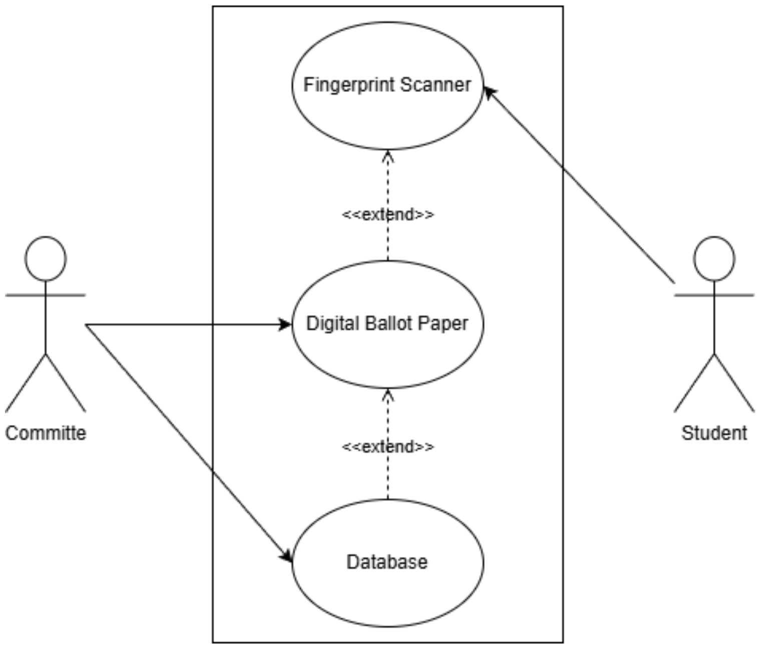

Figure 4. Use Case Design of the Proposed E-Voting System

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The next stage in the system design involves creating a flowchart, which illustrates the overall sequence of system processes[11]. The flowchart outlines the steps starting from the committee entering the ballot code, followed by voter authentication through a fingerprint device, and concluding with the automatic recording and storage of votes in the database.

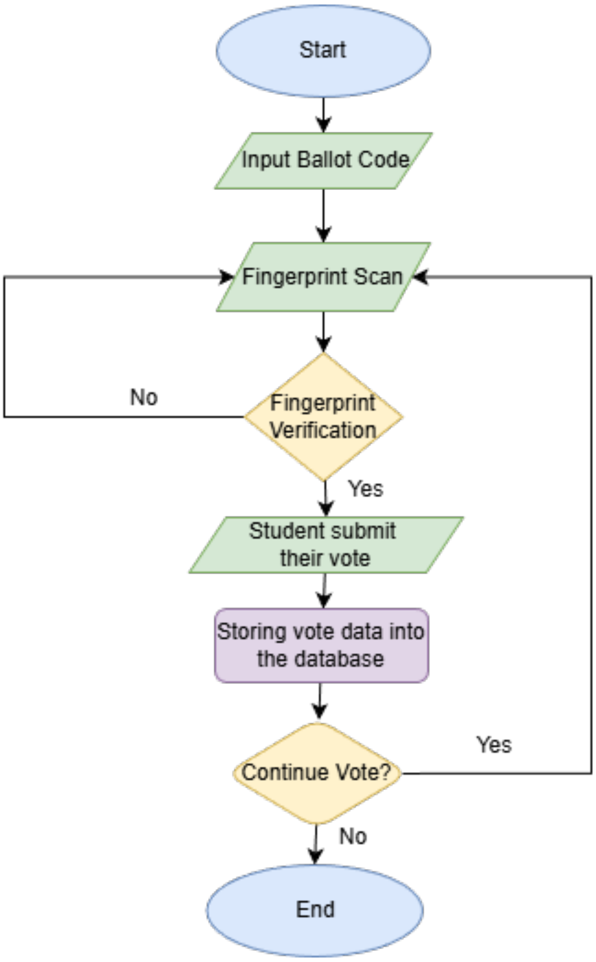

Figure 5. Flowchart of the E-Voting System

The development phase of the e-voting application was carried out based on the previously designed system architecture, integrating several core components: Laravel, Flutter, ESP32, the JM-101B fingerprint sensor, and MQTT as the message broker for inter-device communication. Laravel served as the web dashboard framework, as it is one of the most powerful PHP web application frameworks, utilizing the Model View Controller (MVC) architecture to separate business logic from presentation, thus improving code management and scalability[12], [13], [14]. The mobile e-voting application was developed

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using Flutter, an open-source cross platform framework that enables the creation of high-performance applications for both iOS and Android from a single codebase[15], [16]. To support biometric authentication, the system employed an IoT device based on the ESP32 microcontroller, which is equipped with a dual-core CPU, Wi-Fi, and Bluetooth modules, making it suitable for low-cost and high-performance IoT applications[17]. The ESP32 was connected to a JM-101B fingerprint sensor, which functions as a transducer that converts fingerprint patterns into electrical signals readable by the identification circuitry[18]. However, this sensor has several inherent limitations, including reduced accuracy when reading fingerprints from users with thin or oily skin, as well as a limited internal storage capacity of up to 127 fingerprint templates[19]. To overcome this constraint, fingerprint templates are additionally stored on the server-side database, allowing the system to manage a larger number of templates than the hardware's internal memory permits. For security purposes, all fingerprint templates stored in the database are transformed into hashed representations, ensuring that raw biometric data is never stored directly on the server. Communication between the web application, mobile platform, and IoT device was facilitated through the MQTT protocol, a lightweight publish/subscribe messaging mechanism that enables efficient data exchange among system components[20]. However, because MQTT in this system does not implement Transport Layer Security (TLS), there is a potential risk of message interception by unauthorized parties[21]. Although the transmitted data consists of hashed fingerprint values, this information is still considered sensitive and related to user privacy, making intercepted messages a security concern for the biometric data being transmitted.

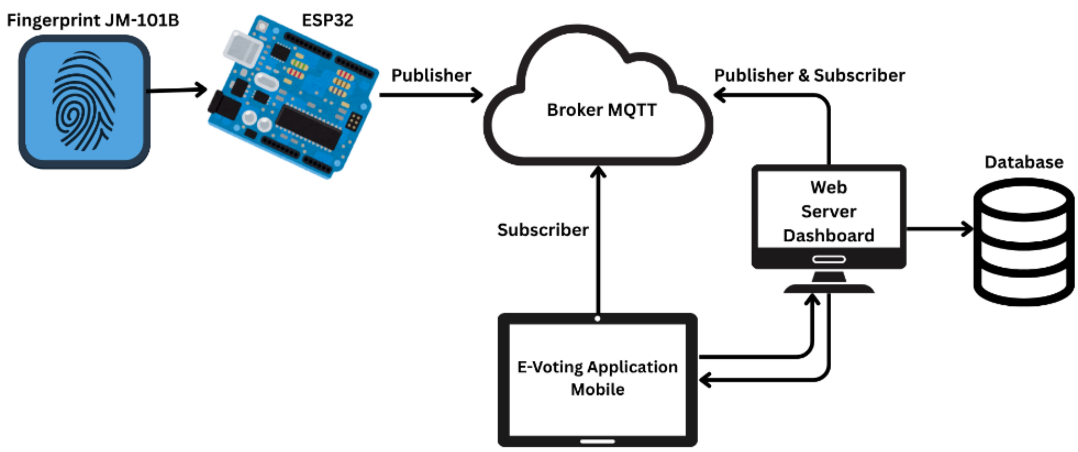

Figure 6. System Architecture of the IoT-Integrated E-Voting System

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The system implementation phase was carried out at SMA Negeri 1 Ulujami, Pemalang Regency, involving 20 students listed in the research data as test participants. This number was selected as a representative sample for prototype evaluation, particularly to verify the proper functioning of key components such as biometric authentication, IoT communication, and vote data processing. During implementation, each student performed authentication using the JM-101B fingerprint sensor connected to the ESP32 microcontroller via MQTT, followed by casting their vote through the Flutter-based mobile application. The voting results were automatically recorded and stored in a database managed by the Laravel-based web dashboard. The tests confirmed that all system components from biometric authentication and IoT communication to data recording and vote counting operated seamlessly without technical issues.

The evaluation phase aims to ensure that the e-voting system operates according to its intended goals and design specifications. This phase focuses on testing the system's functionality, particularly the input and output processes of each main component across both the web and mobile platforms. The evaluation employs the Blackbox Testing method, which assesses the system's output results based on given inputs without examining the internal structure of the program[22]. In addition to functional testing, usability testing was also conducted to assess the system's responsiveness across different device sizes specifically comparing mobile phones and tablets to ensure that the voting interface remains accessible, readable, and easy to interact with on various screen dimensions[23]. The percentage of user comfort for each device type was calculated using Equation 1.

$$\text{Comfort Rate} = \frac{\text{Number of Comfortable Responses}}{\text{Total Participants}} \times 100\% \tag{1}$$

Furthermore, performance testing was conducted to measure the system's operational efficiency by recording the execution time required for fingerprint scanning and the latency of vote submission from the mobile application to the server[24]. The average execution time obtained from 20 trials was calculated using Equation 2.

$$\bar{T} = \frac{\sum_{i=1}^{n} T_i}{n} \tag{2}$$

where $T_i$represents the execution time measured in each trial. This comprehensive testing process verifies that all system features such as fingerprint based voter authentication, vote submission, data storage, and result display operate correctly, responsively, and within acceptable performance thresholds. Through this approach, the evaluation seeks to confirm that the e-voting system is ready for use and capable of delivering accurate, secure, and reliable performance in supporting the student council presidential election at SMA Negeri 1 Ulujami, Pemalang Regency.

3. RESULTS AND DISCUSSION

3.1. IoT-Based E-Voting System

This study produced an Internet of Things (IoT) based e-voting application designed for the election of student council presidents at SMA Negeri 1 Ulujami, Pemalang Regency. The system integrates Laravel as a web-based dashboard responsible for managing voter data, ballots, and vote recapitulation, with Flutter serving as the mobile frontend platform that provides the voting interface for students. A key innovation of this system lies in its use of biometric authentication through an IoT-based fingerprint verification device, designed to enhance both the security and validity of voter data[25].

The resulting system effectively resolves several issues identified in conventional school voting processes such as identity duplication, manual data errors, and lack of transparency while offering superior data integrity compared to previous research. Furthermore, the integrated admin dashboard allows the system to operate sustainably across multiple election cycles, providing administrators with flexible management tools and real-time monitoring capabilities.

The mobile platform interface includes three main components: the voting code input page, the fingerprint verification popup, and the digital ballot interface. The voting code input page serves as an initial authentication mechanism for election officials, where the entered code functions as an access key to retrieve the appropriate ballot data from the system's database. Subsequently, the fingerprint verification popup displays the result of biometric authentication received from the IoT device, ensuring that only verified voters are authorized to proceed to the voting stage. After successful verification, the system presents a digital ballot designed to replicate the structure of a traditional paper ballot, complete with an official letterhead and candidate list, as demonstrated in Figure 7, Figure 8, and Figure 9.

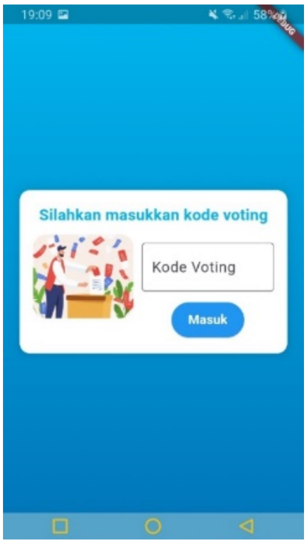

Figure 7. Mobile Interface Voting Code Input Page

Figure 8. Mobile Interface Fingerprint Verification Popup

Figure 9. Mobile Interface Digital Ballot

The web based administrative dashboard, illustrated in **Figure 10**, enables authorized election committees to view and manage key election parameters, including the total number of registered students, ballots, and candidate pairs. In addition, the system provides visual analytics in the form of graphs to display student participation rates for each election period, promoting transparent reporting and data driven decision making.

Figure 10. Web Platform Interface Admin Dashboard

To support the system's biometric authentication mechanism, an IoT hardware configuration was developed, consisting of an ESP32 microcontroller, a fingerprint sensor, an LCD, and an LED indicator. Each voter's fingerprint data is captured and

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processed locally, with verification results transmitted to the main server for secure access to the digital ballot on a connected tablet. This setup ensures real-time identity verification and prevents unauthorized voting, as depicted in Figure 11.

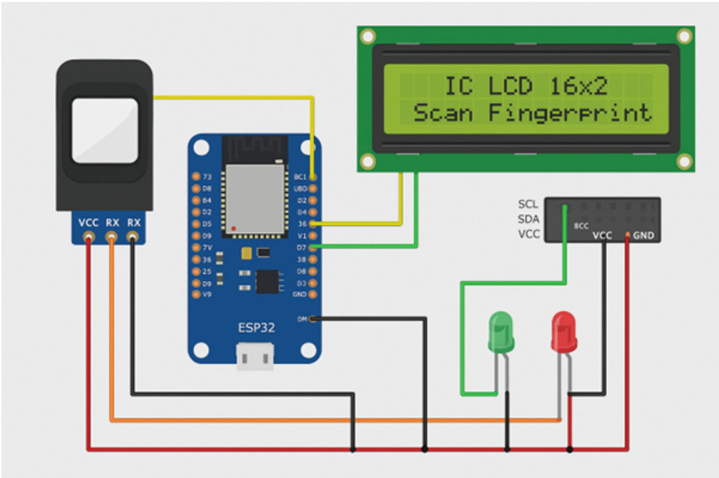

Figure 11. IoT Device Circuit for Biometric Verification

Following the implementation stage, the IoT based e-voting system entered the evaluation phase to assess its performance and reliability under real world usage conditions. This evaluation was carried out through three main types of testing: Blackbox Testing, usability testing, and performance testing. Blackbox Testing was conducted to ensure that all core features on both the web and mobile platforms such as fingerprint-based authentication, voting transactions, data management, and result presentation operated correctly according to the predefined scenarios, without logical or functional errors. Usability testing was performed to compare the comfort and ease of interaction experienced by users when accessing the voting interface on mobile phones versus tablets, based on feedback from the same 20 student participants. Additionally, performance testing was used to measure the system's operational efficiency by recording fingerprint scan time and vote submission latency during the voting process. Together, these testing activities provide a comprehensive basis for evaluating the overall quality and readiness of the system before full deployment, and the detailed results of each evaluation component are presented in the following sections.

The Blackbox testing process focused on six primary scenarios that represent the actual flow of system usage, ranging from the voting code authentication stage to the voting process and data management by the election committee. Details of the testing scenarios, including labels and expected outputs, are presented in Table 2.

Table 2. Testing Scenario

No	Testing Scenario	Expected Output	Label
1	Code voting input	Successfully redirects to the homepage and displays the fingerprint verification popup	A
2	Fingerprint Verification	The fingerprint verification popup disappears after successful authentication.	B
3	Casting a vote for a candidate	A success popup appears and redirects back to the verification popup	C
4	Adding student data	A success popup appears confirming that student data has been added.	D
5	Adding student fingerprint data	A success popup appears confirming that the fingerprint data has been registered.	E
6	Adding ballot data	A success popup appears confirming that the ballot has been successfully created.	F

After defining the six main test scenarios, the system was further evaluated by involving 20 student participants who performed each scenario directly using both the mobile and web platforms. The outcomes of these individual tests are summarized in Table 3, which presents the detailed Blackbox Testing results for every participant based on the predefined functional labels.

Table 3. Blackbox Testing

No	Nis	Testing Results					
		A	B	C	D	E	F
1	9266	√	√	√	√	√	√
2	9267	√	√	√	√	√	√
3	9268	√	√	√	√	√	√
4	9269	√	√	√	√	√	√
5	9270	√	√	√	√	√	√
6	9271	√	√	√	√	√	√
7	9272	√	√	√	√	√	√

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No	Nis	Testing Results					
		A	B	C	D	E	F
8	9273	√	√	√	√	√	√
9	9274	√	√	√	√	√	√
10	9275	√	√	√	√	√	√
11	9276	√	√	√	√	√	√
12	9277	√	√	√	√	√	√
13	9278	√	√	√	√	√	√
14	9279	√	√	√	√	√	√
15	9280	√	√	√	√	√	√
16	9281	√	√	√	√	√	√
17	9282	√	√	√	√	√	√
18	9283	√	√	√	√	√	√
19	9284	√	√	√	√	√	√
20	9285	√	√	√	√	√	√

The detailed outcomes of the functional testing conducted with 20 student participants are shown in Table 3, illustrating the performance of six primary features of the IoT-based e-voting system. All test cases across every participant produced the expected results, with every functional scenario ranging from voting code authentication to ballot creation executing successfully without any logical or system errors. This outcome indicates that the system achieved a 100% success rate across all 120 test instances (20 participants × 6 scenarios).

In addition to the functional evaluation, a usability testing procedure is planned to assess the system's responsiveness across different device screen sizes, specifically by comparing the voting interface on mobile phones and tablets. This testing will involve the same 20 student participants, each of whom will be instructed to use both device types to complete the voting process. After completing the tasks on each device, participants will be asked to provide direct feedback regarding their perceived comfort, readability, and ease of interaction. Their responses will then be categorized using the criteria defined in Table 4, which classifies user experience into "Comfortable" or "Uncomfortable." This categorization aims to identify which device mobile phone or tablet is more suitable and preferable for users in the context of the voting process.

Table 4. Comfort Categorizations

Label	Definition
Comfortable	The interface is easy to read, interact with, and navigate; users experience no difficulty using the device during the voting process.
Uncomfortable	The interface is difficult to read, interact with, or navigate; users experience challenges or discomfort when using the device during the voting process.

Table 5. Usability Comfort Testing Results

No	Nis	Phone	Tablet
1	9266	Comfortable	Comfortable
2	9267	Uncomfortable	Comfortable
3	9268	Uncomfortable	Comfortable
4	9269	Comfortable	Uncomfortable
5	9270	Comfortable	Comfortable
6	9271	Uncomfortable	Comfortable
7	9272	Comfortable	Comfortable
8	9273	Uncomfortable	Comfortable
9	9274	Uncomfortable	Comfortable
10	9275	Uncomfortable	Comfortable
11	9276	Uncomfortable	Comfortable
12	9277	Comfortable	Uncomfortable
13	9278	Uncomfortable	Comfortable
14	9279	Uncomfortable	Comfortable
15	9280	Comfortable	Comfortable
16	9281	Uncomfortable	Comfortable
17	9282	Uncomfortable	Comfortable
18	9283	Uncomfortable	Comfortable
19	9284	Uncomfortable	Comfortable
20	9285	Uncomfortable	Comfortable

Based on the usability comfort testing results presented in Table 5, a comparative analysis was conducted to evaluate user comfort when interacting with the voting interface on mobile phones and tablets. The categorization shows that out of 20 participants, 6 students reported feeling comfortable using the mobile phone, while 14 students expressed discomfort, resulting in a comfort rate of:

$$\text{Phone Comfort Rate} = \frac{6}{20} \times 100\% = 30\%$$

In contrast, 18 students reported feeling comfortable using the tablet, while only 2 students indicated discomfort, producing a significantly higher comfort rate of:

$$\text{Tablet Comfort Rate} = \frac{18}{20} \times 100\% = 90\%$$

These results indicate a clear preference for the tablet interface, with users reporting substantially greater comfort in terms of readability, interaction, and navigation. The large disparity between the two device categories suggests that the larger screen size and wider layout of the tablet contribute to a more accessible and user-friendly voting experience. Therefore, the tablet is recommended as the preferred device for conducting the e-voting process, as it demonstrates a markedly higher comfort level and aligns more effectively with the usability expectations of students and committee members.

After completing functional and usability evaluations, the next stage of assessment is performance testing, which aims to quantify the system's operational efficiency. This test focuses on two primary metrics: fingerprint scan time and vote submission latency. To obtain realistic measurements under actual usage conditions, the same 20 student participants from earlier tests will be asked to perform authentication and voting tasks while the system automatically logs execution times in milliseconds (ms) at the device, application, and server levels. These measurements will be aggregated and analyzed to produce average execution times and to assess the responsiveness and suitability of the system for real-world deployment.

Table 6. Peformance Testing Result

No	Nis	Fingerprint Scan Time (ms)	Vote submission Time (ms)
1	9266	407	324
2	9267	872	469

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No	Nis	Fingerprint Scan Time (ms)	Vote submission Time (ms)
3	9268	702	536
4	9269	736	432
5	9270	815	525
6	9271	444	417
7	9272	831	465
8	9273	549	572
9	9274	517	318
10	9275	719	420
11	9276	800	497
12	9277	636	366
13	9278	426	394
14	9279	479	478
15	9280	617	309
16	9281	798	329
17	9282	635	510
18	9283	891	465
19	9284	677	480
20	9285	841	542

Based on the performance testing results presented in Table 6, the average fingerprint scan time was recorded at 669,6 ms, with the fastest scan occurring at 407 ms and the slowest at 891 ms. Meanwhile, the average vote submission latency was measured at 437,1 ms, with a minimum value of 309 ms and a maximum value of 572 ms. All measurements were collected from 20 trials conducted by the participating students, where each trial captured the execution time for both the fingerprint scanning process and the vote submission process through the system's automated logging mechanism. These findings indicate that the biometric authentication process requires a higher execution time compared to the vote submission process, while vote submission demonstrates more consistent and stable timing across participants. Overall, the calculated averages provide a realistic representation of the system's performance under actual usage conditions and serve as a basis for identifying potential areas for optimization in future development phase.

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3.2. Discussion

The successful implementation and evaluation of the IoT-based e-voting system demonstrate that integrating biometric authentication with mobile and web technologies can significantly enhance security, reliability, and transparency in school-based voting environments. The system achieved a 100% functional success rate across 120 Blackbox test cases, confirming that all application modules including authentication, data management, and vote recording operate consistently according to their intended design. This reliability reflects the system's robustness in managing real-time user interactions and synchronizing data between the IoT hardware, the web dashboard, and the mobile application.

When compared to previous studies, this research presents clear improvements in both security mechanisms and validation procedures. Prior e-voting systems often relied on manual or password-based authentication, which remains vulnerable to impersonation, credential sharing, and multiple voting attempts. In contrast, the IoT-based fingerprint verification mechanism implemented in this system ensures that only registered users with valid biometric templates can access the voting interface, effectively eliminating identity duplication. While alternative authentication methods such as RFID cards or QR codes may offer faster processing speeds, they introduce different security drawbacks. RFID cards can be easily borrowed or misplaced, and QR codes are susceptible to duplication if not cryptographically secured[26]. Fingerprint biometrics, on the other hand, offer non-transferable, user-bound authentication, making them more suitable for ensuring voting integrity in school environments, despite requiring slightly longer verification times as reflected in the performance testing results.

From a usability standpoint, the system demonstrated strong user acceptance. The usability testing results indicated that 90% of participants preferred using tablets over mobile phones due to better readability, larger interactive areas, and improved ease of navigation. This feedback underscores the importance of device selection when deploying digital voting systems at scale. Performance testing further revealed that the average fingerprint scan time was 669,6 ms, while the average vote submission latency was 437,1 ms. These values indicate that the system is sufficiently responsive for real-world usage, although biometric authentication requires more time than vote submission due to variations in user fingerprint conditions and sensor sensitivity.

An additional aspect highlighted by the findings is the system's scalability. While the prototype was tested with 20 participants, its architecture built on Laravel, Flutter, MQTT, and ESP32 can be extended to accommodate larger user bases. For an environment with approximately 1,000 students, scalability can be achieved by deploying multiple fingerprint verification stations, optimizing database query performance, and enabling load balancing for simultaneous vote submissions. MQTT's lightweight publish/subscribe model inherently supports large-scale messaging traffic, allowing the system to maintain real-time communication even under increased load. With these enhancements, the system can reasonably be expected to function effectively in larger institutional elections.

Finally, the discussion must address potential operational risks. Fingerprint sensors are susceptible to hardware failure, degraded accuracy due to dry or oily skin, and increased error rates over time without proper calibration. Spoofing attempts though unlikely in a controlled school environment remain a theoretical risk, implementing stronger liveness detection or anomaly monitoring could mitigate this. Network instability within school Wi-Fi environments may also affect MQTT message delivery, potentially causing temporary verification delays. However, these risks can be managed through redundancy planning, fallback mechanisms, and improved infrastructure support[27].

The findings confirm that the developed IoT based e-voting system not only meets functional, usability, and performance expectations but also surpasses prior studies by integrating secure biometric verification, IoT enabled real-time synchronization, and multi-platform interoperability. With proper scaling strategies and risk mitigation measures, the system presents a robust, user-friendly, and highly adaptable digital election framework suitable for educational institutions and potentially extendable to broader organizational contexts.

4. CONCLUSION

This study demonstrates that the IoT-based e-voting application developed for the student council presidential election at SMA Negeri 1 Ulujami was successfully designed and implemented as a secure, accurate, and user-friendly solution. The integration of a Laravel based administrative dashboard, a Flutter mobile voting interface, and IoT-driven

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fingerprint authentication effectively resolves key limitations of conventional voting methods while ensuring voter validity and system reliability. Results from functional, usability, and performance testing confirm that the system operates stably and responsively under real-world conditions. Future improvements may include integrating cloud-based infrastructure to enhance scalability and real-time synchronization, particularly for deployments involving larger user populations. The system also has the potential to be expanded for multi-school use, supported by additional authentication alternatives such as secure QR codes or RFID cards as backup mechanisms. With these advancements, the IoT based e-voting platform can evolve into a more mature, flexible, and widely applicable digital election system for various educational institutions.

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