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Implementation of Decentralized Systems in Electronic Election Applications

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Abstract

The e-voting system represents a digital innovation designed to enhance efficiency, transparency, and security in the election process. This research discusses the development of a blockchain-based e-voting system built on the Ethereum testnet (Sepolia), integrated with CodeIgniter 4, MySQL, and Tailwind CSS frameworks. The system was developed using the Prototyping method, enabling iterative improvement based on user feedback. The evaluation results indicate that each vote is successfully recorded on the blockchain through a smart contract, providing a verifiable transaction hash (tx_hash) as proof of authenticity. From a usability perspective, 73.7% of respondents stated that the system is easy to use, and 78.9% expressed willingness to adopt it. These findings demonstrate that the proposed blockchain-based e-voting system meets the criteria of usability, security, and user trust, showing strong potential for practical implementation at Esa Unggul University.

Keywords*:* e-voting, blockchain, codeigniter4, ethereum, prototyping, data security

INTRODUCTION

In the development of information and communication technology, many countries have adopted electronic voting systems or E-voting as a means of expressing opinions in decision-making processes across various democratic contexts such as education, business, social organizations, and government. The purpose of this system is to enhance efficiency, accessibility, and transparency in the election process (Supono & Prutratama, 2018). Electronic voting, also known as e-voting, is a voting process conducted electronically, where digital information from election results is recorded, stored, and processed. David Chaum first introduced the concept of electronic voting (E-voting) in the early 1980s. The system initially utilized cryptography-key technology, which serves to help voters remain anonymous (Dew & Putra, 2022).

The existence of student organizations within a university is essential for student development. This is reinforced by the Law of the Republic of Indonesia No. 12 of 2012 concerning Higher Education, particularly Article 77, which regulates student organizations (Nopardo et al., 2023). One of the student organizations on campus is the Student Executive Board (BEM). BEM is an intra-campus organization established by students, functioning as the executive body at both university and faculty levels. It is led by a president and vice president who are democratically elected. They also have the authority to modify the leadership structure and the overall organization (Munthe et al., 2023).

However, the process of electing the BEM president in many universities is still carried out manually, including at the institution where this study was conducted. This often leads to various issues, such as the

possibility of fraud in vote counting, inaccessible voters, and a lack of transparency in the election process itself. Moreover, the large number of parties involved in vote counting and collection frequently causes bureaucratic complexity and conflicts that take time to resolve (Wulandari et al., 2025).
Electronic voting systems are still not fully developed, as many problems remain unsolved. Through decentralized technology, data and information can be recorded and monitored by multiple parties, thereby enhancing the security, transparency, and efficiency of the voting process (Taş & Tanrıöver, 2020). The utilization of decentralized technology also offers significant security advantages (Harahap et al., 2020).

This study adopts the Prototype system development method because it provides a systematic and structured workflow in software development, from the requirement analysis stage to the system maintenance stage. The Prototype approach is considered appropriate since each stage produces clear outputs that serve as the foundation for the next stage, thereby reducing the likelihood of errors during the development process. The stages of this method include Quick Plan, which involves initial planning to identify user needs and the objectives of the evoting system; Modeling Quick Design, which consists of creating a simple design in the form of an initial prototype that illustrates the system flow, user interface, and interactions; Construction of Prototype, which focuses on developing an interactive model that presents the main system features to assess whether they meet user needs; Deployment, where users test the prototype and provide feedback to identify weaknesses or areas for improvement; and finally, Communication, which involves discussions between developers and stakeholders to ensure that the improvements made align with user requirements before the final system is built.

The object of this study is an electronic voting (e-voting) system used to elect the President and Vice President of the Student Executive Board (BEM). The research aims to analyze and evaluate key elements of the system, including voter data security, system stability, vote-counting accuracy, and the transparency of the election process. Through this analysis, the study seeks to determine the extent to which the e-voting system improves the reliability and trustworthiness of the election process.

For data collection, this research uses a quantitative method that focuses on collecting and analyzing numerical data to test hypotheses. Data were collected using questionnaires or online surveys distributed via Google Forms, allowing for more efficient data collection and analysis. Google Forms offers several advantages, such as flexibility in question types (multiple choice, Likert scale, short answers, and so on), ease of distribution to many respondents, and automatic data storage in Google Sheets, which enables faster and more efficient data processing. However, this method also has limitations, such as the need for an internet connection and the potential for bias if respondents are not randomly selected or do not accurately represent the wider population.

Table 1. Research Questionaire

No.	Question	Answer Options
1	Are you aware that Esa Unggul University is currently developing a system for the election of BEM President and Vice President?	☐ ☐ Yes No
2	Do you think the development of the e-voting application is important to support the election of the BEM President and Vice President?	☐ ☐ Yes No
3	Would you be willing to use the e-voting application in the election once it is officially launched?	☐ ☐ Yes No
4	Do you think the e-voting system is easy for students to use?	☐ ☐ Yes No
5	Do you believe that the security of the e-voting system is very important?	☐ ☐ Yes No
6	Are you familiar with what blockchain technology is?	☐ ☐ Yes No
7	Do you agree that blockchain technology should be used in the e-voting system to protect vote data security?	☐ ☐ Yes No
8	Do you believe that blockchain technology can improve the reliability of the evoting system?	☐ ☐ Yes No
9	Would you use a blockchain-based e-voting system for the next BEM election?	☐ ☐ Yes No

10	Do you feel that your personal data would be secure when using a blockchainbased e-voting system?	☐ Yes	☐ No

Various integrated technologies are used in the development of a blockchain-based e-voting system to ensure security, efficiency, and system stability. The main technologies employed include PHP (CodeIgniter 4) for backend development using the MVC (Model-View-Controller) concept, allowing the system to be more structured, with functions to manage candidate data, user authentication, and communication with Ethereum smart contracts via web3.php. For the user interface, Tailwind CSS is used to create a responsive and modern UI easily. MySQL serves as a relational database to store non-blockchain information such as user data and authentication results before being sent to the blockchain network. On the blockchain side, the system utilizes Ethereum (Sepolia Testnet) as a decentralized platform for recording votes, ensuring that every transaction is permanent and tamperproof. The connection between the application and the Ethereum network is facilitated by Infura, allowing interaction without the need to run a dedicated node. The smart contract, developed using Solidity, acts as the core logic for the voting process, ensuring the security and transparency of votes. System integration is supported by web3.php, a library that bridges communication between the PHP backend and the Ethereum blockchain to read, send, and verify voting transactions.

In the system design stage, a prototyping approach was used through a series of diagrams such as use case, class, activity, and sequence diagrams to illustrate user interactions, process flows, and data structures. The main actors in the system include the admin, user (voter), and candidate. The admin has full control over election management, such as adding candidates, setting schedules, and validating voting results, while users can log in, view candidate profiles, cast votes, and monitor voting status. The system architecture is built in a layered structure, consisting of the frontend (Tailwind-based UI), backend (CodeIgniter 4 API), relational database (MySQL), and Ethereum Sepolia blockchain integration. The deployment process is carried out via an Nginx/Apache-based server running the CodeIgniter application, connected to the blockchain network through RPC providers such as Infura or Alchemy.

In the testing and refinement stage, the prototyping method is applied iteratively. The process begins with identifying user requirements, creating a low-fidelity prototype, evaluating feedback, and then developing a functional prototype connected to the blockchain. Testing includes validating login flows, voting processes, and recording transaction hashes (tx_hash) as proof of vote authenticity on the Sepolia network. The final implementation phase focuses on improving the user interface, adding post-vote notification features, and preparing comprehensive system documentation. With this design and technological integration, the blockchainbased e-voting system is expected to deliver a transparent, secure, and publicly auditable election process.

DISCUSSION

The first stage aims to define the scope and core requirements of the e-voting system. Functional requirements include login/registration, election management, candidate management, one-person-one-vote functionality, and real-time result presentation. Meanwhile, non-functional requirements cover basic security, auditability through transaction trails, and system performance. This stage is based on the principles of requirements engineering, which emphasize elicitation, analysis, and specification of requirements before the prototype is built. The main focus is to agree on a definition of done for each feature so that the prototype can be evaluated objectively.

Table 2. Identification of Core E-Voting System Requirements

ID	Category	Requirement	Brief Description	Priority	Acceptance Criteria
F-01	Authentication	User Registration	New users register (email/student ID + password)	Must	After submitting valid data, the account is saved and can log in; input validation rejects empty or incorrect formats.
F-02	Authentication	User Login	Users log in as Admin/Voter	Must	Valid credentials → redirected to the appropriate dashboard; invalid credentials → clear error message.
F-03	Election Management	CRUD Election	Admin can create, edit, delete, and activate/deactivate elections	Must	Election data is saved; active status only within the specified time frame; changes reflected in the election list.
F-04	Candidate Management	CRUD Candidate	Admin can add/edit/delete candidates for each election	Must	Candidates appear in the relevant election; changes are reflected in real-time in the election details.
F-05	Voting	One Person-One Vote	Each voter can only vote once per election	Must	Second voting attempts in the same election are always rejected (status 4xx + specific message).
F-06	Blockchain	Transaction Recording	Votes are sent to the Ethereum Sepolia network; tx_hash is stored	Must	After a successful vote, tx_hash is stored and linked to (user_id, election_id); UI displays proof of transaction.
F-07	Results	Vote Recapitulation	Display aggregate results for each candidate	Must	Results page shows total votes per candidate, updates after each recorded transaction.
F-08	Auditability	Verification Link	Optional link to explorer (Etherscan) for verifying tx_hash	Should	Clicking the link opens the corresponding transaction details; tx_hash matches the application data.

Based on Table 2, the identified functional requirements indicate that the context of the e-voting system aligns with the needs of both administrators and voters. The system will be developed according to these requirements, as illustrated in the following diagram.

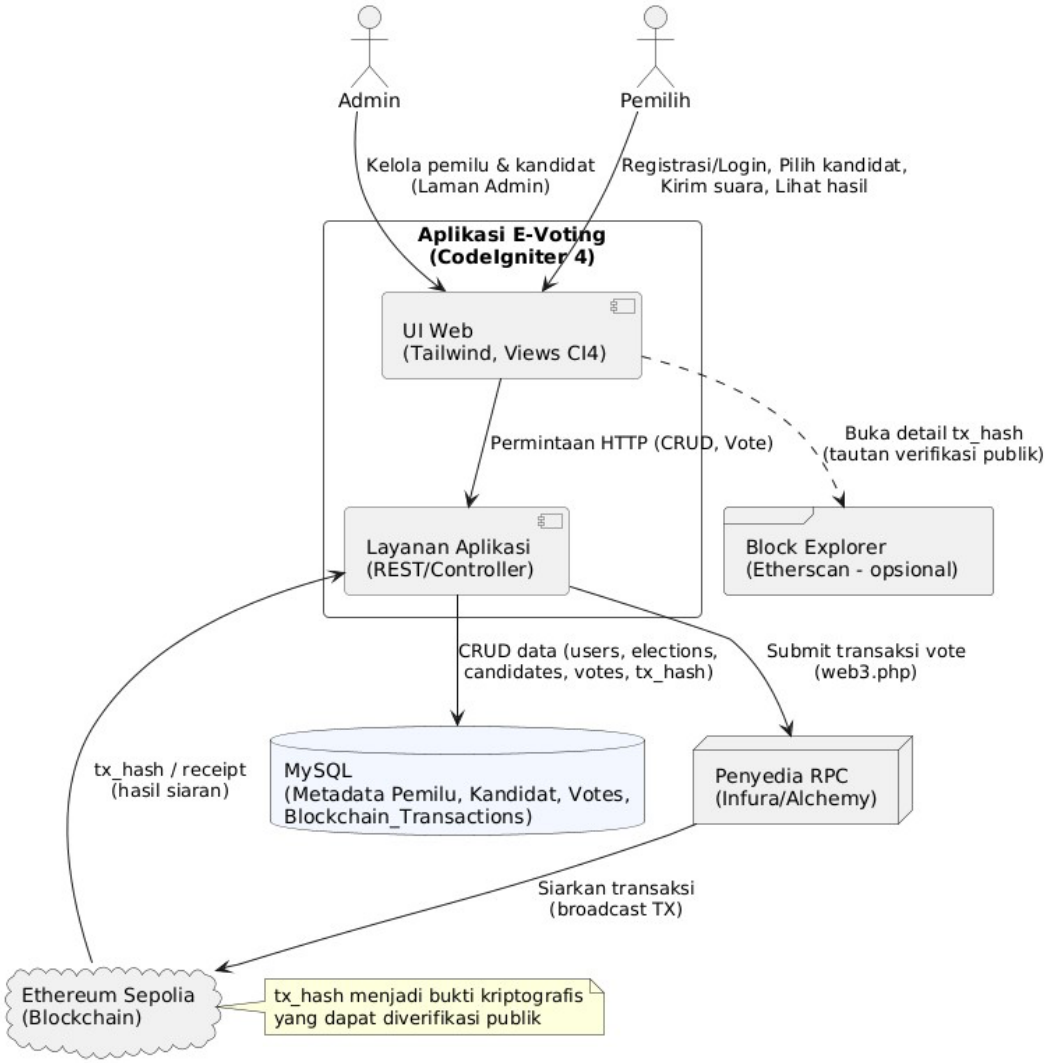

Figure 1. E-Voting System Context Diagram

Development of the Initial Prototype (Low-Fidelity/Wireframe)

The purpose of this stage is to ensure that the flow and organization of interface information are validated before the system is fully implemented, thereby reducing the likelihood of design errors and development costs. This method is based on the concept of human-centered design, where low-fidelity wireframes are used to examine flow and information hierarchy without being distracted by visual details. Although the feedback gathered at this stage is relatively inexpensive, it significantly influences the user experience. Wireframes were created for the Login/Registration, Election List, Candidate Details, Voting Form, and Results pages. Subsequently, an end-toend navigation simulation—from login to viewing election results—was conducted to ensure the system flow was logical. To make key elements easily identifiable, important components such as call-to-action (CTA) buttons, validation messages, and status indicators were clearly marked.

This process resulted in a set of low-fidelity wireframes in PNG format, accompanied by a list of interaction assumptions such as button placement, confirmation texts, and minimal validation rules. Based on the initial evaluation, several issues were identified, including unclear post-vote notifications and the placement of the confirmation button on the voting form, which made some participants feel uncertain.

As a result, the next iteration introduced several improvements: typography size was increased, the contrast of success messages was enhanced, and the results page was updated to include a tx_hash placeholder along with a brief explanation of its function as proof of voting transactions on the blockchain.

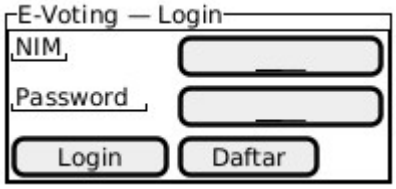

Figure 2. Login Page Wireframe

Figure 3 shows the Login page as the starting point of the process. Registered users log in using their student ID (NIM) and password. A "Register Account" link is provided for new users. After successful authentication, the system directs users to the Election List according to their voting eligibility.

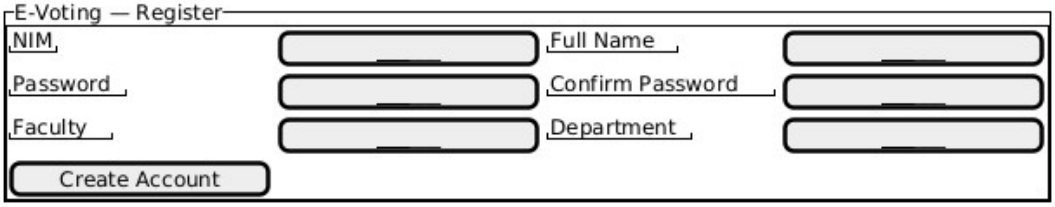

Figure 3. Registration Page Wireframe

Figure 4 shows the Registration page for new users. This form collects basic information such as student ID (NIM), name, password, and organizational unit (faculty/department) as the basis for eligibility. After successful registration, users are redirected to the Login page with a confirmation message before proceeding to the Election List.

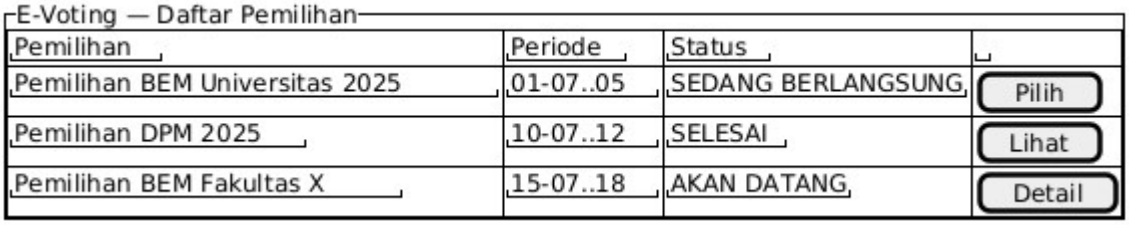

Figure 4. Election List Wireframe

Figure 5 displays the Election List available according to user eligibility. Each election card shows the title, period, and status (active/finished). From this screen, users can select one election to open the Election Details & Candidate page.

Figure 5. Election and Candidate Details Wireframe

Figure 6 presents the Vote Confirmation screen summarizing the selected candidate and election information. Based on testing findings, the confirmation button's position and label were clarified (e.g., "Submit Vote/Confirm") and placed in a visually distinct area to eliminate ambiguity. Users can cancel or continue. If continued, the system records the vote and processes the transaction proof.

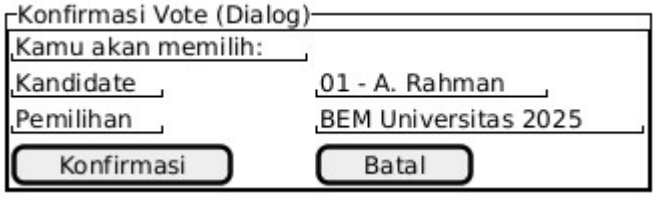

Figure 6. Vote Confirmation Wireframe

Figure 7 shows the Successful Vote Dialog. Following iteration recommendations, typography and contrast for success messages were increased and positioned at the top of the visual hierarchy for better visibility. The dialog also provides next-step options (e.g., "View Results" or "View on Explorer") to ensure the user flow does not end abruptly.

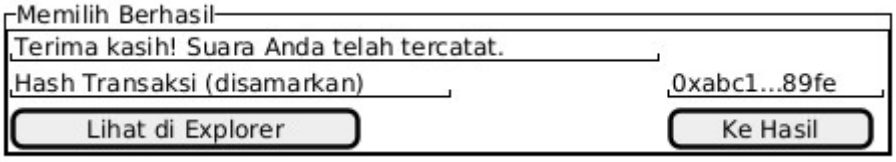

Figure 7 Successful Vote Dialog Wireframe

Figure 8 presents the Results Page, summarizing the total votes per candidate (in chart or table format) along with the election status.

Figure 8. Results Page Wireframe

Prototype Evaluation

The prototype evaluation stage aims to collect empirical data on the usability of the proposed system flow as well as determine the necessary changes before the implementation of core functions. The evaluation was carried out formatively using walkthrough and think-aloud methods, with a focus on identifying cognitive load, points of confusion, and potential errors that could be prevented. This approach is commonly used to minimize the risk of rework in the implementation phase and ensure that the flow of the system is easy for users to understand. The prototype evaluation stage aimed to collect empirical data regarding the usability of the proposed system flow and to determine any necessary changes before implementing the core functions. The evaluation was conducted formatively using walkthrough and think-aloud methods, focusing on identifying cognitive load, points of confusion, and preventable user errors. This approach is commonly used to minimize rework risk during the implementation phase and ensure that the system flow is easy to understand for users.

The evaluation process gathered empirical data on the usability and user acceptance of the blockchain-based evoting system being developed. The formative evaluation employed the walkthrough and think-aloud methods, in which participants interacted directly with the prototype while expressing their experiences and feedback. A total of 19 respondents participated in this trial and completed a questionnaire consisting of ten closed-ended questions with "Yes" and "No" options. The evaluation results were used to assess the system's ease of use, user trust, and readiness to adopt blockchain technology.

1. Awareness of System Development

About 52.6% of respondents (10 out of 19) were aware that Esa Unggul University was developing an evoting system for the election of the Student Executive Board (BEM) President and Vice President, while 47.4% were unaware. This finding suggests that the project's socialization efforts need to be improved so that all students understand the purpose and benefits of the system being developed.

2. Importance of E-Voting Application Development
   The majority of respondents (78.9%) believed that developing an e-voting application is important to support the BEM election process, while 21.1% thought otherwise. This positive perception indicates that students view the digitalization of elections as an efficient step aligned with campus organizational needs.
3. Willingness to Use the System
   Most respondents (78.9%) expressed their willingness to use the e-voting application once it is officially launched. This result reflects a high level of acceptance and readiness to adopt the new system. Factors influencing this positive response include ease of access, time efficiency, and trust in a more modern system.
4. Ease of Use
   A total of 73.7% of respondents (14 people) stated that the e-voting system was easy to use, while 26.3% still found it somewhat difficult. Walkthrough observations revealed that some respondents experienced confusion regarding the placement of the confirmation button and the appearance of post-vote notifications. Based on these findings, improvements were made in the next iteration by clarifying the button placement and enlarging the size and contrast of success messages to make them more prominent in the visual hierarchy.

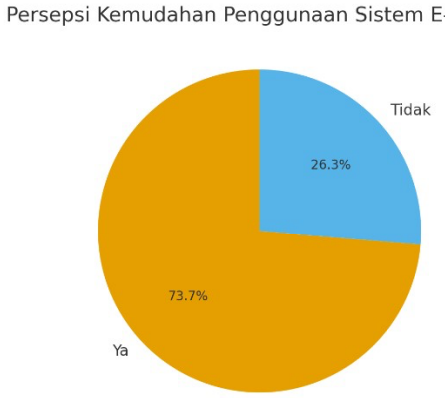

Figure 9. Diagram of Perceived Ease of Use of the E-Voting System

5. Perception of System Security

   A total of 68.4% of respondents stated that security is a crucial aspect of the e-voting system, while 31.6% did not consider it a top priority. This finding confirms that the security factor is a key determinant of system acceptance, particularly in ensuring the integrity of vote data and the authenticity of election results.

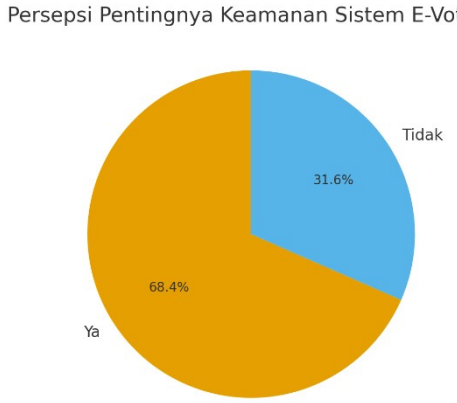

Figure 10. Diagram of Perceived Importance of E-Voting System Security

6. Knowledge of Blockchain Technology

   Approximately 63.2% of respondents reported being familiar with blockchain technology, while 36.8% were not yet familiar with the concept. However, most respondents who were initially unfamiliar with blockchain expressed enthusiasm after receiving a brief explanation of its function as a secure and transparent transaction recording system.

7. Support for the Use of Blockchain

   The majority of respondents (73.7%) agreed that blockchain should be used in the e-voting system to maintain the security of voting data, while 26.3% disagreed. This result indicates that students understand the potential of blockchain to ensure the security and transparency of the election process.

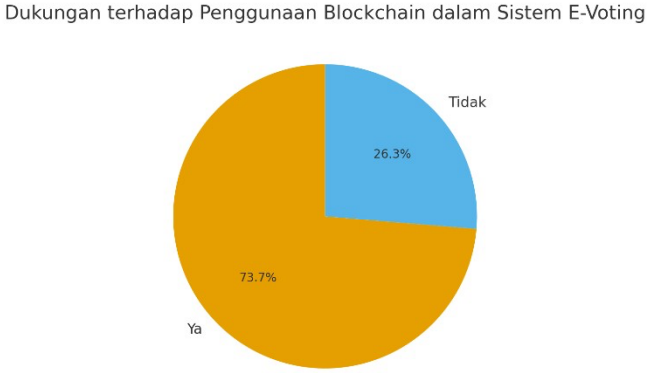

Figure 11. Diagram of Support for the Use of Blockchain in the E-Voting System

8. Confidence in the Reliability of Blockchain

   A total of 78.9% of respondents believed that blockchain technology could enhance the reliability of the e-voting system, while 21.1% remained uncertain. This demonstrates that blockchain is perceived as a solution capable of strengthening trust in system integrity and preventing vote manipulation.

9. Intention to Use the System in Future Elections

   Around 68.4% of respondents expressed their intention to use the blockchain-based e-voting system in future elections, while 31.6% were still uncertain. This data shows that trust and interest in using the system are already quite high, although some respondents are waiting to see proof of system stability after full implementation.

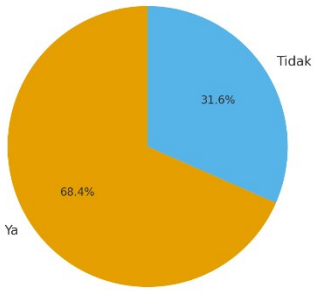

Figure 12. Diagram of Intention to Use the Blockchain-Based E-Voting System in Future Elections

10. Perception of Personal Data Security

    Most respondents (73.7%) felt that their personal data would be safe when using the blockchain-based evoting system, while 26.3% were still unsure. This finding suggests that implementing blockchain has successfully enhanced perceptions of security and trust in user privacy protection.

Based on the prototype evaluation results, it can be concluded that the developed blockchain-based e-voting system meets the aspects of usability, trust, and user readiness. The majority of respondents considered the system easy to use (73.7%) and showed a high level of acceptance toward blockchain technology implementation (73.7%–78.9%).

However, attention is still needed to refine certain interface elements, particularly the placement of confirmation buttons and notification visibility, to ensure more intuitive user interactions. Overall, the evaluation results indicate that the prototype has strong potential for broader implementation as a secure, transparent, and easily accessible digital voting platform within Esa Unggul University.

Advanced Prototype

The purpose of the advanced prototype stage is to execute the core functions of the e-voting system. The main features include the one-person-one-vote mechanism and the recording of votes on the Ethereum Sepolia blockchain to generate a tx_hash as cryptographic proof. Implementation follows the requirements outlined in stages 1–3, ensuring data security through server-side validation and an on-chain audit trail. This method enhances accountability and minimizes potential disputes regarding election results.

At this stage, election and candidate CRUD operations, as well as the login/registration module, are implemented using CodeIgniter 4 with MySQL as the database. Once voter eligibility and election period validations are passed, transactions are transmitted via web3.php using RPC. The tx_hash is stored, and users can view their transaction proof. Additionally, edge cases—such as duplicate voting attempts, inactive periods, and network or transaction failures—are properly handled.

Evaluation Results and Key Findings:

1. The functional end-to-end prototype operated successfully in the testing environment.
2. Duplicate voting attempts for the same election consistently failed.
3. Both the **tx_hash** and transaction logs were securely stored and traceable for audit purposes.

Final Implementation

The final stage focuses on refining the interface, standardizing terminology, and preparing prototype documentation to ensure the results can be easily reproduced and verified. This phase emphasizes visual consistency and report structure while ensuring that each interface element and artifact supports clear presentation and auditing.

Procedures/Activities:

1. Improve UI/UX aspects such as typography, status colors, icons, and element naming.
2. Collect screenshots with consistent numbering based on references in the documentation.
3. Cross-verify the final list of figures and references to ensure accuracy.

Outputs/Deliverables:

1. A stable prototype ready for testing.
2. A package of screenshots with consistent captions and sufficient resolution for supporting documentation.

System Interface Design

Two essential components in developing digital applications are **UI (User Interface)** and **UX (User Experience)**. The blockchain-based e-voting system developed in this study exemplifies how both components work harmoniously to create an application that is not only visually appealing but also user-friendly for both voters and administrators.

The User Interface (UI) includes visual elements that directly interact with users, such as page layout, color schemes, icons, and navigation button designs like "Login," "Register," and "Logout." In this e-voting system, the interface predominantly uses blue tones to convey professionalism and trust. The layout is designed to be simple and symmetrical, ensuring ease of navigation and intuitive use.

Understanding and applying UI/UX principles are crucial in designing this application. The combination of a well-crafted interface (UI) and an optimized user experience (UX) results in an effective, accessible, and userfriendly e-voting system.

The following section provides further explanation of the UI/UX elements implemented in the e-voting system. **1) Halaman Dashboard Users**

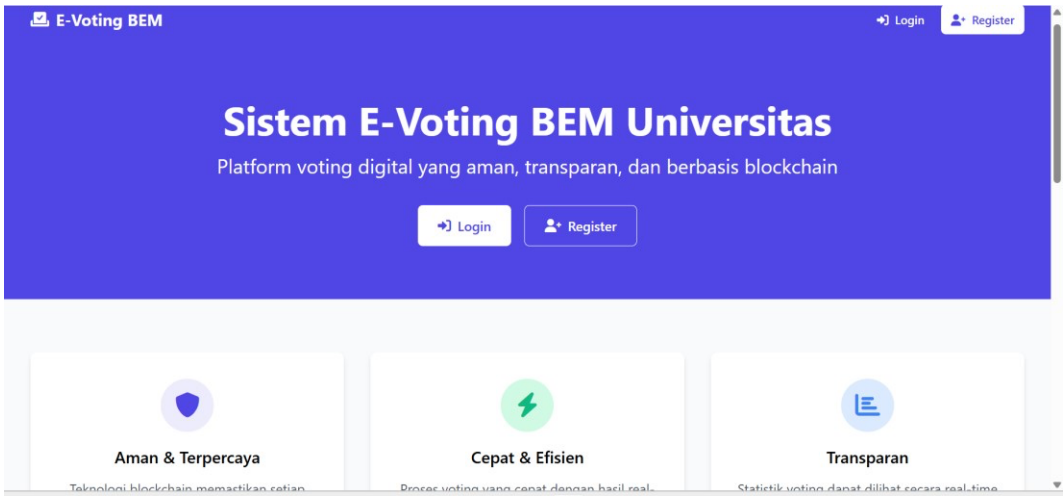

Figure 13. Home Page

The home page display on the *e-vote* system is designed as the starting point for user interaction by displaying opening, login and registration messages. The interface is built in a simple and responsive manner for all users with a calm and professional color dominance.

Registration Page

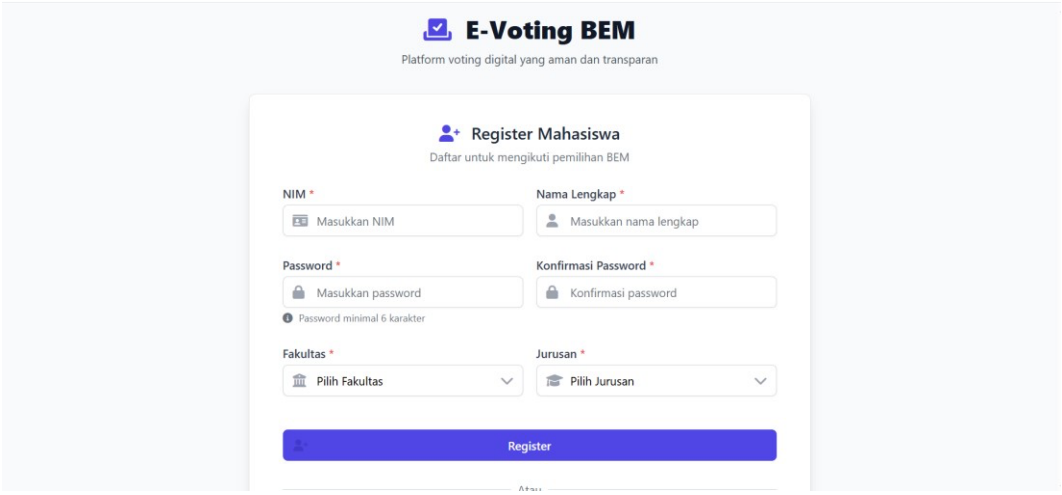

Figure 14. Registration Page

The register display is the second step for users to register as voters in the system *e-voting*. On this page, users are asked to fill in personal information such as, student identification number, full name, *password*confirmation *password*, faculties and departments. When the user has filled in *form* registration correctly and correctly, then the next step is to register, then the system will be directed by the system to the login page.

Login Page

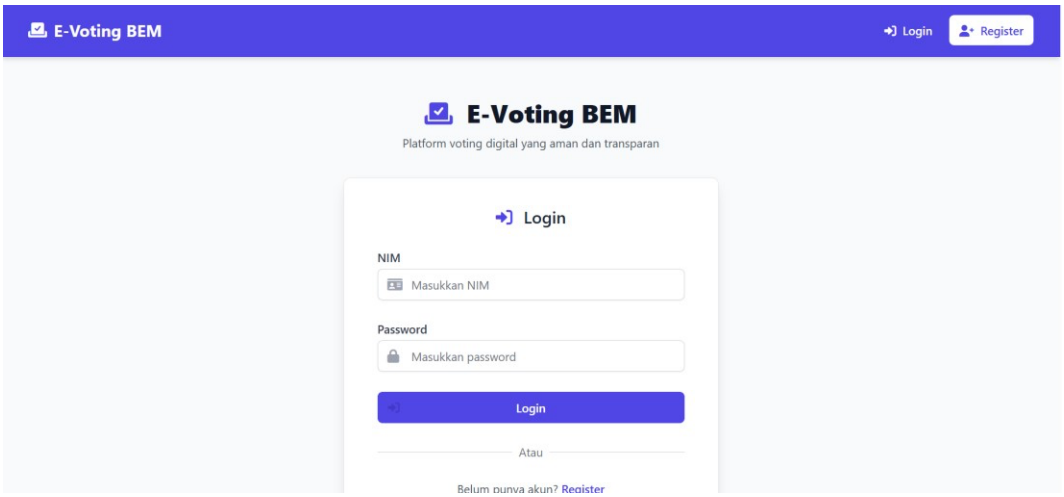

Figure 15. Login Page

After filling out the *registration form* is complete, users will be directed to the login page. On this page, users are asked to enter their student identification number and password that has previously been registered on the registration page. If the user enters the data correctly, the system will be directed to the e-vote Dashboard page

Selection Display

a. BEM E-Voting Dashboard Page

This page, shown in this image, serves as an information center for users once they log in to the system. At the top of the page, you will find a navigation menu that includes the Dashboard, Elections, and the profile of a user named Joko Prabowo. Data about election activity is displayed in the three main information boxes below. The Active Election Box has a number of 1 indicating that an election is in progress, the Voting Box has a number of 0 indicating that the user has not yet completed the election process, and the Unvoting Box has a number 1 indicating that the user still has one election that has not yet been followed.

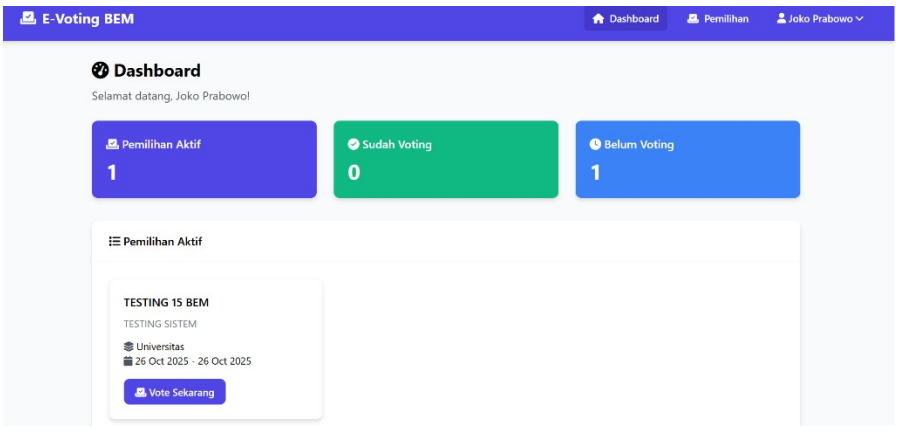

Figure 16. Election Dashboard Page

b. Viewing After Voting

After the user votes, the system will issue a notification containing the date and time of voting, verification of my vote, and view it on *Etherscan.* In this case, users can look into *the Etherscan* which will be directed to the Sepolia website page.

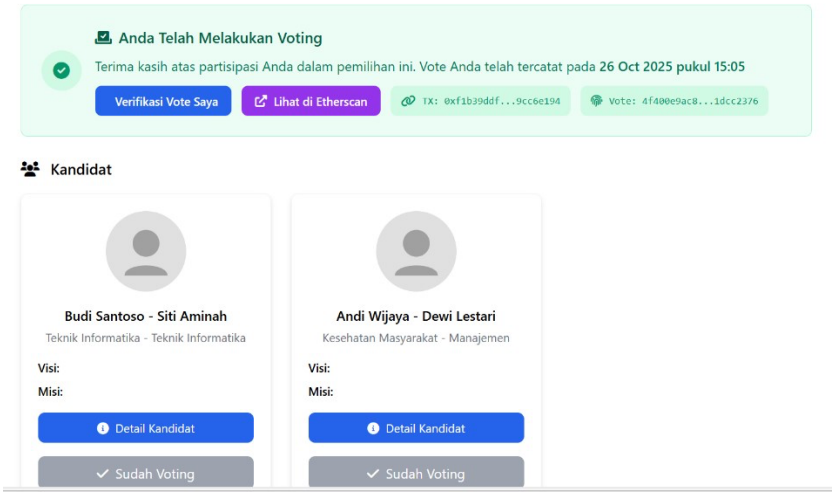

Figure 17. Successful Voting View

Halaman Dashboard E-Vote

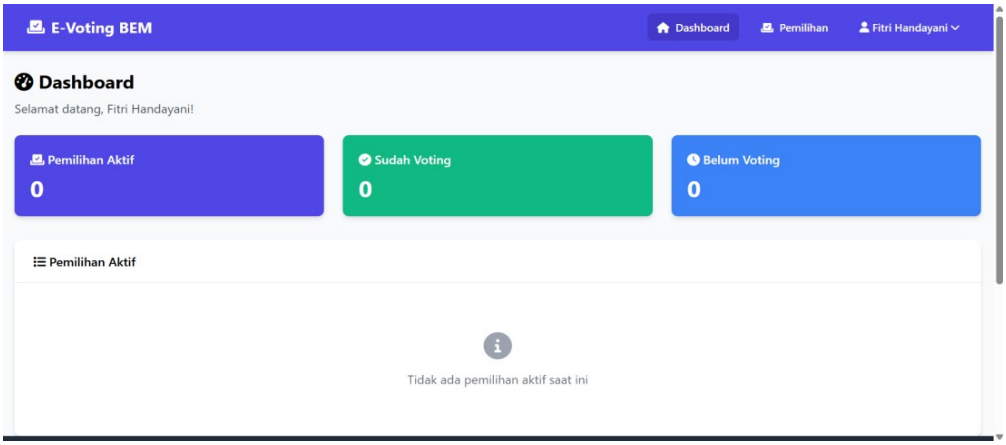

Figure 18. Dashboard E-Vote

Three main indicators in the main part of the dashboard serve to provide quick information about the status of the election implementation: Active Election, Already Voting, and Not Voting. The image shows that all three

are zero, which indicates that the user is not involved in the selection. In addition, the panel that says "Active Elections" is at the bottom and displays the message "There are no active elections at this time" as a sign that the system does not have running election data yet.

Overall, the dashboard interface is simple and easy to use. Users don't need to open additional menus to quickly see the status of their selection. The colors used also help differentiate each category of information, making the data displayed clearer.

Verification of Voting Results

Users can verify previously selected votes by viewing in *Etherscan.* The *Etherscan* display on Sepolia is aimed at verifying the data selected by the user, ensuring that the selected selection is correct.

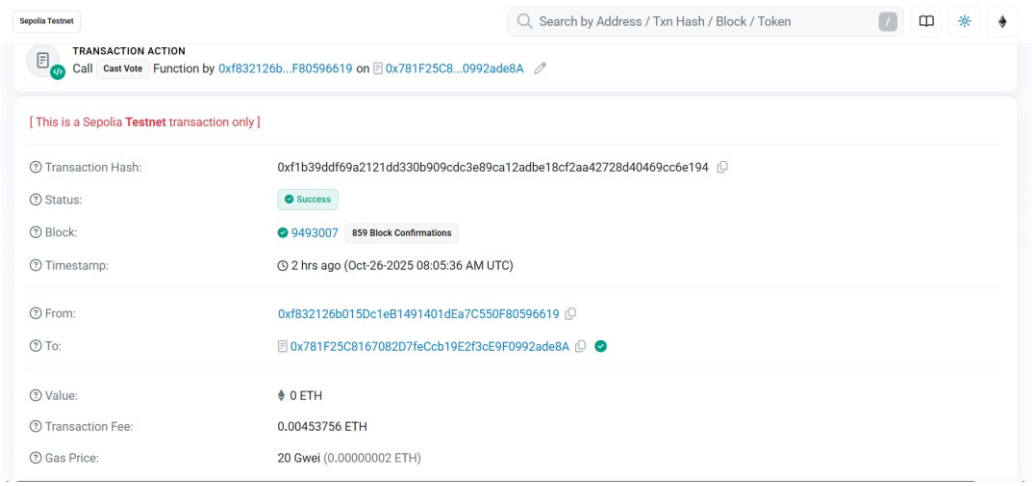

Figure 19. Verification of Voting By Spolia

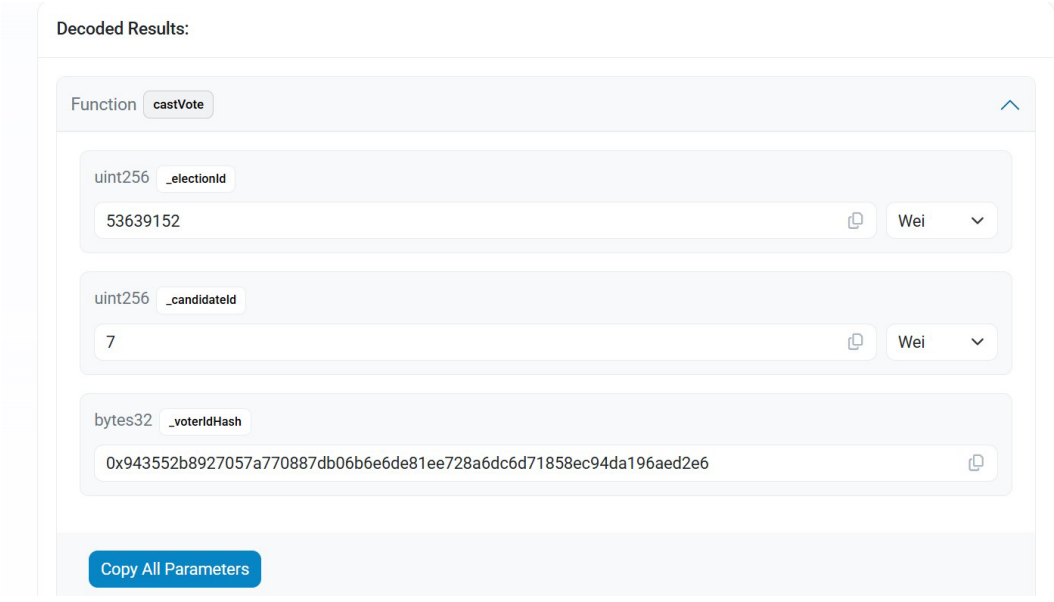

Figure 20. Etherscan Verification Results

Completed Voting View

After the election ended, the candidate pair of Budi Santoso and Siti Aminah was officially decided as the absolute winner by obtaining 1 vote, which is equivalent to 100% of all votes cast. Although the results show that voters are fully engaged, the participation rate is still very low. Only one in 13 eligible voters in the university environment exercise their right to vote. Thus, the Participation Rate is 7.69%.

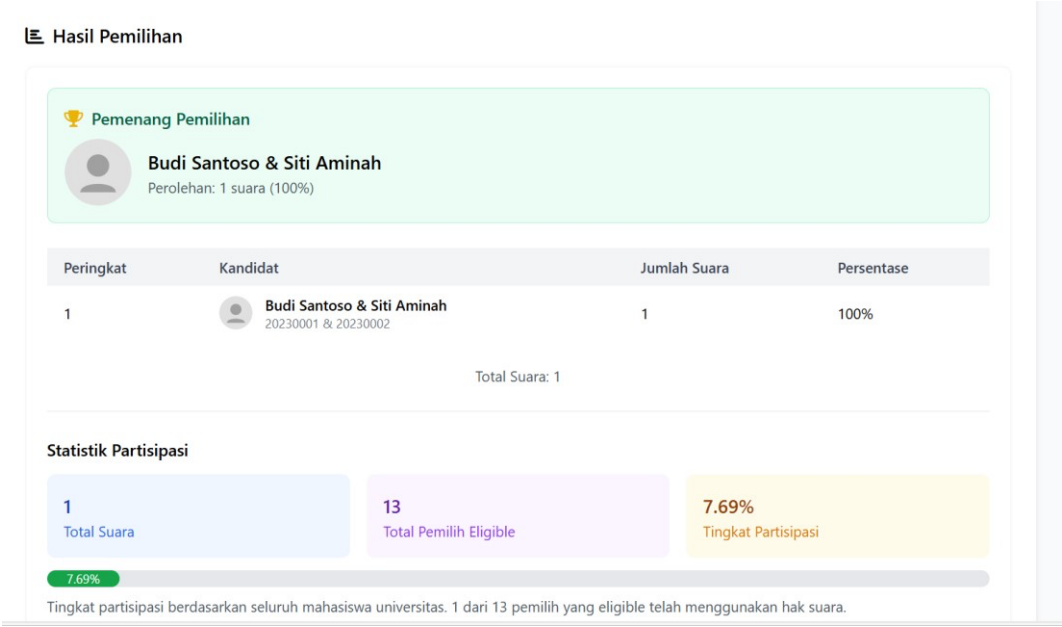

Figure 21. Voting Results Display

System Testing

At this time, a testing process is being carried out on a developed e-voting system that is based on blockchain. The Blackbox testing method, which focuses on the functionality of the system without checking the program code directly, is used to perform the tests. The goal of this test is to ensure that each feature of the app works according to the needs and produces the expected results.

The test scenario includes all the main features of the system, such as the login process, user registration, candidate management by admins, the voting process, and the real-time display of the vote results. The results of these tests are used as a basis for evaluation to assess the success rate of system implementation and find the possibility of errors in certain processes.

Scenario : User Login Successful

In these cases, the user's login process is tested to ensure that the system can correctly identify the user and display the page according to its function. The testing steps carried out include:

a) User Open the login page on the e-voting application
b) The user enters the correct credentials in the form of a student identification number and password
c) The user presses the sign-in or sign-in button to initiate authentication
d) The system will verify whether the data is already registered in the database

Expected result (Expected result): The system successfully identifies the correct login data and directs users to the dashboard page according to their role (Admin or Selector). The header section of the dashboard page displays the username and role as a sign that the login process has been successful

Table 3. Successful Login Scenario

Ts ID	Test Steps	Expected Results	Current	Status
01	Log in, enter your Student Identification Number and password	Login is successful and redirected to the dashboard page	NIM :20230007 Password : password7	[Passed]

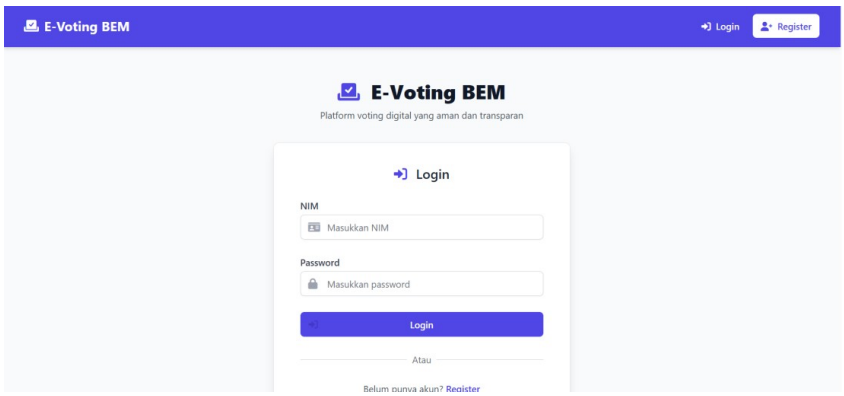

Figure 22. Login Testing

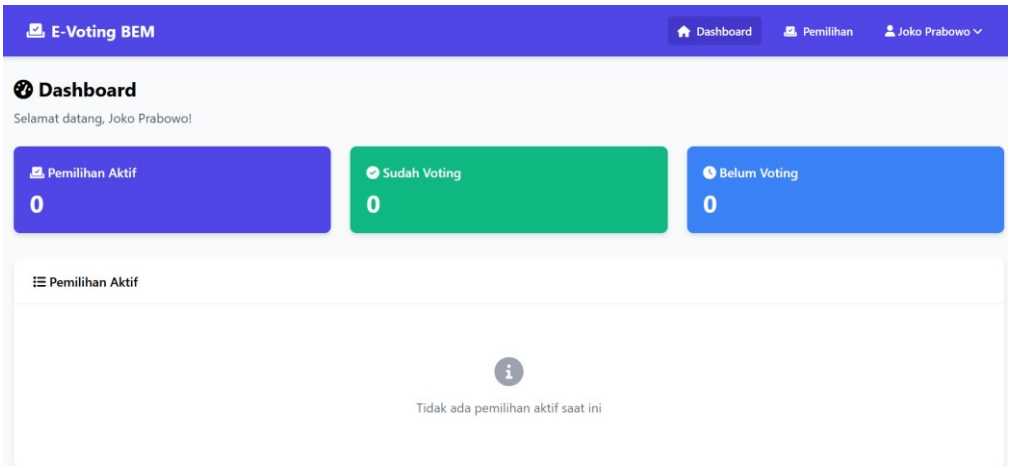

Figure 23. Login Successful – Dashboard Appears 2) Scenario : Login failed

In this case, the login process is tested when the user enters the wrong password. This is done to ensure that the system can reject incorrect authentication and send the correct error message. The testing steps include:

a) Go to the login page
b) Enter the correct NIM and the wrong password
c) Click the login button
d) The system will display the wrong NIM or Password message

Table 4. Login Failed Scenario

Ts ID	Test Steps	Expected Results	Current	Status
02	Login, enter the wrong Student Identification Number and password	The login fails, and the system will display the message "NIM or Password incorrect"	NIM :20230007 Password : password7	[Passed]

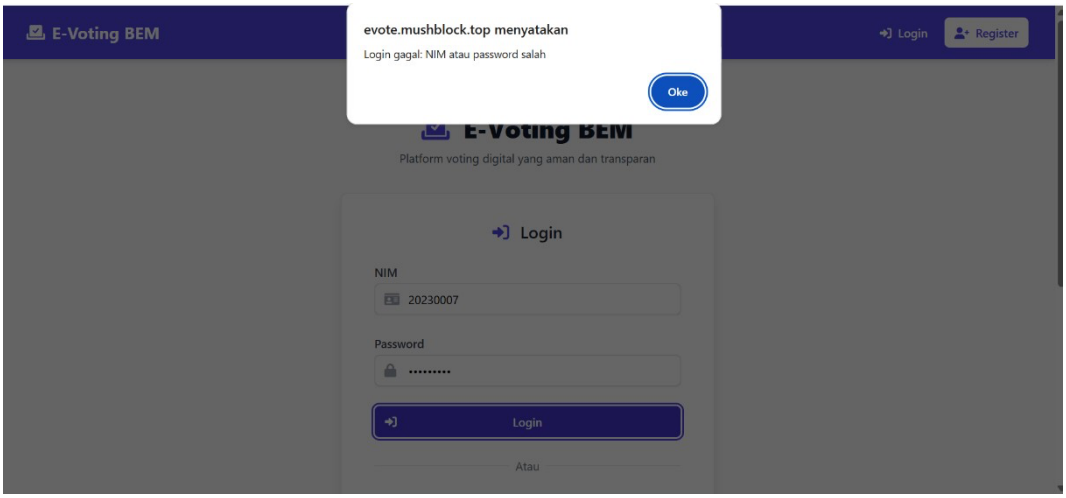

Figure 24. Login Failed

Scenario : Voter Voting Page

Users who have successfully logged in can vote for candidates available for election on the voter voting page. This page displays a list of candidates with information such as names, photos, and short visions, making it easy for voters to make a decision. The voting page in the UI is designed to be easy to understand and use. Each candidate is displayed in the form of an easy-to-understand card or list with a "Vote" button. The use of colors and icons is intended to provide a comfortable visual experience for users and differentiate candidates.

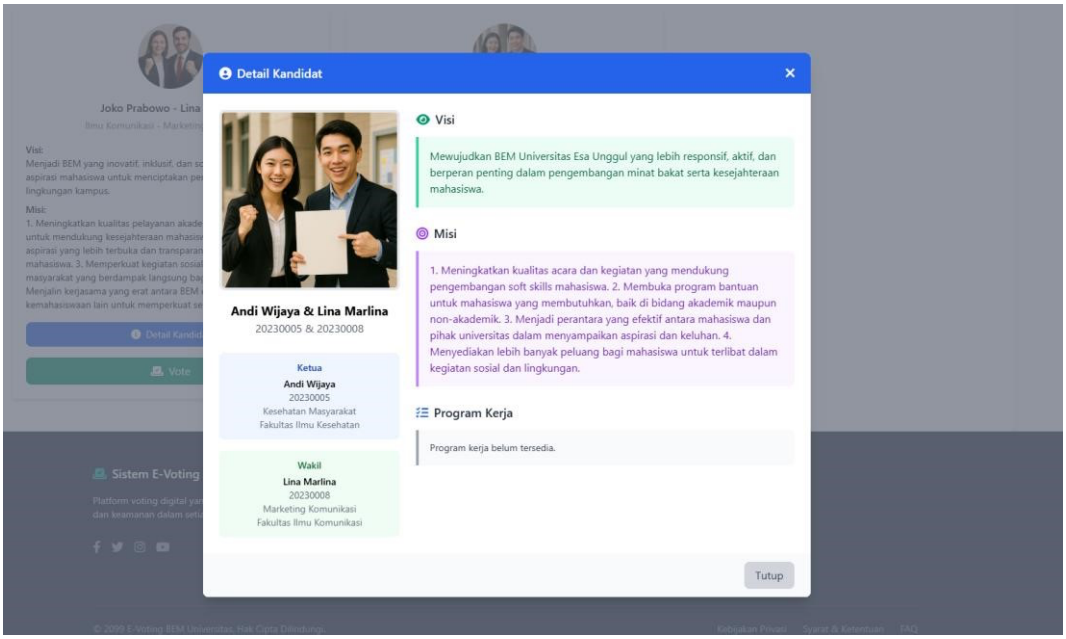

Figure 25. Election Candidate Details 4) Scenario : Successful Voting Process

In this scenario, voter accounts that have never voted are used to test the voting process to ensure that the system can correctly record voter choices into the blockchain network.

a) The testing process is carried out as follows:
b) Log in as a voter who has not yet voted
c) Select the available candidates on the e-voting dashboard
d) Click the vote button
e) The system will send the transaction to the blockchain and display the transaction hash

Table 5. Scenario : Successful Voting Process

Ts ID	Test Steps	Expected Results	Current	Status
03	Log in as a selector2. Select a candidate3. Click the "Vote" button4. System send transactions to the blockchain	generate a hash of a valid transaction; transaction status in Etherscan = Good; Increased Voice	A valid form of hash transaction; the transaction status on Etherscan is successful; the number of votes increases; Voters can no longer cast their votes.	[Passed]

Scenario : Double Voting Prevention

This situation was created to ensure that the e-voting system can maintain the integrity of the vote by preventing voters from voting more than once.

The testing process is carried out as follows:

a) Log in as a voter who has voted in the previous scenario.
b) Re-access the voting page.
c) Try voting for another/the same candidate.
d) Expected Output: The system rejects the second vote; displays the message 'You have voted'. There are no new transactions.

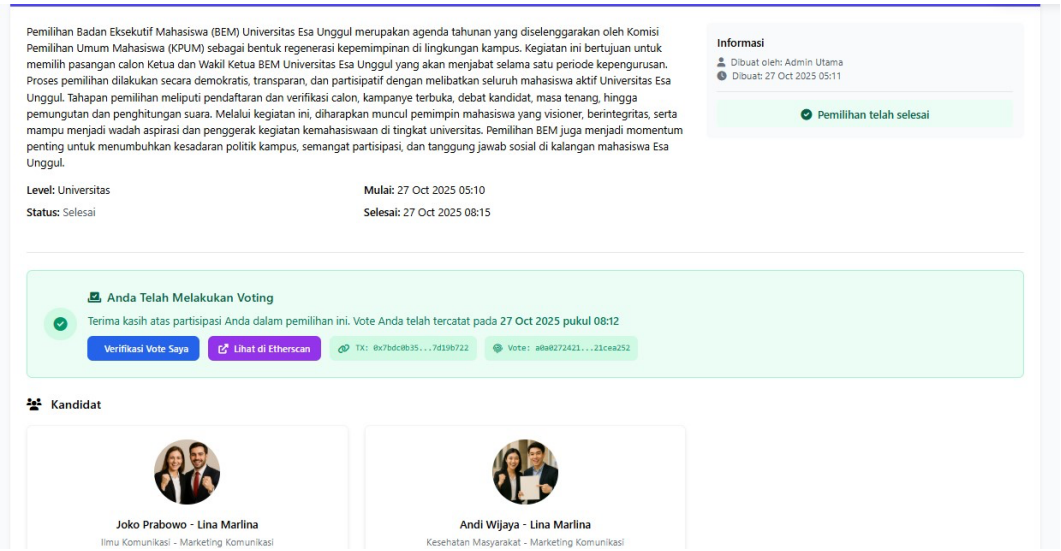

Figure 26. Testing to Prevent Double Voting

Table 6. Scenario : Double Voting Prevention

Ts ID	Test Steps	Expected Results	Current	Status
04	Prevention of double voting	generate a hash of a valid transaction; transaction status in Etherscan = Good; Increased Voice	A valid form of hash transaction; the transaction status on Etherscan is successful; the number of votes increases; Voters can no longer cast their votes.	[Passed]

Scenario : Real-Time Voting Results Visualization
At this point, the election result visualization feature is tested to ensure that the system can display the voting results accurately and according to the data stored on the blockchain. The test also aims to verify that the process of capturing and displaying the data of the vote results is running smoothly, and that the system can provide administrators with clear information about how each candidate got their vote. Expected Results:

Table 7. Scenario: Real-Time Voting Results Visualization

Ts ID	Test Steps	Expected Results	Current	Status
05	1. Access the result visualization feature. 2. Enter input: The admin opens the results page. 3. Click the process button and observe the result.	The graph of voting results appears according to blockchain data.	Users can view the voting results when the time is up.	[Passed]

CONCLUSION

This research aims to design and implement a blockchain-based e-voting system that is secure, transparent, and easy to use in the environment of Esa Unggul University. Based on the results of the design, implementation, and evaluation that have been carried out, several important conclusions were obtained.

First, the system developed successfully answered the main problems related to the security and integrity of voting data in the election process. The application of decentralized technology using the Ethereum blockchain (Sepolia testnet) allows each vote to be recorded in the form of an immutable transaction hash (tx_hash), thus increasing the transparency and accountability of voting results.

Second, through the prototyping development method, the system can be developed gradually by involving users in the feedback process. This approach is effective for finding and fixing weaknesses in the early stages, especially in the aspects of the interface and the flow of user interaction.

Third, the results of the evaluation through the questionnaire showed that the majority of respondents (more than 70%) stated that the system was easy to use, safe, and feasible to implement. As many as 73.7% of respondents considered the system easy to use, 68.4% considered system security very important, 73.7% supported the use of blockchain, and 68.4% stated that they would be willing to use this system in the next election. These results prove that the prototype design has met the aspects of usability, trust, and readiness from the user side.

Fourth, from a technical aspect, the integration between CodeIgniter 4, MySQL, and Ethereum is stable. The three-layered architecture applied, including the user interface, application logic, and database layers, is able to desegregate the management of relational data and blockchain transaction data well.

Finally, this study concludes that the developed blockchain-based e-voting system has been able to improve the reliability, security, and trust of users compared to conventional systems. However, the display and user experience aspects still need to be improved, especially in the placement of the confirmation button and the clarity of post-voting notifications, to make user interaction more intuitive.

SUGGESTION

Based on the results of the research that has been conducted, there are several suggestions for further development and implementation. First, this e-voting system should be integrated with the campus's Single Sign-On (SSO) so that the user authentication process becomes safer and more efficient. Second, the use of blockchain testnets can be upgraded to hybrid or mainnet networks to ensure more realistic transaction validation and resistance to network disruption. Third, it is recommended to add data encryption and digital signatures to each vote to strengthen security and prevent identity abuse.

In addition, it is necessary to conduct advanced usability testing using a quantitative scale such as the System Usability Scale (SUS) to obtain an objective value from the user experience. The user interface (UI/UX) aspect also needs to be improved through wider testing so that the system can be used comfortably by different groups of users.

Finally, before being fully implemented, the system needs to undergo an external security audit of the smart contract and data storage architecture to ensure optimal transparency and accuracy. With these various improvements, this blockchain-based e-voting system is expected to become a reliable, efficient, and adaptive digital election model for campus needs in the future.

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