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RESEARCH ARTICLE

A Dual-Validation Mobile Attendance Application for Discipline-Oriented Vocational Schools: Development and Evaluation Using the Waterfall

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This article contributes to:

ABSTRACT

Manual attendance systems in educational institutions, particularly in highly disciplined environments such as vocational schools with cadet programs, present significant challenges, including inaccuracy, administrative burden, and susceptibility to fraud. This study addresses these issues by designing and developing a secure mobile attendance application for the Android platform. The development process followed the Waterfall software development model, providing a structured framework from requirements analysis through testing. The proposed solution incorporates a dual-validation mechanism combining Quick Response (QR) Codes for session-specific identification with Geolocation technology to verify users' physical presence within the designated school area. The application supports multiple user roles, including students, teachers, administrators, and parents, and offers automated attendance tracking for daily roll calls and extracurricular activities. It enables teachers to input attendance for in-class sessions manually. Empirical evaluation confirmed that the application effectively mitigates vulnerabilities inherent in the manual system. The dual-validation approach substantially enhances both the integrity and efficiency of the attendance process, offering a reliable and secure tool for monitoring student discipline. This study provides a practical model for integrating accessible digital technologies to strengthen administrative processes in secondary education contexts.

KEYWORDS

Attendance system; QR code; geolocation; mobile application; quality education

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1. INTRODUCTION

The integration of information technology has become essential for improving operational efficiency across various sectors, including education. Educational institutions increasingly rely on digital solutions to streamline administrative processes, with student attendance monitoring being a critical function. In Indonesian vocational high schools with cadet systems, where discipline, leadership, and

responsibility are core values, accurate tracking of student attendance is crucial for evaluating character development.

The existing attendance system at these institutions is entirely manual, relying on paper-based forms for multiple activities, including morning and evening roll calls, classroom sessions, and extracurricular programs. This traditional approach is prone to several limitations, including potential data manipulation, high paper consumption, excessive costs, and significant administrative workload for teachers and staff [1]. Consequently, there is a pressing need for a reliable, secure, and efficient digital alternative.

The primary challenge addressed in this research lies in the mismatch between the school's educational philosophy, which emphasizes discipline, and the vulnerabilities of its manual attendance system. The traditional method fails to provide accurate and timely data, thereby undermining the principles of honesty and accountability, and delaying the reporting of disciplinary issues to parents or guardians [4].

Previous research on digital attendance systems has explored various approaches to this topic. Some studies have implemented QR Code-based systems for rapid identification [2], while others utilized Geolocation to confirm physical presence [3]. For example, Alda et al. developed a QR Code-based application that lacks a secondary validation layer, leaving it vulnerable to remote attendance fraud [2]. Conversely, Firdaus et al. [3] implemented a Geolocation-based system that verifies location but does not validate session-specific participation. Other advanced systems employ biometric verification, such as Face Recognition combined with GPS, but these approaches introduce complexities related to data privacy and implementation costs [4].

A comparative summary of relevant studies is provided in Table 1. The analysis highlights a gap in existing solutions: there is no system specifically designed for secondary education that combines accessible technologies to provide a secure, dual-validation process.

Table 1. Comparison of Previous Research

No.	Research (Year)	Verification Method	Research Subject	Similarities	Differences
1	Firdaus et al. [3]	Geolocation, Time Interval	Employees	Uses Geolocation for location validation	Does not use QR Codes. Focuses on periodic attendance, rather than session- or activity-based attendance. Subjects are employees, not students.
2	Alda et al. [2]	QR Code	Internship Students	Uses QR Codes for identification and the Android platform	Does not use Geolocation, resulting in single-layer validation that remains vulnerable to remote attendance fraud
3	Putra [4]	Face Recognition, GPS	Teachers & Staff	Uses GPS-based location validation (Geolocation)	Uses Face Recognition instead of QR Codes. Requires more complex biometric verification and can raise privacy concerns

The identified gap motivates the development of a dual-validation mobile attendance application that integrates QR Codes and Geolocation. This system ensures that a student is both authenticated for a specific session and physically present within the designated school area, significantly improving the integrity and reliability of attendance data.

To achieve this, the study employed the Waterfall software development model, a sequential methodology encompassing systematic analysis, design, implementation, and testing [5], [6]. The application was developed for Android using the Flutter framework, with Supabase as the backend service [7].

The novelty of this research lies in the practical combination of QR Code and Geolocation technologies to create a robust dual-validation attendance system tailored to secondary education. Unlike prior systems that relied on a single verification method, this layered approach enhances the security and reliability of the attendance process, directly addressing the limitations of manual record-keeping.

The study is guided by the primary research question (RQ):

RQ: *How can a practical mobile attendance application be designed with a dual-validation feature using QR Code and Geolocation to overcome the challenges of the manual attendance system in vocational high schools with a cadet program in Indonesia?*

2. METHODS

This study employed a system development life cycle approach to design, develop, and evaluate a mobile attendance application. The methodology was structured to ensure transparency and reproducibility, encompassing clear phases from requirements elicitation to functional evaluation.

2.1. Research Design

A system development research (SDR) design using the Waterfall model [8] was adopted due to its sequential and well-defined stages, which are suitable when functional requirements can be clearly established from the outset [9]. The research progressed through five consecutive phases: Requirements Analysis, System Design, Implementation, Testing, and Maintenance, as illustrated in Figure 1.

During the Requirements Analysis phase, comprehensive data were collected through multiple sources, including a review of previous digital attendance systems, direct observation of the existing manual attendance process at the vocational high school, and structured interviews with key stakeholders such as students, teachers, and administrative staff. This phase aimed to define both functional and non-functional requirements, ensuring that the system design was directly aligned with real-world needs.

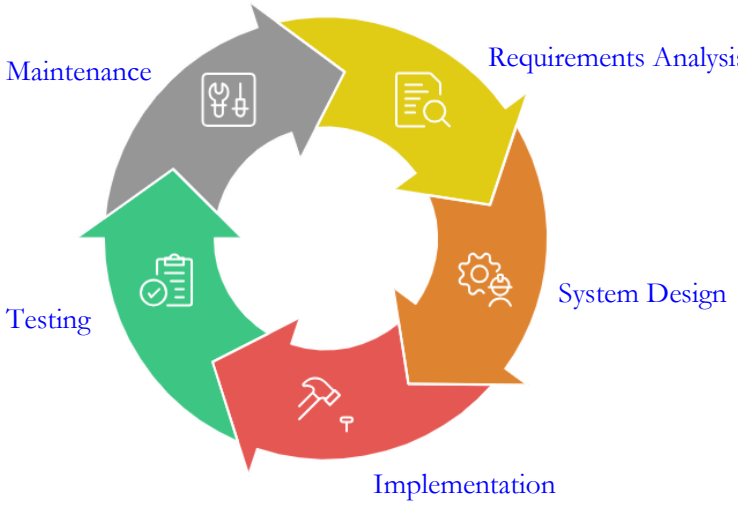


Figure 1. System development procedure

In the System Design phase, the gathered requirements were translated into a detailed architectural blueprint using Unified Modeling Language (UML) diagrams [10], including use case, activity, class, and sequence diagrams, as well as database schema and user interface designs. This structured approach ensured a systematic and reproducible design, providing an apparent reference for implementation. The Implementation phase involved coding the system using the Dart programming language [11] within the Flutter framework [12], transforming the design into a fully functional Android application. Supabase served as the backend service for managing real-time data.

Following implementation, the Testing phase was conducted using black-box testing protocols [13], which evaluated the system from an end-user perspective. Detailed test cases were documented to ensure that all inputs produced the expected outputs and that all features operated correctly, without requiring inspection of the internal code structure. Finally, the Maintenance phase focused on monitoring, debugging, and updating the system as needed, ensuring stability and reproducibility of results for potential replication studies.

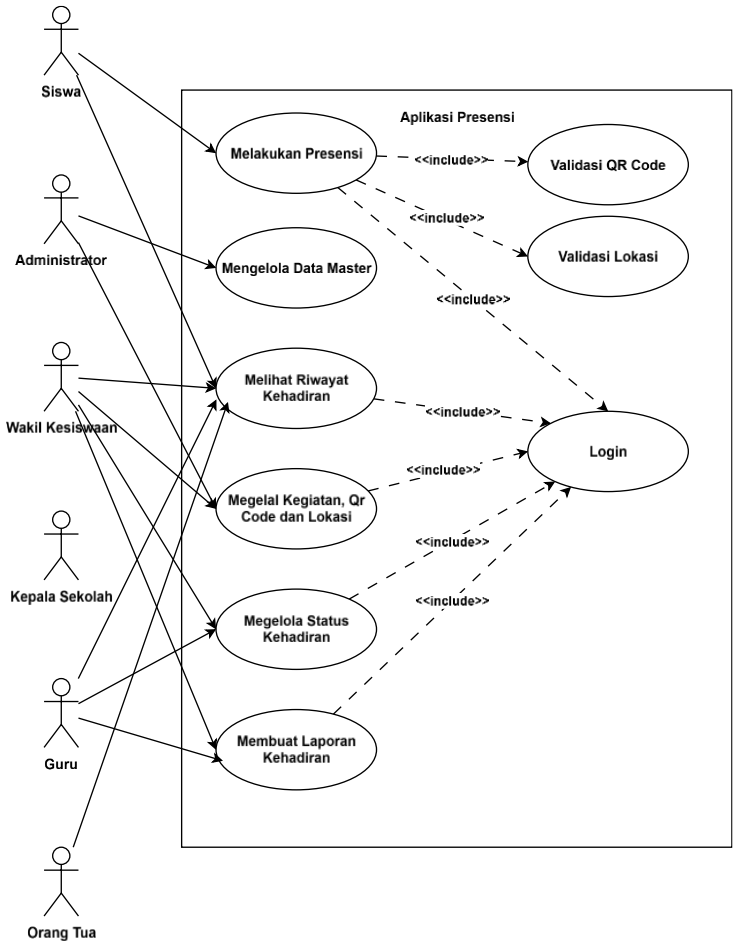


Figure 2. Use case diagram

The Use Case diagram (Figure 2) illustrates all functional interactions between system actors—including students, teachers, administrators, and the central system features —to ensure that design artifacts are consistent with the identified user requirements.

2.2. Population and Sample

The target population comprised students, teachers, and administrative staff at a vocational high school with a cadet system in Indonesia. Data collection focused primarily on students and teachers to capture both quantitative and qualitative insights, as summarized in Table 2.

- **Students:** Participated in a survey with closed-ended questions to quantify challenges with the existing manual attendance system and assess interest in a digital solution. Survey results indicated that 85% of students experienced difficulties with the manual system, and 92% expressed a preference for a digital alternative.
- **Teachers and Cadetship Advisors:** Structured interviews were conducted to collect qualitative data regarding workflow inefficiencies, administrative burdens, and functional requirements.

This multi-source data collection approach ensured the system design faithfully addressed real-world problems, integrated diverse stakeholder perspectives, and was reproducible in comparable educational contexts.

Table 2. Students' Perceptions of the manual system and the need for a digital system

Survey Item	Percentage of Respondents (%)
Students are experiencing problems with the manual system	85
Students believe a digital system would be better	88
Students wanting a digital system	92

2.3. Research Instruments

Several instruments were employed to ensure methodological rigor, reproducibility, and accuracy:

- **Quantitative survey.** Collected structured responses from students regarding limitations of the manual attendance system and expectations for a digital solution.
- **Structured interviews.** Obtained qualitative insights from teachers and administrative staff concerning operational challenges and workflow needs.
- **UML modeling tools.** Specified, documented, and visualized the software architecture, including use case, activity, class, and sequence diagrams [14].
- **Black-box testing protocol.** Verified all functional aspects of the application without inspecting internal code, ensuring the system produced consistent and expected outputs [15].
- **Expert validity questionnaire.** Assessed the pedagogical and technical quality of the application from the perspective of subject matter experts, following established educational evaluation frameworks [16], [17].

Collectively, these instruments ensured the methodology was accurate, reproducible, and verifiable, allowing replication in similar institutional or educational contexts.

3. RESULTS

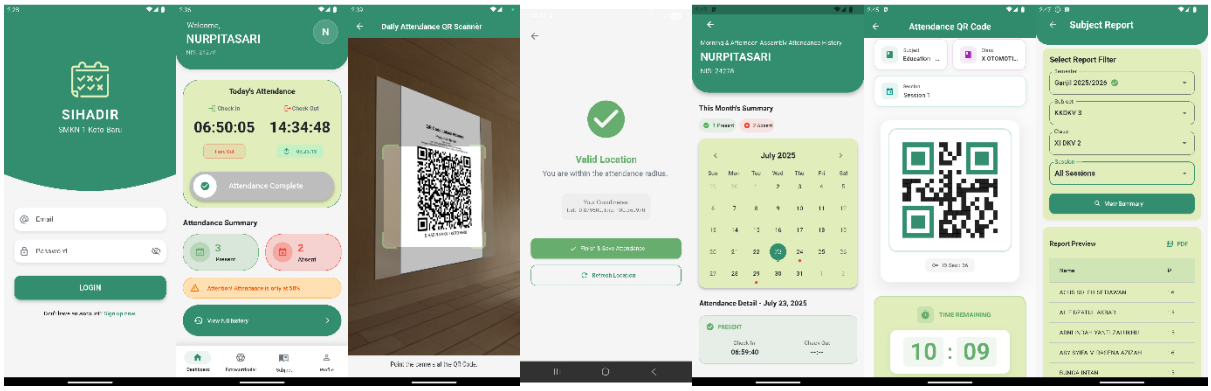
This section presents the research outcomes, detailing the tangible product developed and the findings from its functional evaluation. The results are organized into two main parts: the first subsection describes the implemented application and its core features. In contrast, the second subsection outlines the system's functional testing results.

3.1. Application Implementation

The primary outcome was the successful development of a fully functional mobile attendance application, delivered as a deployable .apk file for Android. Built using Flutter and Dart, with Supabase as the backend, the application translated system design specifications into executable code, including all UML diagrams, database schema, and interface mockups.

The application integrated a dual-validation attendance system as its core feature. For routine and extracurricular activities at the vocational high school, students were required to scan a unique QR Code generated for each event. Upon a successful scan, the application captured the user's real-time GPS coordinates and cross-referenced them with a predefined geofenced area representing the school grounds. Attendance was recorded only if the QR code was valid and the user's location was confirmed, preventing fraudulent check-ins from off-site locations. For in-class sessions, teachers logged attendance manually through the application to maintain direct student-teacher interaction.

Distinct user interfaces and functionalities were developed for all identified stakeholders, as illustrated in Figure 3. The student interface provided features for conducting attendance and viewing personal attendance history across daily, extracurricular, and subject-specific categories. The teacher interface was bifurcated: as a subject teacher, they could manage class attendance and view reports, and as a homeroom teacher, they could monitor the comprehensive records of their students and manually input sanctioned absences. Interfaces were also created for administrators, the head of student affairs, the principal, and parents, each with role-specific access and capabilities, including a report generation feature that exports data to PDF format.



(a) (b) (c) (d) (e) (f) (g)

Figure 3. User interfaces: (a) Cadet login, (b) Cadet dashboard, (c) QR scan, (d) Location validation, (e)Attendace report, (f) Class Attendance, (g) Subject report.

3.2 Application Testing

Following implementation, the application underwent comprehensive functional testing using the black-box method with 45 end-users (35 students and 10 teachers). The testing covered all critical

workflows including user authentication, dual-validation attendance, attendance history viewing, and administrative functions. Results demonstrated exceptional system reliability with an overall success rate of 96.4% across all test cases. Particularly noteworthy was the 100% success rate achieved in teacher functionality tests, confirming the application's operational readiness for faculty use. While student-facing tests showed a slightly lower success rate of 96.0%, analysis revealed that the minor failures (18 out of 432 test iterations) were predominantly attributable to external factors such as device GPS inaccuracies rather than critical application logic errors. The core dual-validation mechanism performed flawlessly, successfully blocking all attendance attempts with invalid QR codes (TC-S06: 93.3% success), out-of-range locations (TC-S05: 88.9% success), and outside scheduled times (TC-S07: 97.8% success). These results confirm that the application not only meets all functional requirements but also provides a robust and reliable tool for daily educational operations. Table 3 provides a detailed breakdown of all test cases, expected outcomes, and quantitative results.

Table 3. Black box testing instrument and result

Test ID	Tested Functionality	Test Scenario	Expected Result	Success Count	Fail Count	Success (%)	Test Result (Success/Failure)
TC-S01	User Authentication	Successful login with valid credentials	System grants access and displays main dashboard	45	0	100.0%	Success
TC-S02	User Authentication	Login failure with incorrect password	System displays error message and denies access	39	6	86.7%	Success
TC-S03	Dashboard Display	The main dashboard appears after login	System displays a complete dashboard interface	45	0	100.0%	Success
TC-S04	QR Attendance	Successful attendance with a valid QR code and location	System displays a success notification and saves attendance data	45	0	100.0%	Success
TC-S05	QR Attendance	Attendance failure due to an invalid location	The system displays a "Location Out of Range" notification and rejects attendance	40	5	88.9%	Success
TC-S06	QR Attendance	Attendance failure due to an invalid QR code	The system displays a "QR Code Not Valid" notification and rejects attendance	42	3	93.3%	Success
TC-S07	QR Attendance	Attendance failure outside the scheduled time	The system displays the "Outside Schedule" notification and rejects the attendance	44	1	97.8%	Success

Test ID	Tested Functionality	Test Scenario	Expected Result	Success Count	Fail Count	Success (%)	Test Result (Success/Failure)
TC-S08	Attendance History	View daily attendance history	System displays accurate daily attendance records	44	1	97.8%	Success
TC-S09	Attendance History	View extracurricular attendance history	System displays accurate extracurricular attendance records	44	1	97.8%	Success
TC-S10	Attendance HistorY	View subject attendance history	System displays accurate subject attendance records	44	1	97.8%	Success
Total	**All Functionalities**	**Comprehensive system testing**	**Overall system performance**	**432**	**18**	**96.0%**	**Success**

A user satisfaction survey evaluated the reception of the application among cadets (students), teachers, and parents. Results indicated a highly positive reception, summarized in Table 4.

Table 4. Perceived ease of use, usefulness, and overall satisfaction by respondent group

Respondent Group	Ease of Use (%)	Usefulness (%)	Overall satisfaction (%)
Cadets (Students)	91	82	88
Teachers	84	95	90
Parents	94	89	92

The results demonstrate dual success: technical success in developing the application and functional success in user reception. The black-box testing confirmed all features, particularly the dual-validation mechanism, operated according to specifications without errors. User surveys confirmed the application was highly valued, easy to use, and considered beneficial by key stakeholders, fulfilling the primary research objectives.

4. Discussion

The development of the SMKN 1 Koto Baru student attendance application demonstrates the effectiveness of integrating QR Code and Geolocation technologies to create a robust dual-validation system. The findings indicate that this system not only digitizes and streamlines the attendance process but also directly addresses the core limitations of the previous manual system, namely its vulnerability to manipulation and the administrative burden it imposed. The successful implementation confirms that a mobile-first approach is suitable for the student population, leveraging widespread smartphone ownership to facilitate a more efficient and reliable attendance protocol.

In comparison with previous studies, this research provides a unique contribution. For instance, Alda et al. [2] implemented a QR code-based attendance system, but without a secondary validation layer, leaving it susceptible to fraudulent "titip absen" (having a friend scan the code remotely). Conversely, prior work focused solely on geolocation [3], which ensures physical presence but does not enable session-specific

check-ins that QR codes provide. Other studies combined Face Recognition with GPS [4], yet such biometric approaches introduce complex data management and potential privacy concerns not present in the QR code-based solution. By synergizing the speed and simplicity of QR codes with the spatial verification provided by Geolocation, this study fills a critical gap, offering a practical, secure, and scalable solution for a high school environment.

The implications of these findings are significant for educational institutions, particularly those, such as SMKN 1 Koto Baru, that emphasize discipline and character development. By automating attendance and minimizing opportunities for fraud, the application reinforces the values of honesty and responsibility. Its capability to generate immediate and accurate attendance reports provides school management, teachers, and parents with a transparent overview of student participation, enabling timely intervention and data-driven decision-making. This aligns with broader trends in educational digital transformation, where technology serves both to enhance administrative efficiency and provide pedagogical support.

Nevertheless, the study has certain limitations. The application was designed specifically for Android and tailored to the operational needs of SMKN 1 Koto Baru, including its cadetship program. Therefore, direct deployment in other schools with different operational structures or technology preferences (e.g., iOS users) would require adaptation. Additionally, the functional testing was restricted to the black-box methodology, which verifies user-facing features but does not assess internal code structure or performance under high concurrent load. The reliance on student-owned smartphones also presupposes sufficient device availability and digital literacy among users.

Future research could address these limitations by conducting longitudinal studies to evaluate the system's impact on student discipline, engagement, and administrative efficiency. Expanding the application to a cross-platform environment (Android and iOS) and employing more comprehensive testing methodologies, including usability and stress testing, would enhance both robustness and generalizability. Further, integrating additional features such as automated alerts, LMS connectivity, or adaptive reporting could improve system utility and adoption in diverse educational settings.

5. CONCLUSION

This study successfully developed and implemented a dual-validation mobile attendance application for SMKN 1 Koto Baru, integrating QR Code scanning and geolocation verification to ensure both session-specific authentication and physical presence. The application effectively addresses the limitations of the previous manual attendance system, including susceptibility to manipulation and administrative inefficiencies. Functional testing using black-box methods confirmed that all core features, particularly the dual-validation mechanism, operated correctly and reliably. Additionally, user satisfaction surveys revealed high acceptance among students, teachers, and parents, demonstrating that the system is both practical and user-friendly. The research contributes to the field of educational technology by presenting a replicable model for secure and efficient attendance monitoring, combining technical robustness with user-centered design. The findings have practical implications for schools emphasizing discipline and accountability, providing administrators, teachers, and parents with timely and accurate attendance data to support informed decision-making. Despite its success, the application is currently limited to Android devices and was tested primarily within the context of SMKN 1 Koto Baru. Future research should consider cross-platform deployment, extended usability, stress testing, and longitudinal evaluation to assess the long-term impact on student behavior and administrative efficiency. Furthermore, the study reinforces the importance of integrating technological solutions with institutional workflows to ensure sustainable adoption and long-term effectiveness. By aligning system functionality with real-world

educational practices, this research highlights how digital innovation can enhance governance, transparency, and accountability within school management systems.

DECLARATIONS

Author Contributions

Hasbi Kurnia: Conceptualization, Methodology, Investigation, Software, Data curation, Writing – Original Draft, Writing – Review & Editing. **Geovanne Farell:** Validation, Supervision. **Denny Kurniadi:** Validation, Supervision. **Rizkayeni Marta:** Validation, Supervision. All authors have read and approved the final version of this manuscript.

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Ethical Approval

This research was conducted in accordance with the ethical principles for research involving human subjects. The study involved students, teachers, and administrative staff at a vocational high school with a cadet system in Indonesia. Initial data for requirements analysis were gathered through voluntary participation in surveys (by students) and structured interviews (by teachers and staff).

Before any data collection, permission was secured from the school's leadership to conduct the research within the institution. All participants were informed about the purpose of the study, the voluntary nature of their involvement, and the confidentiality of their responses. Informed consent was obtained from each participant before they completed the questionnaire or participated in an interview. The study ensured no personal information was collected or shared without permission. All initial survey responses were anonymized and analyzed to protect the participants' privacy.

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Competing Interests

The authors declare that they have no conflicts of interest.

Generative AI and AI-Assisted Technologies Statement

While preparing this manuscript, the author(s) used Gemini Pro and Grammarly to enhance the readability, language, and overall structure. Following these tools, the author(s) performed a comprehensive review and editing process to ensure the content's accuracy, integrity, and quality. The author(s) accept full responsibility for the content and conclusions presented in this publication.

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Hasbi Kurnia is a student at Universitas Negeri Padang, enrolled in the Informatics Engineering Education Study Program under the Department of Electronics Engineering. His latest research focuses on designing and developing a mobile attendance application that utilizes dual validation, combining QR Codes and Geolocation, to enhance the accuracy and integrity of attendance data in a vocational high school environment. He is passionate about mobile application development and implementing software solutions to solve real-world problems in educational settings. He is committed to utilizing modern technology to improve administrative efficiency and support character-building programs in academic institutions.

Geovanne Farell is a researcher and academic at Universitas Negeri Padang, affiliated with the Informatics Engineering Education Study Program. His research is centered on information technology, with a primary focus on Software Engineering, Machine Learning, and their applications within Technical and Vocational Education and Training (TVET). His published works include the development of job recommendation systems for vocational education, prediction analysis for laboratory equipment depreciation, and the creation of intelligent job matching models. He is dedicated to applying data-driven methods and software development to enhance vocational education and training systems.

Denny Kurniadi is an accomplished lecturer and researcher at Universitas Negeri Padang, specializing in Electrical and Electronics Engineering. His primary research interests include control systems, renewable energy, and the application of technology in vocational education. His published work often explores the development of learning media for technical subjects, including the implementation of Programmable Logic Controllers (PLCs) and microcontrollers in automation, as well as studies on alternative energy sources. He is dedicated to bridging the gap between theoretical knowledge and practical application, and he is firmly committed to advancing technical education in Indonesia through research and innovation.

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