

Development of AI-Based Chatbot for Information Services at SMK Negeri 1 Sumedang

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ARTICLE INFO

Article history

Received: Dec 18, 2025

Revised: Jun 29, 2026

Accepted: Jun 30, 2026

Keywords

Chatbot

Artificial Intelligence

Rapid Application Development

Workflow Automation

School Information System

ABSTRACT

This study developed an artificial intelligence (AI)-based chatbot to improve communication and academic information management at SMK Negeri 1 Sumedang. Using the Rapid Application Development (RAD) methodology, the chatbot automated the delivery of schedules, announcements, and institutional information. The system integrated n8n workflow automation, a Supabase database, the WAHA API for WhatsApp communication, and natural language processing to handle user queries dynamically. Evaluation results showed strong performance, achieving 92% response accuracy with an average response time of less than one minute. Stress testing under high-concurrency conditions revealed slight performance degradation, particularly in processing informal language and handling peak user traffic. Future improvements include implementing Redis-based asynchronous queueing and server load balancing to enhance scalability. Overall, the chatbot reduced dependence on manual information dissemination, accelerated communication, and established a responsive digital ecosystem that benefits students, teachers, administrative staff, and parents.

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Introduction

The rapid advancement of digital technologies in the 21st century has profoundly reshaped various sectors, with education being no exception. In particular, artificial intelligence (AI) has fundamentally altered traditional paradigms of workflow, communication, and information retrieval. Integrating AI into organizational frameworks holds the potential to elevate collective

intelligence by clarifying team objectives, resolving conflicts, and augmenting both collective memory and attention management, although challenges pertaining to trust and ethics persist Woolley (2025). Within the educational landscape, these advancements present substantial opportunities to enhance the quality of information services, streamline communication, and ensure seamless access for all stakeholders, including students, educators, administrative staff, and parents Alhassan and Soui (2021). Among the most rapidly proliferating applications in this domain is the AI-driven chatbot, a system designed to autonomously simulate human interaction. Owing to their capacity to deliver prompt, efficient, and round-the-clock responses, such conversational agents have already seen widespread adoption across industries like customer service, healthcare, and digital marketing Yatoo and Habib (2023).

The development of a chatbot at SMK Negeri 1 Sumedang was specifically designed to facilitate the dissemination of school information—such as class schedules, announcements, and other essential updates—which were previously delivered through conventional methods like physical bulletin boards and WhatsApp groups Yang (2024). Prior to the implementation of this intelligent system, the large-scale school ecosystem, comprising over 1,500 students along with hundreds of educators and administrative staff, relied heavily on these traditional media. This reliance engendered significant communication challenges, particularly concerning operational inefficiency and a high risk of misinformation. Although WhatsApp remains highly popular among students due to its practicality, the platform is prone to burying crucial information beneath an influx of irrelevant conversations, causing important announcements to frequently be overlooked Suárez-Lantarón et al (2022). This ineffectiveness triggered a cascading effect on the administrative staff, who were ultimately forced to shoulder a repetitive workload by continuously responding to similar inquiries—both in-person and via private messages Soens et al (2025).

Chatbots are generally classified into two primary paradigms: rule-based and AI-driven. While rule-based chatbots operate on predefined scripts, AI-driven chatbots leverage Natural Language Processing (NLP) and Machine Learning (ML) to simulate human conversation and execute a wide array of tasks across various domains. These intelligent agents are seamlessly integrated into platforms such as messaging applications and websites to deliver instantaneous, automated responses, effectively managing tasks like answering frequently asked questions, scheduling appointments, and generating recommendations Lin et al (2023). The synergy of AI and NLP empowers these chatbots not only to comprehend and respond to user inputs but also to incorporate emotional intelligence—thereby elevating user satisfaction by detecting emotions and

generating contextually empathetic responses Bilquise et al (2022). Furthermore, NLP enables AI chatbots to understand and process human language more naturally, whereas ML allows them to evolve over time, continuously refining their capacity to handle diverse inquiries and yield more accurate answers Kusal et al (2022). In the educational context, this technology facilitates dynamic communication among students, teachers, administrative staff, and parents. By mitigating the reliance on manual communication methods—such as printed announcements or in-person inquiries Lin et al (2023)—chatbots provide personalized guidance and automate administrative duties, ultimately enriching the overall learning experience Rakshitha et al (2025).

The implementation of AI-based chatbots within the educational sector, specifically at SMK Negeri 1 Sumedang, presents several challenges that necessitate resolution. Chief among these is ensuring the accuracy of the information provided by the system. Given the critical nature of the data stored within the architecture, the chatbot must deliver precise and contextually relevant responses to users. Currently, for instance, the chatbot still struggles to provide adequate answers regarding complex school policies or frequently altered information, such as examination schedules. Furthermore, maximizing the chatbot's effectiveness in supporting learning processes and fostering communication among students, educators, and administrative staff remains a distinct hurdle. The ultimate success of the chatbot hinges upon its capacity to accurately comprehend and respond to inquiries while managing dialogues within the appropriate context Adiguzel et al (2023). To address these challenges, this study aims to provide a comprehensive overview of the chatbot's development phases—spanning from user requirements analysis and system design to implementation and user evaluation—ultimately enhancing communication efficiency and information management within the institution.

In alignment with these efficiency enhancements, the deployment of this system offers strategic advantages for various stakeholders at SMK Negeri 1 Sumedang. From the students' perspective, this technology facilitates instantaneous access to academic information—such as class schedules, institutional agendas, and other vital announcements—thereby bypassing the delays of manual updates and the necessity for face-to-face interactions. Conversely, for educators and administrative personnel, the chatbot mitigates operational workloads stemming from repetitive inquiries, allowing them to reallocate their focus toward more complex instructional duties. On a macro level, integrating this intelligent system into institutional governance manifests the accelerating digital transformation within the educational sector, where computing technologies are increasingly optimized to support pedagogical functions, institutional services, and student welfare Pereira et al

(2023)Lambebo and Chen (2024). Consequently, information dissemination becomes substantially swifter, more structured, and more precise, as the chatbot leverages a dynamically updated database accessible at any time. This initiative ultimately reinforces the broader trajectory of educational digitalization, aiming to elevate the efficiency and quality of communication across all organizational levels Almufarreh and Arshad (2023).

The deployment of the AI-driven chatbot at SMK Negeri 1 Sumedang is anticipated to serve as an effective solution for enhancing communication efficiency and streamlining information dissemination within the institution. Despite persistent challenges concerning response accuracy and conversational complexity, the system significantly contributes to the ongoing digital transformation within the educational sector. Future developmental endeavors should prioritize refining the chatbot's capacity to comprehend multifaceted user queries, alongside optimizing system scalability to accommodate heavier traffic during peak periods, such as examination schedules or student enrollment phases Lambebo and Chen (2025).

Method

The methodology employed in this study utilizes Rapid Application Development (RAD), selected for its capacity to expedite system development through an iterative approach and direct user feedback. This paradigm aligns with user-centered design principles emphasized in the architecture of AI-based educational software, which highlights the critical importance of usability and user satisfaction achieved via continuous feedback loops and iterative refinement Cen et al., (2023). By leveraging RAD, the development team rapidly generated functional prototypes and evaluated them alongside users to facilitate mutual adjustments, thereby enabling the ongoing refinement and adaptation of the system Persson et al (2022). User evaluation was executed via usability testing paired with a Likert-scale questionnaire to quantify satisfaction levels and the ease of interaction. Participants were selected using a purposive sampling technique to comprehensively represent school stakeholders, comprising 30 students, 5 teachers, and 3 administrative staff members. Through the active engagement of these participants, the chatbot was systematically evolved to meet the specific demands of communication and operational efficiency within the school environment Bellino et al (2023) Wang et al (2023).

This methodology proves uniquely advantageous for developing the AI-driven chatbot at SMK Negeri 1 Sumedang, given the imperative to swiftly and dynamically adapt the system to evolving user requirements—particularly in delivering efficient and precise information. By leveraging the

RAD framework, the development process remains highly agile, ensuring that the final system not only satisfies user expectations but also yields optimal utility in enhancing institutional communication and operational efficiency.

1. The needs analysis for this chatbot focuses on identifying target demographics, mapping specific informational requirements, and delineating optimal interaction patterns. Within educational ecosystems, these conversational agents are engineered to streamline academic and administrative workflows via an intuitive interface. This accessibility is vital for accommodating users with varying degrees of digital literacy, thereby fostering seamless communication between students and institutional personnel Mendoza et al (2022). Accordingly, the functional and system requirements established for the chatbot at SMK Negeri 1 Sumedang are detailed below:

- a) Development Objectives. The primary objective of engineering this chatbot is to optimize information dissemination workflows at SMK Negeri 1 Sumedang. By mitigating dependencies on conventional manual processes, the system aims to significantly expedite user access to critical institutional data.
- b) Main Users
 - Students. Require instantaneous access to academic timetables, extracurricular announcements, and other vital scholastic data.
 - Educators and Administrative Staff. Leverage the platform to disseminate official notifications and significantly mitigate the burden of addressing repetitive operational inquiries.
 - Parents and Prospective Students: Utilize the system to retrieve institutional profiles, enrollment protocols (New Student Admissions), and essential school policies.
 - Alumni: Engage with the chatbot to explore career opportunities and alumni-specific job vacancies.
- c) Legacy Communication Architecture. Prior to the chatbot's deployment, information dissemination relied predominantly on manual workflows—such as printed announcements, decentralized WhatsApp groups, and direct verbal exchanges. This fragmented approach inherently diminished operational efficiency and frequently resulted in delayed access to critical institutional updates.

- d) Legacy Communication Architecture. Prior to the chatbot's deployment, information dissemination relied predominantly on manual workflows—such as printed announcements, decentralized WhatsApp groups, and direct verbal exchanges. This fragmented approach inherently diminished operational efficiency and frequently resulted in delayed access to critical institutional updates.
- Functional Requirements. The chatbot must autonomously process and respond to user inquiries pertaining to academic schedules, institutional announcements, and general administrative information via the WhatsApp interface.
 - Non-Functional Requirements The system must guarantee intuitive usability, low-latency response times, high availability, and rigorous data security. To safeguard data privacy during database integration with WhatsApp, the architecture employs end-to-end encryption via the WhatsApp Business API, enforces strict Role-Based Access Control (RBAC), and implements automated data masking for sensitive attributes such as personal identification numbers ensuring they are never fully exposed within the chat environment.
2. User-Centered System Design. The successful deployment of the AI-driven chatbot at SMK Negeri 1 Sumedang necessitates a robust and meticulously structured system architecture. Guided by user-centered conversational principles, this framework prioritizes the integration of linguistic, visual, and interactive elements to maximize both user satisfaction and sustained engagement (Silva & Canedo, 2024). Furthermore, the architecture is engineered to guarantee seamless interoperability among the user interface, backend processing modules, and primary data repositories. This cohesive integration empowers the chatbot to deliver highly accurate and efficient informational services. The structural components of the proposed system are delineated below:
- a) Architectural Objectives. The primary objective of this phase is to synthesize the findings from the user needs analysis into a robust technical architecture. This framework is specifically engineered to integrate seamlessly with the WhatsApp platform, thereby establishing an accessible and highly responsive channel for user interaction.
- b) System Architecture Overview
- User Interface. The WhatsApp platform serves as the primary conversational

interface, facilitating ubiquitous and seamless communication between end-users and the chatbot.

- Backend Infrastructure. Functions as the core processing unit responsible for parsing incoming queries, orchestrating conversational workflows, and executing secure data retrieval protocols.
- Data Repositories. All institutional knowledge is securely stored within a centralized database, which undergoes periodic synchronization and curation by authorized administrative personnel.

c) Conversational Flow Orchestration.

- Structured Data Pathway. Tailored for deterministic, highly categorized information retrieval, such as academic timetables and official institutional announcements.
- Natural Language Processing (NLP) Pathway. Deployed to interpret unstructured, free-text inquiries that necessitate semantic analysis, intent classification, and contextual comprehension.

d) Core System Features

- Continuous Automated Assistance. The chatbot delivers round-the-clock, automated question-answering (QA) services, ensuring unhindered user accessibility without time constraints.
- Institutional Data Synchronization. The system interfaces directly with official school databases, thereby securing strict information consistency and maintaining data integrity across all user interactions.

3. The successful deployment of the AI-driven chatbot at SMK Negeri 1 Sumedang relies fundamentally on the strategic selection of technological instruments and the execution of a structured architectural design to deliver an efficient, highly resilient communication framework. As a cognitive system embedded within an instructional environment, the chatbot integrates Natural Language Processing (NLP) and Machine Learning techniques to simulate human-like cognition. This integration establishes a robust foundation for adaptive conversational flows that facilitate personalized user experiences and institutional learning paradigms Karyotaki et al (2022). From a systems engineering perspective, the optimization of this intelligent agent is achieved through a platform-based design pattern. By utilizing formal models—specifically state machines and logical execution paths—the architecture automates

complex system functionalities while systematically managing multi-stage data governance and real-time state transitions Telenyk et al (2022). The following sections delineate the core technological stack utilized and the sequential development phases executed to operationalize the platform.

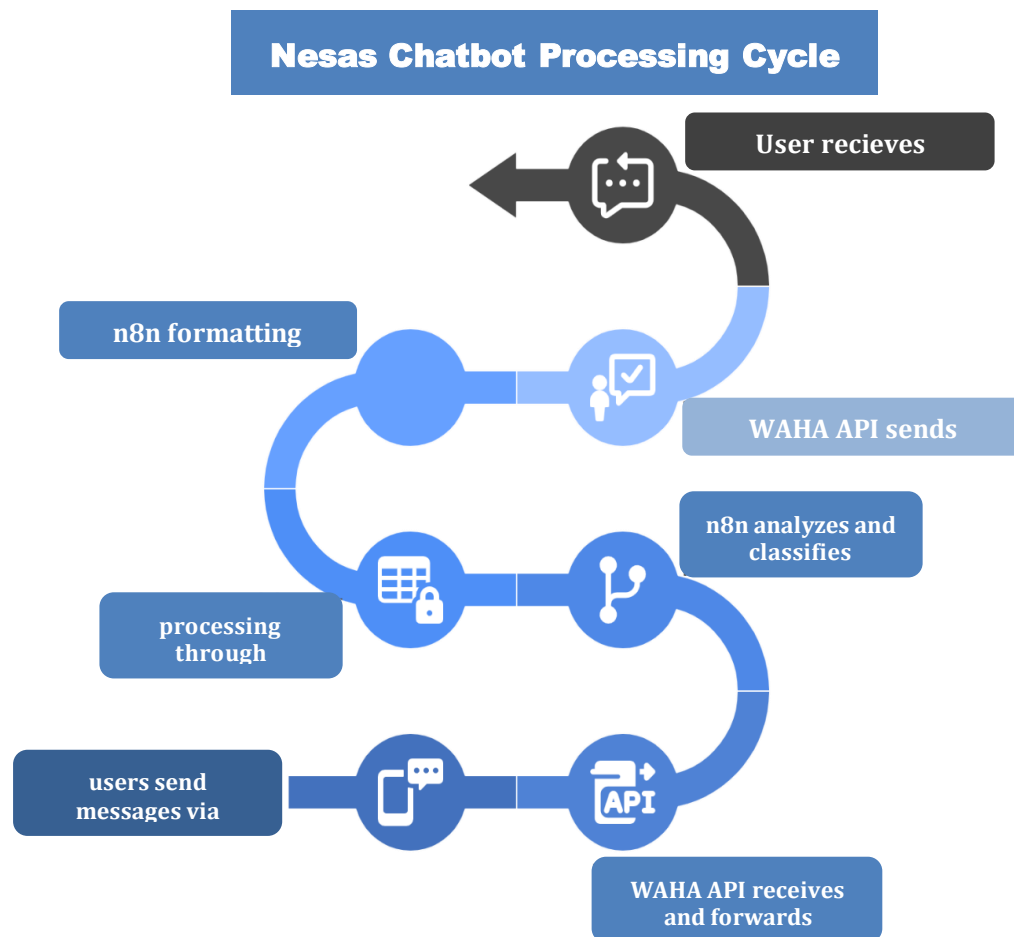


Fig 1: Chatbot Conversation Flow Design

a) Technology Stack and Development Tooling

- VPS Sumopod. Functions as the primary cloud hosting infrastructure, provisioning the necessary computing resources to deploy all backend subsystems, sustain workflow orchestration, and maintain continuous network integration.
- n8n Workflow Engine. Utilized as the central middleware orchestrator to manage complex conversational logic, handle conditional data routing, and seamlessly synchronize operations among WhatsApp, Supabase, and the Gemini AI API.

- WAHA API (WhatsApp HTTP API). Serves as the dedicated communication gateway, establishing a stable bridge to the WhatsApp ecosystem and facilitating low-latency, bidirectional messaging between users and the system.
- Supabase (Backend-as-a-Service). Operates as the centralized data repository, securely storing and managing structured relational assets—such as academic timetables, institutional notices, and FAQs—for dynamic real-time retrieval.
- Google Gemini AI. Leveraged as the core Large Language Model (LLM) engine to perform advanced semantic processing, intent recognition, and contextual response generation for unstructured, free-form user prompts.

b) System Development Phases

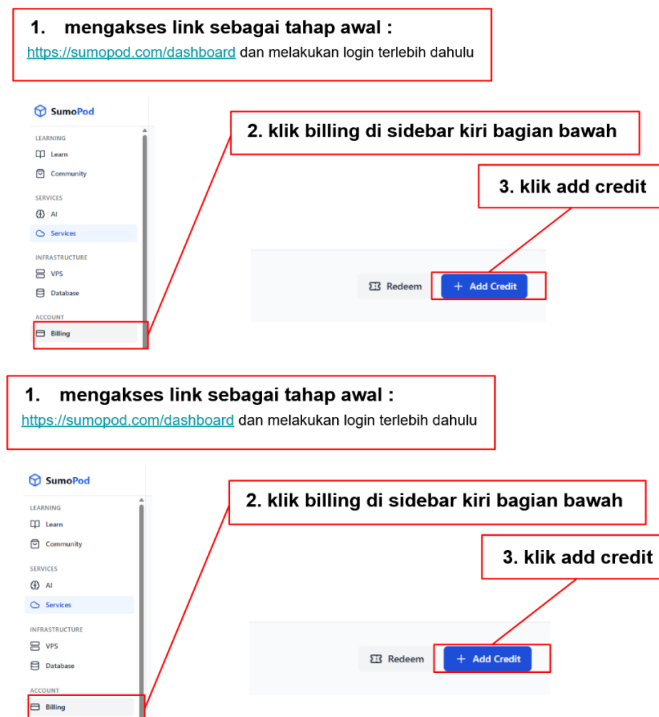


Fig 2: Sumopod VPS Configuration Steps

- Data Preparation and Ingestion. Institutional knowledge comprising school profiles, academic timetables, and FAQs was initially compiled via spreadsheet formats (Excel) and subsequently migrated into the Supabase relational database. This ensures structured, real-time accessibility for backend data retrieval.

- **Infrastructure Provisioning.** The VPS environment was systematically configured to host both the n8n orchestration engine and the WAHA API. This foundational deployment guarantees stable backend-to-WhatsApp connectivity and ensures cross-platform operational fluidity.
- **Workflow Orchestration.** Complex conversational logic was engineered within the n8n environment to govern incoming message parsing, execute dynamic queries against Supabase, and route unstructured text to the Google Gemini LLM. This phase establishes the core algorithmic intelligence necessary for delivering accurate, context-aware responses.



Fig 3: WAHA trigger setup steps

- **System Integration and Quality Assurance (QA).** All individual components (n8n, WAHA API, Supabase, Gemini AI) were unified into a cohesive architecture. Rigorous end-to-end testing was subsequently conducted to validate system responsiveness, verify seamless interoperability, and ensure the deployment met all predefined performance benchmarks.
4. Within the Rapid Application Development (RAD) framework, the Cutover phase represents the terminal deployment stage before the software is fully transitioned to live institutional operations. At this critical juncture, all underlying core engineering and iterative design loops reach termination, rendering the system architecture prepared for comprehensive, end-to-end validation and deployment into the production environment. This operational transition from development to live implementation mirrors established paradigms in collaborative governance, where the integration of blended services is systematically optimized to escalate production success while emphasizing the absolute necessity of rigid pre-deployment verification Ambrose et al (2025). Consequently, the Cutover phase focuses structurally on three interrelated execution tracks: system testing, production implementation, and institutional rollout.

- a) Comprehensive System Validation. Following the iterative evaluations conducted during the Construction phase, the finalized architecture undergoes rigorous end-to-end testing. The primary objective is to validate that the system strictly adheres to the predefined requirements specifications and to systematically identify and resolve any residual software defects or operational anomalies prior to launch.
- b) Production Deployment. Upon successful validation and formal approval, the chatbot transitions into the deployment stage. The system architecture is officially migrated from the localized staging environment to the live production server, rendering the platform fully operational and accessible to the institutional end-users.
- c) System Rollout and Handover. Following successful deployment, the application is officially launched for institutional use. To guarantee a frictionless transition and maximize user adoption, the rollout strategy incorporates the following critical phases:
 - End-User Onboarding. Comprehensive training and instructional guidelines are provided to the school community, ensuring they can effectively interact with the chatbot's interface.
 - Post-Deployment Technical Support. The engineering team establishes a dedicated support framework to rapidly troubleshoot and resolve any unforeseen operational anomalies encountered during the initial live phase.
 - Continuous Performance Monitoring. The system is actively audited post-launch to track operational stability, evaluate user engagement metrics, and identify actionable areas for future architectural enhancements.

Result and Discussion

System Functionalities and Feature Specifications

The AI-driven chatbot deployed at SMK Negeri 1 Sumedang is engineered to optimize institutional communication workflows and streamline data accessibility for the academic community. To achieve this, the system integrates a robust suite of informational features, structured as follows:

- Institutional Data Retrieval. Provides on-demand access to foundational information, including school profiles, vocational program hierarchies, and administrative directories for both educators and the student body.
- Academic and Extracurricular Updates: Enables students to instantly retrieve class timetables and event notifications, thereby eliminating dependencies on manual broadcasts or direct staff inquiries.
- Admissions and Policy Guidance: Serves as a dedicated portal for parents and prospective students to easily navigate the New Student Admission procedures (PPDB) and review core institutional policies.
- Alumni Career Services: Incorporates a targeted job vacancy module tailored to the specific vocational expertise of school graduates.
- Automated FAQ Resolution: Features a dynamic Frequently Asked Questions (FAQ) module designed to autonomously resolve recurring inquiries pertaining to academic and administrative protocols.

Ultimately, this comprehensive feature set significantly mitigates the administrative burden on school personnel, accelerating information dissemination and establishing a highly responsive, modernized communication ecosystem.

Implementation and Testing

The implementation stage of the AI-driven chatbot at SMK Negeri 1 Sumedang initiates with administrative provisioning, seamlessly integrating the institutional WhatsApp account via the WAHA API gateway. Following this integration, the n8n workflow engine is activated to orchestrate the automated and structured conversational logic. System administrators assume overarching responsibility for system oversight, dynamic data curation, and performance monitoring, thereby ensuring the architecture is fully primed to deliver efficient information services to the entire academic community. Chatbot Account Configuration using WAHA and n8n explain in Figure 4.

Subsequently, deploying the chatbot for direct user interaction leverages WhatsApp as a ubiquitous frontend interface, democratizing real-time data access across diverse demographics, including students, teachers, administrative staff, parents, and alumni. This familiar ecosystem enables users to asynchronously send messages and retrieve vital academic timetables, institutional notices, and related data. This setup effectively bypasses traditional administrative bottlenecks, allowing continuous information access entirely independent of school operational hours or manual broadcasting constraints.

Email : joves@mpv.uad.ac.id

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menghubungkan Whatsapp dengan Waha

<https://waha-u85hvf59einp.axpq.sumopod.my.id/dashboard>

username: 57BsNHk7

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Login Whatsapp



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2.akses n8n

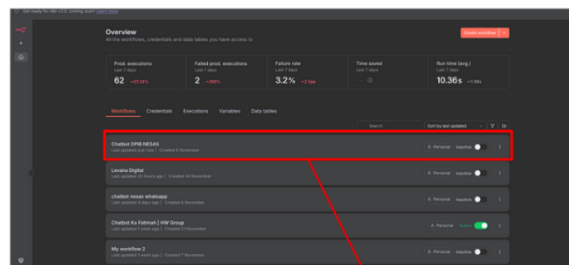
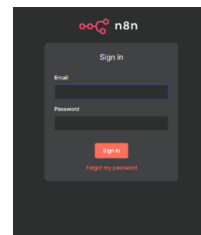
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informasi login

email : DPIBNesas@gmail.com

Password : @N8n12345

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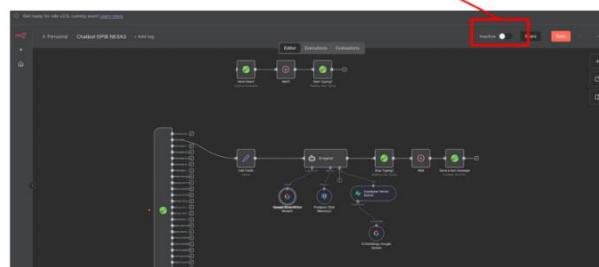


Fig 4: Chatbot Account Configuration using WAHA and n8n

Following the deployment, rigorous functional evaluations were conducted to assess the system's operational viability. The empirical testing results demonstrate the chatbot's high proficiency in executing rapid, highly accurate query resolutions for standardized, rule-based

inquiries. However, stress testing revealed a marginal performance degradation and increased latency during high-concurrency usage scenarios involving multiple simultaneous user inputs. Furthermore, the chatbot exhibited operational constraints when processing highly complex or unstructured linguistic prompts, highlighting a clear necessity for future architectural optimizations within the chatbot's Natural Language Processing (NLP) pipeline to enhance deep semantic context comprehension.

Analysis of Testing Results

The empirical findings demonstrate that the chatbot exhibits a high degree of precision, consistently delivering accurate information that aligns perfectly with the underlying database records. Furthermore, the system's response latency remains safely within a threshold of less than one minute, indicating that the platform can provide near-instantaneous query resolution provided there is stable network connectivity. However, under high-concurrency scenarios involving simultaneous multi-user interactions, a marginal degradation in processing performance was observed. This indicates that while the system operates optimally under standard baseline conditions, further architectural optimizations are imperative to enhance scalability and guarantee structural stability under peak-load constraints. Chatbot Response Speed presented in Figure 5.



Fig 5: Chatbot Response Speed

In terms of linguistic processing, the chatbot displays robust adaptability in managing minor variations in user phrasing, particularly for highly structured and recurring queries. Conversely, when confronted with unstructured, ambiguous, or open-ended inputs, the system occasionally reaches its operational limits, requiring conversational clarification or manual administrative intervention to achieve an accurate resolution. Inquiries that diverge significantly from the pre-programmed conversational pathways frequently yield suboptimal or generalized responses. This limitation underscores a critical requirement for future iterations to integrate advanced Natural Language Understanding (NLU) capabilities capable of handling complex contextual edge cases.

From a User Experience (UX) standpoint, the platform achieved exceptional usability scores, largely driven by the users' pre-existing familiarity with the WhatsApp ecosystem. End-users demonstrated a virtually non-existent learning curve, adapting immediately to the conversational interface and expressing high satisfaction regarding the seamless accessibility of institutional data. The qualitative feedback was overwhelmingly positive, with participants confirming that the chatbot significantly accelerates information retrieval while reducing administrative friction. Nevertheless, users also noted an actionable opportunity for future development, suggesting a substantial expansion in both the quality and volume of the database to accommodate a broader and more diverse spectrum of school information.

The respondents of this study were 12th grade TKR students and graduates of the Automotive Light Vehicle Engineering department of SMK YPPT Garut who had undergone practice in the production unit for at least 6 months, then 1 year and more than 1 year. Characteristics of students based on the competence of Automotive Light Vehicle expertise based on grade level.

Table 1 shows that 24 respondents (42.4%) completed six months of WBL, 18 respondents (32.2%) completed one year, and 16 respondents (25.4%) participated for more than one year. All were drawn from SMK YPPT Garut and had direct hands-on experience in the Automotive Service Workshop Production Unit, numbering 58 participants in total. Student characteristics based on skill level and length of learning. The data are displayed in Table 1.

From a system performance perspective, the chatbot demonstrates operational stability under baseline conditions, yet exhibits a marginal reduction in execution speed during high-concurrency intervals involving multiple simultaneous users, as well as when processing informal or colloquial linguistic inputs. This performance variance indicates that while the core architecture remains resilient, iterative stress testing and framework optimizations are essential to enhance scalability and guarantee robust throughput under elevated traffic volumes and intensive operational demands.

Synthetically, the deployment of the chatbot has successfully fulfilled the majority of its predetermined objectives, notably in accelerating information dissemination and maximizing communicative efficiency within the institution. Nevertheless, substantial opportunities for architectural refinement persist, particularly regarding the enhancement of the platform's natural language understanding to resolve intricate, non-linear queries and the fortification of backend infrastructure to withstand peak-load conditions. Chatbot Response Speed explain in Figure 6.



Fig 6: Chatbot Response Speed

Challenges and Solutions

During the development and implementation phases of conversational agents, various technical impediments have been demonstrated to significantly compromise system performance and operational efficacy, particularly regarding the preservation of personalization and knowledge-sharing capabilities—two critical elements required for multi-domain support and real-time monitoring Calvaresi et al (2023). Consequently, a comprehensive approach to identifying and mitigating these anomalies during the evaluation phase is paramount to ensuring that the chatbot operates reliably and delivers optimal service quality. Accordingly, the subsequent narrative delineates the specific technical bottlenecks encountered during testing, diagnoses their root causes, and details the engineering interventions applied for remediation.

- a. **Loss of Conversational Context.** This anomaly manifests when the chatbot abruptly loses contextual continuity, resulting in disjointed or topically irrelevant responses during multi-turn interactions. The root cause of this disruption was identified as a critical failure in session persistence; specifically, ongoing conversational states and user prompt histories were not being adequately committed to the backend database. Consequently, the system's inability to retain short-term conversational memory severely compromised its capacity to track ongoing topics. To remediate this architectural flaw, comprehensive diagnostic re-testing and simulated chat replays were executed to audit the workflow configurations. These rigorous debugging protocols verified that session logs were successfully synchronized and persisted within the database infrastructure, ultimately restoring the chatbot's ability to maintain contextual integrity and deliver highly relevant, historically informed responses.

- b. Semantic Incongruity and Irrelevant AI Output. A secondary anomaly encountered during the evaluation phase involved the chatbot generating responses that were semantically incongruent with the users' explicit queries. In these instances, the generated outputs either lacked contextual relevance or deviated significantly from the established institutional database. The root cause of this misalignment was traced to an unoptimized vector store architecture, coupled with the AI engine executing superficial data retrieval rather than deep semantic comprehension. To rectify this vulnerability, rigorous prompt engineering techniques were implemented alongside the introduction of strict rule-based constraints within the orchestration logic. By recalibrating the system prompts to include highly specific, technical parameters, the AI's analytical processing was significantly sharpened. These architectural adjustments effectively bounded the model's generative scope, ensuring that subsequent outputs were highly precise, strictly anchored to the validated backend repository, and perfectly aligned with the ongoing conversational context.
- c. API Throttling and Rate Limit Exceedance. A significant operational bottleneck emerges when the chatbot exhibits system freezes, yields null outputs, or experiences total workflow suspension upon exhausting the allocated API request quota of the underlying language model. This disruption is fundamentally caused by strict service throttling policies enforced by the AI provider, which typically cap interactions at approximately 20 to 40 requests per hour on standard tiers. Exceeding this predefined threshold automatically triggers an HTTP 429 "Too Many Requests" error, effectively halting algorithmic processing due to excessive request velocity. To definitively neutralize this constraint, the foundational infrastructure was upgraded to a premium subscription tier of the Google Gemini API, which affords a significantly expanded hourly request bandwidth. This strategic escalation guarantees continuous operational fluidity, ensuring the platform remains highly responsive and reliable even during peak concurrency intervals. Furthermore, to holistically fortify application scalability against future high-load scenarios, supplementary backend optimizations were integrated into the architecture, encompassing asynchronous queue management, enhanced data payload efficiency, and dynamic server load balancing.

Conclusion

The deployment of the AI-driven chatbot at SMK Negeri 1 Sumedang has successfully realized its primary objective of optimizing communicative efficiency and expediting information dissemination across the institutional ecosystem. By furnishing students, educators, administrative

personnel, and parents with rapid, highly accurate, and frictionless access to essential data, the system significantly diminishes institutional reliance on traditional, manual broadcasting paradigms. Throughout the deployment phase, the architecture demonstrated substantial efficacy in autonomously retrieving academic timetables, institutional notices, and resolving standardized inquiries. Crucially, the current scope of the foundational database is constrained to the Design Modeling and Building Information (DPIB) vocational program, which serves as an initial pilot framework. Consequently, institutional data corresponding to other vocational competencies remains unintegrated at this juncture. Despite this constraint, the platform has delivered robust informational services for the DPIB cohort, successfully democratizing access to highly relevant departmental data.

Empirical evaluations also identified specific technical constraints, notably in contextual state management and the resolution of highly complex, unstructured linguistic prompts, illuminating clear trajectories for future architectural refinement. Furthermore, the marginal degradation of system performance under high-concurrency loads represents a critical vulnerability. To definitively resolve these scalability bottlenecks, subsequent developmental iterations must architecturally integrate a Redis-backed asynchronous queueing mechanism to decouple incoming message streams. Additionally, implementing advanced caching protocols will drastically mitigate backend database query loads, while the deployment of load balancing across intermediary servers will guarantee equitable traffic distribution during abrupt surges in user concurrency. Ultimately, this initiative establishes a substantial foundation for the digital transformation of SMK Negeri 1 Sumedang, fostering a modernized, highly responsive, and technologically integrated communication paradigm, with future phases prioritizing the systematic expansion of the knowledge base to encompass all remaining vocational competencies.

References

- Adiguzel, T., Kaya, M. H., & Cansu, F. K. (2023). Revolutionizing education with AI: Exploring the transformative potential of ChatGPT. *Contemporary Educational Technology*, 15(3), ep429. <https://doi.org/10.30935/cedtech/13152>
- Alhassan, I., & Soui, M. (2021). Special issue on digital transformation. *Journal of Decision Systems*, 30(2–3), 97–101. <https://doi.org/10.1080/12460125.2021.1938358>
- Almufarreh, A., & Arshad, M. (2023). Promising emerging technologies for teaching and learning: Recent developments and future challenges. *Sustainability*, 15(8), Article 6917.

<https://doi.org/10.3390/su15086917>

- Ambrose, G., Imperial, M. T., & Ambrose, G. (2025). Transitioning from planning to implementation: Comparing collaborative governance and developmental dynamics in four watersheds. *Policy Sciences*, 58(3). <https://doi.org/10.1007/s11077-025-09583-8>
- Anjulo Lambebo, E., & Chen, H.-L. (2025). Chatbots in higher education: A systematic review. *Interactive Learning Environments*, 33(4), 2781–2807. <https://doi.org/10.1080/10494820.2024.2436931>
- Bellino, A., De Michelis, G., & De Paoli, F. (2023). Design and evaluation of Protbody: A tool for rapid prototyping of interactive products. *IEEE Access*, 11, 13280–13292. <https://doi.org/10.1109/ACCESS.2023.3242873>
- Bilquise, G., Ibrahim, S., & Shaalan, K. (2022). Emotionally intelligent chatbots: A systematic literature review. *Computational Intelligence and Neuroscience*, 2022. <https://doi.org/10.1155/2022/9601630>
- Calvaresi, D., Eggenschwiler, S., Mualla, Y., Schumacher, M., & Calbimonte, J.-P. (2023). Exploring agent-based chatbots: A systematic literature review. *Journal of Ambient Intelligence and Humanized Computing*, 14(8), 11207–11226. <https://doi.org/10.1007/s12652-023-04626-5>
- Cen, C., Luo, G., Li, L., Liang, Y., Li, K., Jiang, T., & Xiong, Q. (2023). User-centered software design: User interface redesign for Blockly–Electron, artificial intelligence educational software for primary and secondary schools. *Sustainability*, 15(6), Article 5232. <https://doi.org/10.3390/su15065232>
- Karyotaki, M., Drigas, A., & Skianis, C. (2022). A new decade for social changes. *Technium Social Sciences Journal*, 30. <https://doi.org/10.47577/tssj.v30i1.6277>
- Kusal, S., Patil, S., Choudrie, J., Kotecha, K., Mishra, S., & Abraham, A. (2022). AI-based conversational agents: A scoping review from technologies to future directions. *IEEE Access*, 10, 92337–92356. <https://doi.org/10.1109/ACCESS.2022.3201144>
- Lin, C.-C., Huang, A. Y. Q., & Yang, S. J. H. (2023). A review of AI-driven conversational chatbots implementation methodologies and challenges (1999–2022). *Sustainability*, 15(5), Article 4012. <https://doi.org/10.3390/su15054012>
- Mendoza, S., Sánchez-Adame, L. M., Urquiza-Yllescas, J. F., González-Beltrán, B. A., & Decouchant, D. (2022). A model to develop chatbots for assisting the teaching and learning process. *Sensors*, 22(15), Article 5532. <https://doi.org/10.3390/s22155532>

- Pereira, D. S. M., Falcao, F., Costa, L., Lunn, B. S., Pego, J. M., & Costa, P. (2023). Conversational agents in higher education: A scoping review. *International Journal of Educational Research*, 122, Article 102233. <https://doi.org/10.1016/j.ijer.2023.102233>
- Persson, J. S., Bruun, A., Larusdottir, M. K., & Nielsen, P. A. (2022). Agile software development and UX design: A case study of integration by mutual adjustment. *Information and Software Technology*, 152, Article 107059. <https://doi.org/10.1016/j.infsof.2022.107059>
- Rakshitha, B. R., Anu, V. B., Belavigi, S. I., Arkachari, P. R., & Banashankari, K. B. (2025). AI-powered chatbots in education: Enhancing learning through intelligent technology. *Journal of Artificial Intelligence Research and Applications*, 16(3), 1–6.
- Silva, G. R. S., & Canedo, E. D. (2024). Towards user-centric guidelines for chatbot conversational design. *International Journal of Human-Computer Interaction*, 40(2), 98–120. <https://doi.org/10.1080/10447318.2022.2118244>
- Soens, E., Claeys, A., & Yue, C. A. (2025). A double-edged sword? The consequences of work-related instant messaging use for employees. *Management Communication Quarterly*. Advance online publication. <https://doi.org/10.1177/00936502251401642>
- Suárez-Lantarón, B., Deocano-Ruíz, Y., García-Perales, N., & Castillo-Reche, I. S. (2022). The educational use of WhatsApp. *Sustainability*, 14(17), Article 10510. <https://doi.org/10.3390/su141710510>
- Telenyk, S., Nowakowski, G., Vovk, Y., & Anosov, I. (2022). Development and implementation of technology for creating a wide class of applications like chatbots based on formal models. *NaUKMA Research Papers. Computer Science*, 5, 97–107. <https://doi.org/10.18523/2617-3808.2022.5.97-107>
- Wang, J., Ranscombe, C., & Eisenbart, B. (2023). Prototyping in smart product design: Investigating prototyping tools to support communication in the early stage smart product development. *International Journal of Design Creativity and Innovation*, 11(3), 159–184. <https://doi.org/10.1080/21650349.2023.2222115>
- Woolley, A. W. (2025). Generative AI and collaboration: Opportunities for cultivating collective intelligence. *Journal of Organization Design*. Advance online publication. <https://doi.org/10.1007/s41469-025-00199-z>
- Yang, L. (2024). Exploration of digital transformation path of education management in colleges and universities in the internet era. *Applied Mathematics and Nonlinear Sciences*, 9(1).

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<https://doi.org/10.2478/amns-2024-0802>

Yatoo, M. A., & Habib, F. (2023). ChatGPT: A friend or a foe? *MRS Bulletin*, 48(4), 310–313.

<https://doi.org/10.1557/s43577-023-00520-9>