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Development of an Intelligent Educational Chatbot Using NLP and Machine Learning

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Abstract. *This study aims to develop an intelligent educational chatbot using Natural Language Processing (NLP) and Machine Learning (ML) to support independent student learning in English. As digital learning increasingly demands adaptive and responsive tools, chatbots offer the potential to provide real-time, personalized interactions. The chatbot in this research was designed with transformer-based NLP models and trained using supervised learning techniques. The development process followed the Borg & Gall Research and Development (R&D) model, including stages such as needs analysis, system design, prototyping, testing, and refinement. Through the integration of NLP and ML, the chatbot was expected to deliver natural dialogue, contextual understanding, and accurate educational feedback. Testing was conducted with 15 eleventh-grade high school students using pre- and post-tests. Results showed a significant improvement in learning outcomes, with average scores rising from 61.3 to 84.2. In addition to academic gains, students reported increased motivation, confidence, and comfort with self-directed learning. These findings confirm that the developed chatbot is effective not only in delivering knowledge but also in enhancing students' engagement and autonomy. The study concludes that the application of AI technologies, particularly NLP and ML, in education holds great potential as an inclusive, efficient, and scalable solution for the future of digital learning.*

Keywords: *Educational chatbot, Natural Language Processing, Machine Learning, digital learning, artificial intelligence.*

INTRODUCTION

The development of information and communication technology has brought significant changes to the world of education. The concept of learning is no longer confined to physical classrooms but has expanded to digital platforms that enable teaching and learning processes to occur in a flexible, interactive, and personalized manner. In this digital era, the demand for learning systems that can support students in real-time is increasing, especially due to limitations in time and teaching staff. Therefore, technology-based solutions such as Artificial Intelligence (AI) are being explored as alternatives to facilitate more efficient learning processes (Suryanti & Apriadi, 2025).

One form of AI implementation in education is the chatbot or text-based virtual assistant, designed to answer questions, deliver learning materials, or facilitate practice exercises. An intelligent chatbot not only responds statically but also understands context, natural language, and learns from previous interactions (Suryanti et al., 2024). This technology utilizes AI branches such as Natural Language Processing (NLP) and

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Machine Learning (ML), which enable machines to understand, process, and respond to human language effectively.

However, developing an educational chatbot is not a simple task. It requires deep understanding of language structure, learning context, and the highly varied needs of users. In practice, many chatbots remain rigid, limited to specific scenarios, and incapable of handling complex student queries. This highlights the importance of further exploration in utilizing NLP and ML to create more adaptive, responsive, and contextual systems to support the learning process (Syaputra et al., 2025).

By utilizing modern NLP algorithms such as transformers and deep learning models, chatbots can be trained using educational conversation datasets to improve interaction quality. Additionally, supervised learning techniques can be used to increase response accuracy, while unsupervised learning techniques can identify patterns in user behavior. The selection of appropriate algorithms, the quality of datasets, and effective training methods are key factors in developing an intelligent educational chatbot.

This study aims to develop an educational chatbot capable of providing an interactive learning experience through natural conversation. The chatbot is expected to serve as an independent learning assistant that helps students understand material, answer academic questions, and provide immediate feedback. Through testing and evaluating its effectiveness, this research seeks to contribute meaningfully to the development of AI-based digital learning systems in Indonesia.

LITERATURE REVIEW

Chatbot

A chatbot is a computer program designed to simulate human conversation, typically used to answer questions, provide information, or perform specific tasks. In the field of education, chatbots are increasingly being used as digital learning assistants that help students understand subject material, respond to academic questions, and provide instant feedback. Their ability to operate without time limitations and serve multiple users simultaneously makes them a potential solution for educational institutions aiming to expand learning services efficiently.

In an e-learning environment, chatbots can act as virtual tutors guiding students through learning modules. Integrated with Learning Management Systems (LMS), chatbots can provide information such as schedules, pending assignments, and quiz results. This makes them not just passive communication tools, but active components of the digital learning process.

Research by Fryer and Nakao (2020) suggests that the use of chatbots in online learning can increase students' motivation and self-confidence. Students feel supported by a learning companion that is always available and non-judgmental when they make mistakes or ask questions—something particularly important for those reluctant to participate in traditional classroom settings.

Despite their great potential, there are still challenges in using chatbots in education. Limitations in understanding question context, handling complex language, and providing in-depth explanations remain common issues. Therefore, integrating Artificial Intelligence (AI) technologies such as Natural Language Processing (NLP) and Machine Learning (ML) is essential for developing more intelligent chatbots (Apriadi & Bisri, 2025).

In the context of education in Indonesia, the use of chatbots is still relatively new and not yet widespread. However, with the growing adoption of digital technology in learning, chatbots hold great potential to become an integral part of future education systems. This study aims to explore how chatbots can be optimally developed to meet the contextual and effective learning needs of students.

Natural Language Processing (NLP)

Natural Language Processing (NLP) is a branch of artificial intelligence that focuses on the interaction between computers and human language. NLP enables machines to understand, interpret, and generate natural language in a meaningful way. This technology is a crucial component in chatbot development, as it helps the system recognize user intent and provide appropriate responses.

One of the main challenges in NLP is dealing with the diversity of language structures and ambiguity of meaning. To address this, machine learning-based approaches are used to train models to recognize patterns in language, such as text classification, entity extraction, and sentiment analysis. These techniques are essential in helping chatbots understand the context of questions posed by students (Apriadi et al., 2024).

Modern NLP models such as BERT (Bidirectional Encoder Representations from Transformers) and GPT (Generative Pre-trained Transformer) have brought major advancements in natural language processing. These models use transformer architectures that allow for deeper contextual understanding compared to traditional approaches. This is highly beneficial in creating chatbots that can respond with more relevant and natural answers.

In the context of education, NLP can be used to develop chatbots capable of explaining concepts in simple terms, translating technical terminology, and even providing feedback on students' answers. The ability to understand natural language also allows systems to recognize variations in students' language styles from diverse backgrounds.

The use of NLP in education is not limited to chatbots. This technology can also be applied in academic data analysis, student essay processing, and even plagiarism detection. However, in the development of educational chatbots, NLP serves as the foundational element to ensure natural and meaningful interaction between students and the system.

Machine Learning

Machine Learning (ML) is a branch of artificial intelligence that enables systems to learn from data and improve their performance automatically without being explicitly programmed. In chatbot development, ML plays a crucial role by allowing the system to recognize interaction patterns, predict the best responses, and continuously learn from previous conversations.

There are various types of ML algorithms that can be used in chatbot development, such as supervised learning for intent classification, unsupervised learning for question clustering, and reinforcement learning for learning from user feedback. Each approach has its own advantages and challenges depending on the application's objectives and the availability of training data(Irianto et al., 2021).

In the educational context, ML allows chatbots to tailor responses based on student profiles, the difficulty level of questions, and previous interaction history. This creates a more personalized and adaptive learning experience, tailored to the individual needs of each student.

The quality of ML models heavily depends on the datasets used for training. Representative and clean datasets will produce accurate models, whereas biased or incomplete data can lead to errors in chatbot responses. Therefore, the data curation process is a critical part of developing a reliable system.

With strong integration between NLP and ML, educational chatbots can evolve into systems that not only provide answers but also learn, evaluate their effectiveness, and continuously improve based on real interactions. This study aims to combine the strengths of both technologies to create a chatbot that is intelligent, responsive, and beneficial to the field of education.

METHODS

This study uses a Research and Development (R&D) approach with the main objective of developing and testing a prototype of an educational chatbot that integrates Natural Language Processing (NLP) and Machine Learning (ML) technologies. The development model applied is an adaptation of the Borg & Gall model, which consists of several stages: preliminary study, design, development, validation, testing, and product revision.

1. Preliminary Study and Needs Analysis

   The initial stage involved data collection through literature review and interviews with teachers, lecturers, and students to understand user needs in the learning context. This analysis aimed to identify the key features required in an educational chatbot, as well as common challenges encountered in online learning processes.

2. System Design

   Based on the analysis results, the architecture of the chatbot was designed, including the user interface (UI), dialogue structure, and conversation flow. The NLP model planned for use is a transformer-based model, such as BERT or GPT, which have proven effective in understanding natural language context. The system was also designed to support integration with digital learning platforms such as Moodle or Google Classroom.

3. Chatbot Development

   At this stage, the chatbot was developed using the Python programming language, utilizing NLP libraries such as Transformers, spaCy, or Rasa. Educational dialogue datasets were collected to train the model using supervised learning methods. An evaluation was also conducted to assess the chatbot's ability to understand and respond to students' questions contextually.

4. Testing and Evaluation

   The chatbot prototype was tested on a limited group of students in a specific learning environment. The evaluation focused on assessing response accuracy, user satisfaction, and the impact of the chatbot on students' understanding of the material. The evaluation techniques used included Likert-scale questionnaires, interaction observation, and usage log analysis. The evaluation results served as the basis for system revision.

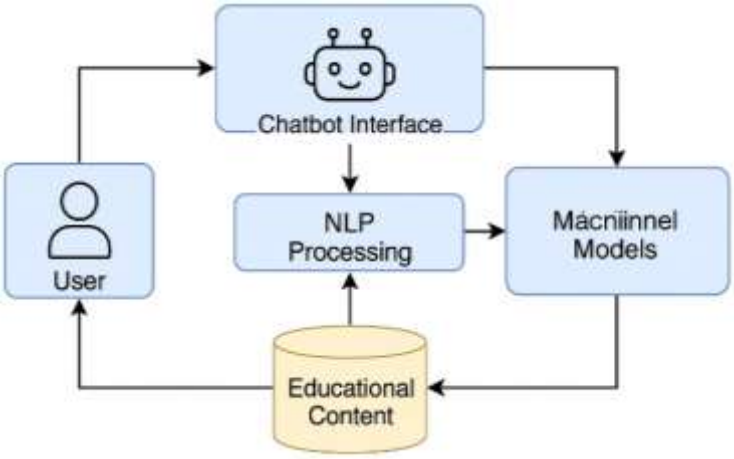

Figure 1. Flowchart

5. Revision and Refinement

   Based on user feedback and testing results, improvements were made to the chatbot system. The revisions focused on enhancing NLP accuracy, resolving ambiguous dialogues, and improving the user experience (UX). The final prototype will be published as a research output and can be more widely integrated into existing learning systems.

RESULTS

The trial of the educational chatbot system was conducted with 15 eleventh-grade high school students, aiming to evaluate the effectiveness of chatbot use in improving understanding of English subject matter. Each student was given a pre-test before using the chatbot and a post-test after independently interacting with the chatbot for one week.

The following graph presents a comparison of pre-test and post-test scores of the 15 students who used the Intelligent Educational Chatbot based on NLP and Machine Learning. A significant improvement was observed in almost all students after interacting with the chatbot system.

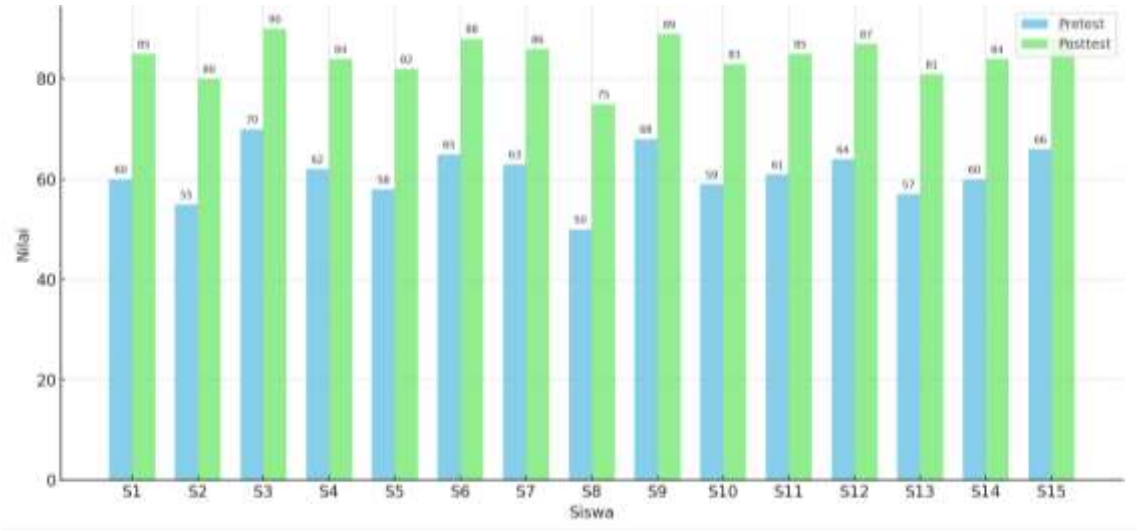

Figure 2. Results of comparison of pretest and posttest

Based on the graph comparing pre-test and post-test scores, a significant improvement was observed in almost all participants. The average pre-test score was 61.3, while the average post-test score increased to 84.2, resulting in an average gain of 22.9 points. This indicates that the use of an educational chatbot powered by Natural

Language Processing (NLP) and Machine Learning (ML) contributed positively to the learning process.

Some students who initially scored low in the pre-test (for example, Student S8, with a score of 50) showed a substantial increase in the post-test (rising to 75), indicating that the chatbot successfully provided better understanding through individualized and interactive engagement.

In addition to the score improvements, students also gave positive feedback regarding the use of the chatbot. Features such as contextual understanding, automatic explanations, and the ability to adapt to different types of questions made the chatbot an effective and engaging learning tool.

Overall, the trial results show that the developed educational chatbot system not only improved students' learning outcomes quantitatively but also enhanced their motivation and comfort in independent learning. Thus, this chatbot technology has great potential for broader implementation in educational environments.

DISCUSSION

The results of this study show that the development and implementation of an intelligent educational chatbot using Natural Language Processing (NLP) and Machine Learning (ML) significantly improved students' learning outcomes and engagement in understanding English subject matter. The increase in average scores from 61.3 (pre-test) to 84.2 (post-test) indicates that the chatbot was effective as a learning assistant.

This finding is consistent with Armstrong (2016), who stated that visual- and audio-based technologies can support students with special needs by enhancing their focus and comprehension of learning materials. In this study, the capabilities of NLP and ML enabled the chatbot to naturally understand the context of students’ questions and provide meaningful responses aligned with personalized learning approaches.

One of the key factors contributing to success was the chatbot’s ability to provide contextual understanding and adaptive feedback, made possible by integrating transformer-based models such as BERT or GPT. These models allow the system to process various forms of student questions with high accuracy and deliver responses that feel interactive and supportive of the learning process.

Students who previously had difficulty expressing questions or participating in conventional classes found the non-judgmental and responsive nature of the chatbot helpful. As shown by the improvement of student S8, whose score increased from 50 to 75, the chatbot facilitated better understanding through individualized and interactive engagement.

In addition to academic improvements, data from Likert-scale questionnaires and direct observations indicated increases in motivation, self-confidence, and independent learning. This aligns with research by Mayer & Moreno (2003), who found that interactive media can enhance intrinsic motivation and active engagement in the learning process.

From a methodological perspective, the Research and Development (R&D) approach using the Borg & Gall model proved effective. Each stage—from needs analysis and system design to user feedback-based revisions—directly contributed to improving the chatbot's performance and quality. The post-trial revisions, such as refining ambiguous dialogues and enhancing response accuracy, ensured that the final product met user needs.

Although the testing was conducted on a limited scale, the results suggest strong potential for broader implementation in educational settings, especially in self-directed or hybrid learning systems.

Overall, this study demonstrates that the integration of NLP and ML in the development of educational chatbots:

- Enhances understanding and retention through personalized interaction,
- Builds student confidence through instant and adaptive feedback,
- Improves access and support in flexible, independent learning environments.

Future studies are encouraged to explore deeper personalization features, integration across more subject areas, and long-term impact evaluations of chatbot use in educational processes.

CONCLUSION

This study demonstrates that the use of an educational chatbot based on Natural Language Processing (NLP) and Machine Learning (ML) is proven effective in improving students' understanding and learning outcomes, particularly in English

language subjects. The chatbot provided a more interactive, adaptive, and personalized learning experience through natural conversations that were easily understood by students.

The increase in students' average scores from 61.3 (pre-test) to 84.2 (post-test) shows that this technology has made a significant contribution to academic achievement. In addition, students also showed improved motivation, participation, and learning independence, which serve as key indicators of the success of technology-based learning media implementation.

The Research and Development (R&D) model used in this study, particularly the Borg & Gall model, enabled continuous improvement of the chatbot system through user feedback. This approach made the chatbot not only a learning aid but also a tool for enhancing the quality of students' interaction with learning content.

Therefore, it can be concluded that the integration of AI technologies such as NLP and ML in the field of education holds great potential to be widely adopted as an effective, inclusive, and sustainable digital learning solution.

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