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Enhancing vocational computer engineering education with a GPT-driven speech recognition tool

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ABSTRACT

This research investigates the effectiveness of an AI-driven speech recognition and GPT-powered learning tool in enhancing vocational students' proficiency in computer networks. The study involved 100 students from vocational hig school, who used the prototype as part of their learning process. A pre-test/post-test design was employed to assess changes in proficiency, and students also provided feedback on the tool's usability and impact. The results showed a consistent improvement in proficiency across all classes. A strong positive correlation was found between students' feedback and their proficiency improvement, suggesting that students who rated the prototype as Very Helpful were more likely to see significant learning gains. However, the correlation between time spent using the tool and proficiency improvement was minimal, indicating that the quality of engagement with the tool was more important than the duration of usage. These findings highlight the prototype's potential to improve vocational learning outcomes and underscore the importance of user satisfaction in driving success, with future refinements necessary to ensure the tool's broader effectiveness across different learning contexts.

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1. INTRODUCTION

The "Kurikulum Merdeka", also known as the Merdeka (Independent) curriculum, was introduced in Indonesia as part of educational reforms to promote flexible, student-centered learning. Initially piloted during the COVID-19 pandemic, it began implementation in 2022, aiming to reduce learning burdens and improve educational quality by allowing teachers greater autonomy [1], [2]. The curriculum was designed to move away from rigid, uniform standards towards a more competency-based approach that supports personalized learning pathways for each student. It emphasizes critical thinking, creativity, collaboration, and character development [3]. Eventually, the curriculum seeks to nurture lifelong learners capable of facing modern societal challenges with resilience and adaptability.

From a computer science, specifically an educational technology perspective, this is not entirely a novel learning model but builds upon existing educational frameworks that emphasize adaptive, personalized, and student-centered learning [4], [5]. Research into those areas has demonstrated its effectiveness in allowing students to progress at their own pace and achieve mastery, which is a key aspect of the Merdeka curriculum. However, several studies show that the new curriculum faces challenges due to infrastructural inequities and inadequate teacher training, particularly in rural areas [1], [6]. This results in inconsistencies in education quality, potentially creating a gap between well-resourced and under-resourced schools. Limited digital tools and resources further complicate the situation.

In terms of technology usage, the review of technology applications in language learning studies found positive results where learners showed better outcomes and positive perceptions [7]. Technology, specifically through AI, could improve motivation, provide target language input, and help teachers organize content [8]. In recent years, AI has demonstrated the capability to deliver learning content and adapt to the individual needs of students, even though they learned in different scenarios and dynamic environments [9], [10]. Scholars demonstrate that a personalized learning system that supports individual needs through adaptive content, path, and context awareness, focusing on learning styles, can improve students' learning [11], [12]. The recent implementation of explainable AI shows its ability to identify students' interests, revealing influential factors that influence their studies and the nation's future [13]. Moreover, implementing an optimization based decision support system and classification techniques significantly predicts learner performance, creating a platform for performance estimating among students, addressing learning analytics issues [14]. However, it should be noted that the majority of studies agree on prioritizing learning objectives over technical means [7], [11], [13].

In this work, we seek to enhance learning capabilities in line with the Merdeka curriculum by integrating AI into voice recognition and natural language processing (NLP) using language models such as ChatGPT. Voice recognition can create an interactive and inclusive learning environment, making it more accessible and personalized for younger students or those with learning disabilities [15]. Voice assistants are tempting due to children's inquiring behaviors, yet understanding their interactions is critical in order to design effective conversational agents and prevent potential risks [16]. ChatGPT's NLP capabilities can support personalized learning by providing tailored responses to student inquiries, adapted to individual understanding levels [17], [18]. AI-driven conversational agents can provide instant feedback, engage in dialogue-based learning, and access resources tailored to students' learning pace, promoting a more interactive and student-centered educational experience [19], [20]. Specifically, this paper addressed the following research questions:

a) How should the GPT language model be integrated with speech recognition technology to achieve a porsonalized learning user experience?
b) How does user satisfaction with AI-generated feedback correlate with vocational computer network students' proficiency improvement?

2. METHOD

We have developed our research design by prioritizing practical problem-solving in an educational environment, with a focus on delopment and implementation of a design that is dedicated to directly enhancing outcomes. Therefore, the fundamental element of this research is design science research method.

2.1. Research design

The process as shows in Figure 1, is divided into six distinct phases: problem identification, objectives of solution, design and development, implementation, evaluation, and conclusion. Each phase is designed to build upon the insights and results of the previous stages [21], [22]. The objective of this design is to create, execute, and optimize an AI-based system that will improve the learning experience of computer network engineering students.

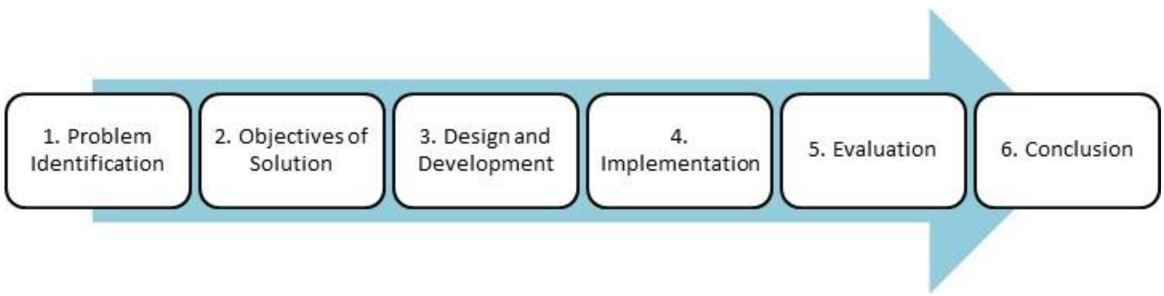

Figure 1. Six phases of research design

The design and development phase involves conceptualizing and building the proposed AI-based system, including the architecture that integrates speech recognition with the GPT language model. The system's functionality is defined based on the identified educational requirements, and considerations are made during this stage, including user interface, AI algorithm selection, and the voice recognition system's compatibility with specific vocabulary and technical language. Following the implementation phase involves deploying the system for real use in a classroom, providing access to the AI tool, and ensuring smooth integration with existing learning activities. Collaboration with educators is required to ensure the system aligns with teaching objectives and supports classroom dynamics.

Evaluation is a critical phase that determines the effectiveness of the AI-based learning system. It involves gathering data on the system's performance, its impact on student learning outcomes, and how well it meets pre-defined objectives. The insights gained through evaluation help identify areas for further improvement and guide the iterative development of the system. In conclusion, the research concludes by summarizing the results and determining the effectiveness of the implemented AI solution in addressing initial learning challenges.

2.2. Encoder-decoder architecture for speech recognition

The encoder-decoder scheme for speech recognition application in this research can be illustrated in Figure 2. The user speaks into the microphone as an audio input. Then, the audio input from the microphone is recorded and converted into acoustic features, including feature extraction and positional information through the positional encoding process using the `speech_recognition` library. The encoder consists of multiple layers, each comprising a self-attention sub-layer to process the input while considering all parts simultaneously. This is followed by normalization and a feed-forward layer to process the previous output, which is also normalized. This process is repeated several times (N layers) to produce enriched intermediate representations, which are then used by the decoder.

The decoder, in turn, consists of layers similar to the encoder, including self-attention, normalization, encoder-decoder attention to merge information from the encoder with internal representations in the decoder, and feed-forward, each followed by normalization. This process is also repeated several times (N layers) to produce the final representation of the predicted text. This representation is then transformed using a linear layer to logits for each word in the vocabulary, followed by a softmax layer to convert the logits to word probabilities, with the highest probability word being chosen as the output text.

This output text is then used to create a request to the OpenAI API, which provides a text response based on the input. The response text from the OpenAI API is converted back to audio using gTTS or pyttsx3, and the audio response is played using `pygame` as the final output that the user can hear. Thus, this scheme illustrates the complete process from audio input to audio output through the integration of speech recognition technology and the OpenAI GPT language model. To support the effectiveness of the application described in this study, a key part of the development involved building an encoder-decoder structure utilizing speech recognition technology and integrating it with OpenAI's GPT-3.

Below is a summary of the essential parts of the Python source code that implements this functionality, with an emphasis on the speech recognition component. The core Python code used includes several libraries like speech_recognition for capturing voice input, gTTS for converting text to audio, and OpenAI's GPT-3 API for generating intelligent responses. The encoder-decoder model starts by recording the user's voice through the microphone, which is then processed and used as input for GPT-3. Here's an Pseudocode 1. excerpt of the important parts of the implementation:

Pseudocode 1. The Python source code with an emphasis on the speech recognition component
```
import speech_recognition as sr
import pyttsx3 as pyt
from gtts import gTTS
import openai
import pygame

# Setting up OpenAI API Key
openai.api_key = 'YOUR_API_KEY'

# Speech Recognition to capture user's question
def listen_for_question():
    recognizer = sr.Recognizer()
    with sr.Microphone() as source:
        audio = recognizer.listen(source, phrase_time_limit=5)
        try:
            question = recognizer.recognize_google(audio, language='id-ID')
            return question
        except sr.UnknownValueError:
            return None
```

```
# GPT-3 Response Generation
def get_ai_response(question):
    response = openai.Completion.create(
        engine='gpt-3.5-turbo-instruct',
        prompt=question,
        max_tokens=200
    )
    return response.choices[0].text.strip()

# Text-to-Speech Conversion
def text_to_speech(text):
    tts = gTTS(text=text, lang='id', slow=False)
    output_file = 'output.mp3'
    tts.save(output_file)
    pygame.mixer.init()
    pygame.mixer.music.load(output_file)
    pygame.mixer.music.play()
    while pygame.mixer.music.get_busy():
        continue
    pygame.quit()
    os.remove(output_file)
```

The speech recognition component is a crucial part of the interaction between users and the AI system. The function listen_for_question() makes use of the speech_recognition library to capture audio input from the user via a microphone. The code utilizes the Recognizer class, which provides various methods for recognizing speech, including Google Web Speech API, which is used here (recognize_google() method). The microphone input is recorded using sr.Microphone(), which acts as the primary interface between the user and the encoder-decoder system. The phrase time limit is set to 5 seconds (phrase_time_limit=5) to ensure concise questions, which helps in maintaining fluidity during interaction. In the event that the speech is unclear or cannot be recognized, an exception (sr.UnknownValueError) is handled to allow the user to try again, ensuring robustness in the recognition process. Once a valid input is captured, the transcribed text serves as an input for the GPT model, which generates a response (get_ai_response()), and subsequently, this response is converted back into speech using the gTTS library (text_to_speech() function).

This combination of speech recognition, NLP, and text-to-speech forms the backbone of the interactive AI-driven learning assistant. By allowing students to ask questions naturally and receive personalized verbal responses, the application fosters a more dynamic and engaging learning experience. The encoder-decoder model thus plays a crucial role in enhancing learning by bridging human interaction with advanced AI capabilities.

2.3. Participants and procedures

Experimental trials are conducted to test the functionality and effectiveness of the application in real-world situations at SMK Telkom Purwokerto, a vocational high school in Indonesia that focuses on technical education. SMK (*Sekolah Menengah Kejuruan*) are vocational schools that aim to provide students with practical skills and industry-relevant knowledge, preparing them to directly enter the workforce or pursue higher education in technical fields. SMK Telkom Purwokerto, in particular, specializes in computer and network engineering, making it an ideal setting for evaluating how the model can enhance technical learning experiences. A total of 100 students from the Department of Networking Engineering who participated in the experiment. The students were grouped into four based on their classes.

A pilot study is conducted to assess the effectiveness of the prototype in this research. The study involves 100 participants, all of whom will use the prototype over a two-week period. A pre-test and post-test design is employed to measure the prototype's impact on learning. Before students use the prototype, they will complete a pre-test to establish their baseline knowledge. After using the prototype for two weeks, students will take a post-test to determine their learning gains. After conducting the post-test, the teacher will assess the student's competency and categorize them into basic, intermediate and advanced network knowledge groups. Lastly, we will investigate the relationship between interaction time duration on improving students' competency status using correlation analysis. The goal of a correlation analysis in this context is to determine whether there is a relationship between the time spent using the prototype (measured in hours per week) and proficiency improvement (from pre-test to post-test). Essentially, in exploring whether students who spend more time using the application tend to show greater improvements in their skill levels.

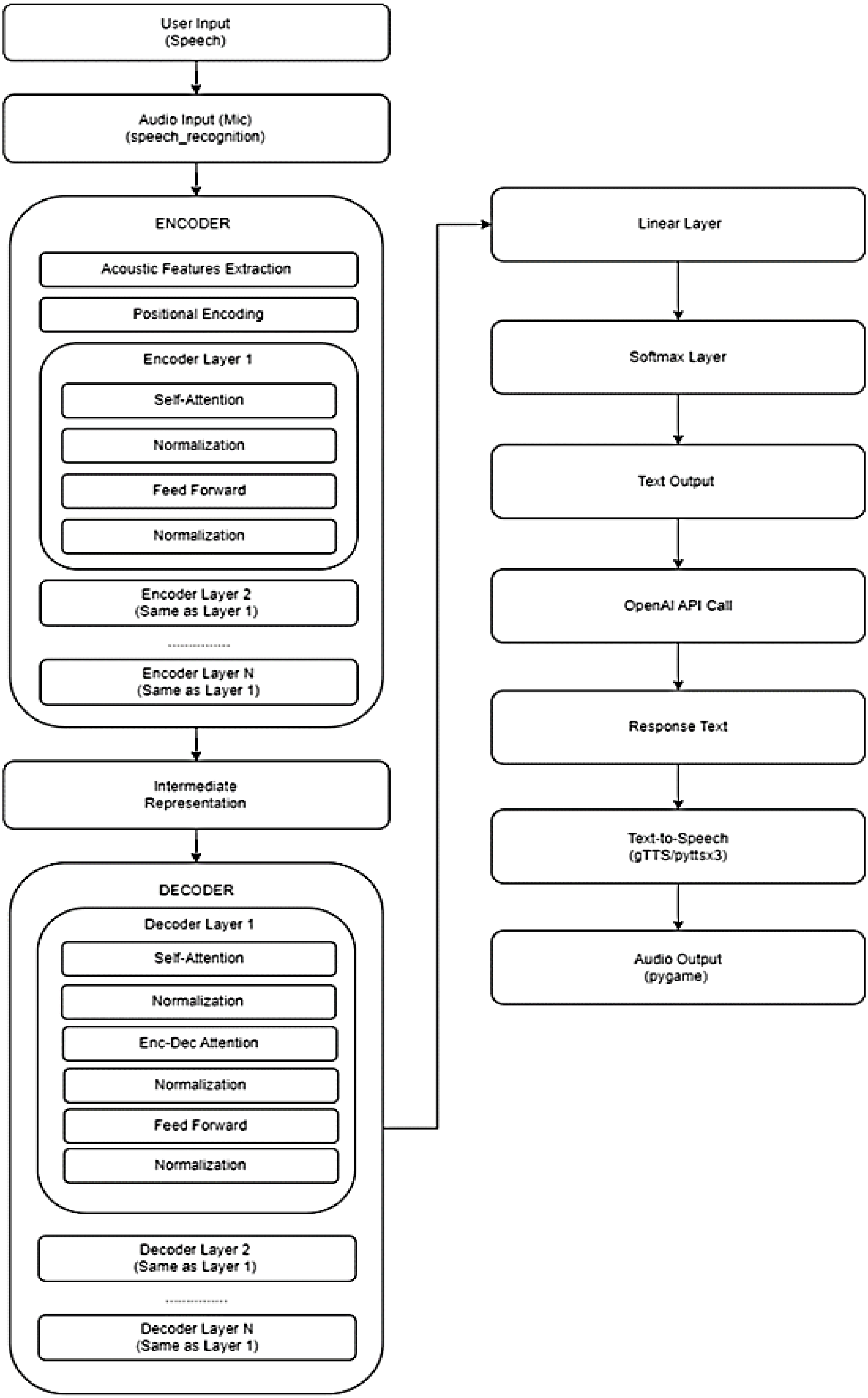

Figure 2. Encoder-decoder scheme for speech recognition

Alongside the quantitative data from the pre-test and post-test, qualitative feedback will be gathered to provide deeper insights into the students' experiences. Students will be asked to fill out surveys that explore aspects such as engagement and perceived learning benefits. The qualitative analysis process involves several methodologies to gain a comprehensive understanding of the application's impact. Content analysis from literature studies is used to evaluate the relevance of existing findings with the school setting. Thematic analysis of interviews is employed to identify key patterns and themes, providing insights into their experiences and expectations regarding the use of the technology. Table 1 shows a sample of a semi-structured interview process that includes questions related to the use of the application for conceptual understanding, practical exercises, and troubleshooting in network learning.

Table 1. Semi-structured interviews for qulitative analysis

Learning skills in networking	Example interview questions	Data analysis methods
Concept understanding	How has the use of the application helped you improve your conceptual understanding? Can you provide an example?	Thematic analysis, content analysis
Practical understanding	Have you used the application to practice practical skills? How was the outcome according to you?	Thematic analysis, content analysis
Troubleshooting Understanding	Have you used the application to practice troubleshooting? How was the outcome?	Thematic analysis, content analysis
…	…	…

3. RESULTS AND DISCUSSION

3.1. Implementation overview

An application was developed to address the first research question concerning the integration of the GPT language model with speech recognition technology. As mentioned earlier, we employ a Python script in the application. The program initiates by executing a function that welcomes the user through the playback of an audio file, accompanied by a visual message displayed on the screen. Subsequently, the command function is activated to receive commands from the user via the microphone, utilizing the speech_recognition library. Without a detected command, the function generates a return value of none.

The program utilizes speech recognition technology to capture the user's voice, subsequently converting the audio into text format. The subsequent step involves assessing whether the identified command corresponds to exit or close. Should this occur, the program will play the appropriate exit audio file and terminate by utilizing the exit function. If the command does not constitute an exit instruction, the program employs OpenAI's service to produce a response informed by the user's input. This response is then transformed into audio format utilizing Google Text-to-Speech (gTTS). The generated audio response is subsequently played back to the user. Upon delivering the response, the program reinitiates the loop by executing the welcome function again, thereby greeting the user and awaiting the subsequent command. The entire process operates within an infinite loop, facilitating ongoing interaction with the user. Figure 3 illustrates the implementation of the application in which the user inquires about a definition related to computer networking. Users can view command prompts and status messages, ensuring an efficient and informative experience. The speech recognition system captures and processes user voice input, converting it into text and displayed on the terminal.

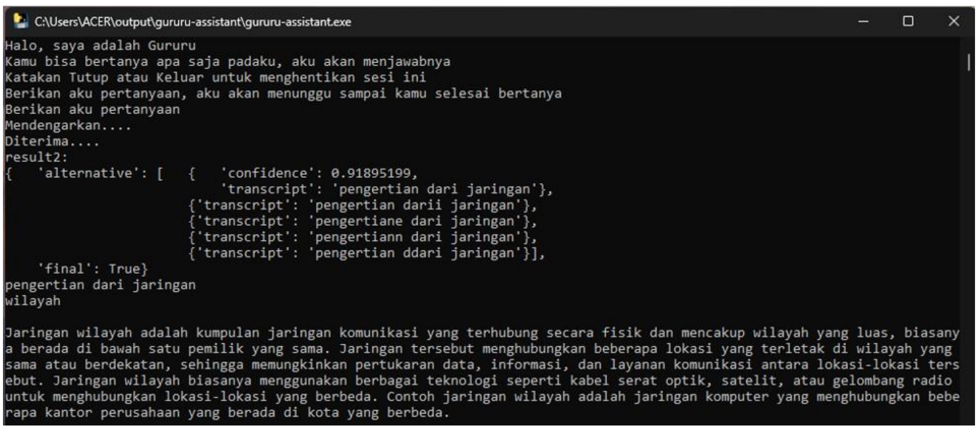

Figure 3. Implementation of prototype

3.2. Results

In the experimental procedure, a pre-test was administered to assess the participants' initial understanding of key concepts, practical skills, and troubleshooting related to Basic Computers and Networks before they began the learning process. The students participated in regular classroom activities, including laboratory sessions, while also using the prototype as part of their learning experience. The material covered sections 1-4 of the basic computers and networks curriculum. The entire learning process spanned three weeks, during which students were assigned tasks by their teacher. Each task took approximately 60 minutes to complete, though the time varied based on individual student abilities. After the learning phase, a post-test was conducted within 30 minutes to evaluate the students' immediate grasp of the material following their use of the prototype. The identical assessment is used in both the pre-test and post-test to evaluate the effectiveness of the learning process.

The pilot study results clearly demonstrated an improvement in students' learning outcomes after learning using an assisted prototype. As illustrated in Figure 4, the green bars represent the post-test results, while the blue bars show the pre-test results, with the pre-test scores of the four groups being reasonably close. The differences between the four groups' post-test results were not statistically significant, though Class D had the best performance and Class A the lowest. Despite this, all groups showed improvements in their post-test results compared to their pre-test scores, with an average increase of 28% across all groups. This quantitative data reinforces the conclusion that the prototype effectively enhanced students' knowledge, fulfilling the primary objective of the study.

The variation in proficiency improvement between classes can be attributed to several factors. As depicted in Figure 5, Class B, which showed the highest improvement, may have benefited from more engaged students and a positive classroom dynamic, leading to greater interaction with the prototype. Additionally, the teaching approach might have played a role, with teachers in Class B possibly providing better guidance on using the tool or aligning it more effectively with the curriculum. Students' familiarity with technology could also have contributed, as more tech-savvy students may have found it easier to navigate the prototype. Finally, the ability to understand and apply the feedback provided by the AI system likely influenced the results, with Class B potentially better at utilizing this feedback, while Class C may have struggled in this area.

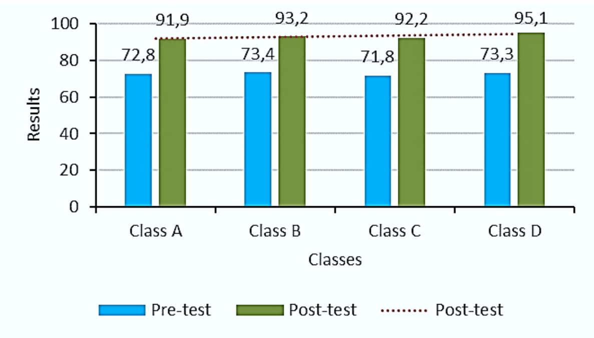

Figure 4. The experimental results of pre-test and post-test

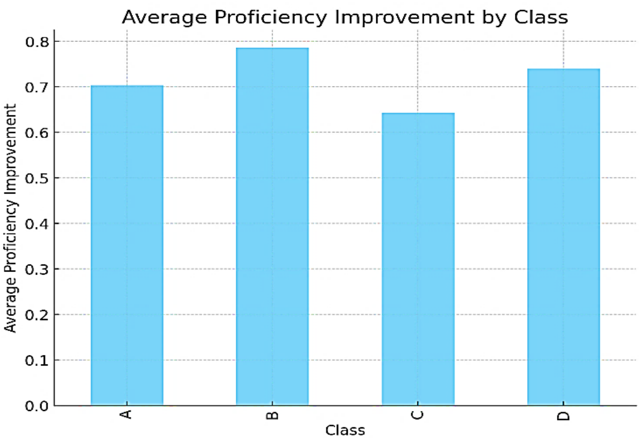

Figure 5. The experimental results of pre-test and post-test

Furthermore, the results of the study show a strong correlation between student feedback and proficiency improvement, with a correlation coefficient of 0.85. This high correlation indicates that students who rated the prototype as "Very Helpful" experienced significantly greater gains in their learning outcomes compared to those who provided lower ratings. The positive experiences with the prototype likely fostered better engagement, allowing these students to more effectively utilize its features, such as individualized feedback, to enhance their understanding and skills. This suggests that user satisfaction plays a critical role in determining how beneficial the tool can be for learning.

As shown in Figure 6, the scatter plots of feedback scores versus proficiency improvement for each Class (A, B, C, and D) reinforce this trend, showing that higher feedback scores were consistently associated with higher proficiency gains across all classes. In every class, students who rated the tool more favorably tended to show better improvements in their skills. This consistency across groups highlights the importance of creating a positive user experience, regardless of the specific classroom environment. It also suggests that the prototype's design successfully met the needs of many students, especially those who actively engaged with its features.

However, it is important to note that the majority of students across all classes clustered around feedback scores of 2 (Somewhat Helpful) or 3 (Very Helpful). This clustering reflects a generally positive reception of the prototype, with most students finding it at least somewhat helpful. The fact that higher feedback scores were linked to better proficiency improvement further emphasizes the importance of enhancing student satisfaction with the tool. By focusing on refining the prototype to address issues raised by students who provided lower feedback, there is potential to increase its effectiveness for a broader range of learners. These findings indicate that the tool is already providing substantial value, but further optimizations could amplify its impact.

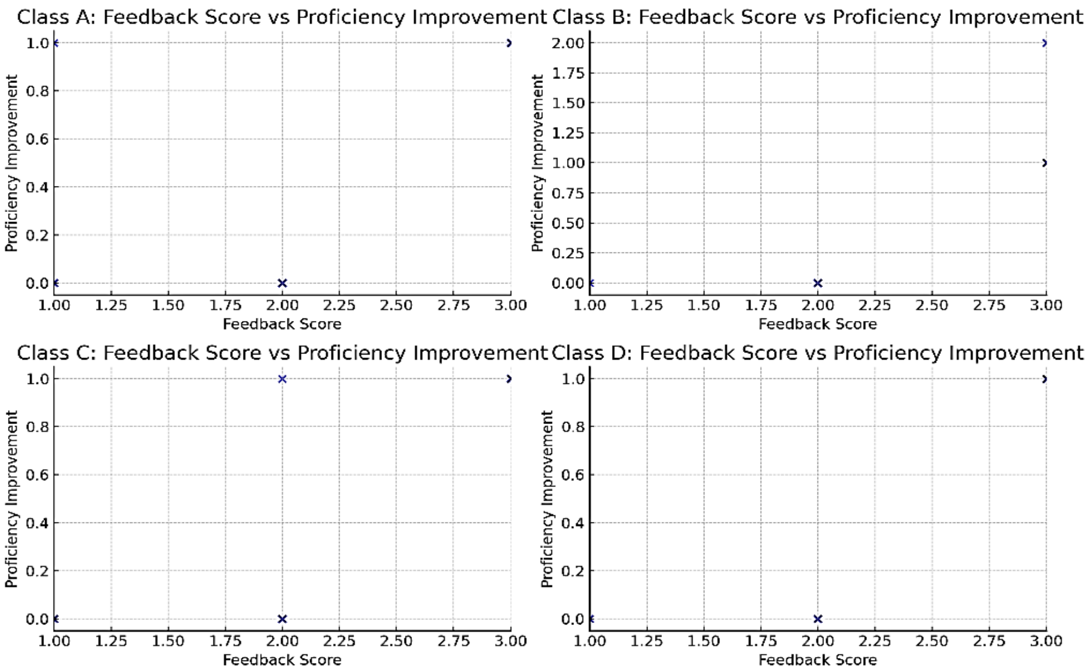

Figure 6. The experimental results of pre-test and post-test

3.3. Discussion

Considering the Merdeka curriculum, which emphasizes personalized learning and flexibility in education, the findings of this study align with its core principles [2]. The AI-driven speech recognition and GPT prototype was designed to support students' individualized learning journeys, where learners can progress at their own pace and engage with tools that meet their unique needs. The study's results show that the prototype had a generally positive effect on all classes. However, there were notable differences in performance improvement between the groups, particularly with Class B demonstrating the highest proficiency gains. This could be attributed to several factors, including classroom dynamics, teaching methods, or how effectively students in Class B engaged with the prototype. Engagement plays a crucial role in determining how much a student can benefit from a learning tool, and it is possible that students in Class B were more motivated or had a more robust support system, leading to better outcomes. Understanding the specific characteristics of this class, such as how the teacher facilitated learning or how students interacted with the tool, could provide valuable insights into best practices that can be applied to other groups.

The varied performance across classes also underscores the importance of tailoring learning tools to fit different contexts, a critical aspect of Merdeka curriculum's flexibility. While Class C showed lower improvement, this could indicate that students in this class struggled with factors like lower engagement with the tool, difficulty understanding the content, or external influences such as lack of access to resources [1], [6]. Investigating these potential barriers through qualitative methods, such as student surveys or teacher interviews, would help identify the specific challenges faced by Class C. For example, were students in this class less comfortable with technology? Did they find the prototype difficult to navigate or less relevant to their learning needs? By addressing these concerns, adjustments can be made to better support students in lower-performing groups.

Despite the variations across the classes, all students demonstrated some level of proficiency improvement, indicating the prototype's overall effectiveness. This reinforces the idea that the tool is beneficial for learning, though its impact may differ depending on classroom contexts. Even if the gains in some classes were lower, the general trend of improvement suggests that with further refinement and targeted interventions, the prototype could deliver even more substantial learning benefits. Supporting previous studies [23], [24], our results also provide a promising foundation for further development and highlight the importance of understanding the nuances of how students from different backgrounds and learning environments interact with educational technology.

To further enhance the tool's effectiveness, it would be valuable to analyze the practices that worked well in Class B, which had the most success using the prototype. Understanding the strategies employed in this class, such as how the teacher integrated the tool into the curriculum or how students were encouraged to engage with its features, can offer actionable recommendations for other groups. These best practices can be shared with other teachers to create more consistent and impactful learning experiences across all classes. Identifying what worked in Class B could also help tailor the tool's deployment in future iterations to maximize its effectiveness. Given the strong correlation between feedback and proficiency improvement, we answer the second research question by directly addressing the relationship between students' perceptions of AI-generated feedback (satisfaction) and their learning outcomes.

Interestingly, the data showed no strong correlation between the time spent using the application and proficiency improvement. This suggests that merely increasing the hours spent on the tool may not necessarily lead to better outcomes [25]. It could be more important to focus on how the tool is used rather than how long it is used. For instance, students in higher-performing classes may have utilized the tool more strategically or in conjunction with other learning resources [26]. This emphasizes the need to focus on quality of usage over quantity, possibly by offering more guidance on how to effectively use the tool to enhance learning rather than simply encouraging students to spend more time with it.

Finally, a more detailed investigation into the specific issues faced by Class C and other lower-performing groups could yield important insights for improving the prototype. By gathering detailed feedback on how the students interacted with the tool, educators and developers can better understand what might be preventing certain students from benefiting fully. Factors such as content alignment with the curriculum, ease of use, or even external influences like technical support or access to devices could affect their performance. Tailoring the tool to address these specific needs or challenges, such as offering more simplified instructions or enhanced support features, would help improve the outcomes for all students.

4. CONCLUSION

This study's findings are consistent with the fundamental ideas of the Merdeka curriculum, which prioritizes customized learning and educational flexibility. The research aimed to evaluate the effectiveness of an AI-driven speech recognition and GPT-powered prototype in improving vocational students' proficiency in computer networks. This approach can create an interactive and inclusive learning environment, making it more accessible and personalized for younger students or those with learning disabilities. Again, this research aligns with the primary goal of Merdeka curriculum, which allows learners to advance at their own speed and utilize resources tailored to their own requirements. Experimental trials were conducted at SMK Telkom Purwokerto, a vocational high school in Indonesia, to test the functionality and effectiveness of the application in real-world situations. The study involved four classes, where students' pre-test and post-test scores were compared, alongside feedback on their experience with the tool. Results showed that all classes demonstrated proficiency improvement, with Class B achieving the highest gains and Class C the lowest. A strong correlation (0.85) between positive feedback and proficiency improvement highlighted the importance of user satisfaction in learning outcomes. However, the correlation between time spent using the tool and improvement was weak, suggesting that quality of engagement mattered more than quantity. These findings emphasize the need for refining the prototype to better address the needs of all students while enhancing its usability and impact.

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AUTHOR CONTRIBUTIONS STATEMENT

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Alva Hendi Muhammad		✓			✓	✓		✓		✓	✓	✓		✓
Asro Nasiri				✓	✓		✓			✓		✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, AHM. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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