Research Project Topic Recommender System Using Generative Language Model

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Abstract

Education has become a driver of a person's continuous innovation to improve their quality. Currently, the use of artificial intelligence determines progress in education. In this research, artificial intelligence technology was applied to develop a web-based recommendation system to help students at the Faculty of Computer Science, Klabat University, choose appropriate research topics for their final assignments. To provide personalized and contextually relevant suggestions, the recommendation system leverages deep learning and generative language models, specifically GPT-3. The Rapid Application Development process model is employed to develop the system. Its key components include semantic search, rapid engineering, and an advanced vector database for effective data management and retrieval. The functions provided by the system include user account registration, login, input of major subject grades and research preferences, and personalized recommendation results. Some additional features such as profile management, previous recommendation history, and password reset options are also provided. All these functions have been tested using the black box method.

Keywords— Recommendation System, Research Project Topics, Artificial Intelligence, Generative Language Model, GPT-3.

1. INTRODUCTION

Education is one of the means that supports a person's development. This leads to the continuous development of innovations aimed at enhancing the existing quality of education. One example of technological innovation in education is the use of AI in teaching and learning activities. Netex Learning, accessible via their official website at https://www.netexlearning.com/en/, provides a customized cloud platform for virtual training and workshops. It also suggests diverse multimedia subjects like books, videos, and virtual training based on the user's preferences.

Traditionally, the goal of artificial intelligence (AI) is to create advanced computers and machines that have the same intelligence as human beings [1]. While AI is generally defined as computer-assisted artificial intelligence that can imitate human intellectual abilities, the application of AI has brought increased efficiency and reduced costs, which is beneficial to economic growth, social development, and human well-being [2]. For students, in particular at the Faculty of Computer Science at Klabat University, completing a research project is a mandatory requirement for completion. However, some students still find it difficult to choose a research topic to cover in their future studies due to some internal and external factors. Internal factors include students' lack of interest or motivation to finish their research. External factors include challenges in locating relevant literature or data related to the research topic, as well as challenges in effectively communicating with the relevant supervisor. This study intends to

develop a website-based recommendation system that aims to assist students in choosing which topics are suitable for use in their final research.

2. LITERATURE REVIEW

2.1. Deep Learning

Deep learning is a method of applying machine learning that uses artificial reasoning networks to mimic the workings of the human brain. Deep learning is a method that involves overlapping hidden layers. These layers serve as algorithms that perform classification from input to output. [3].

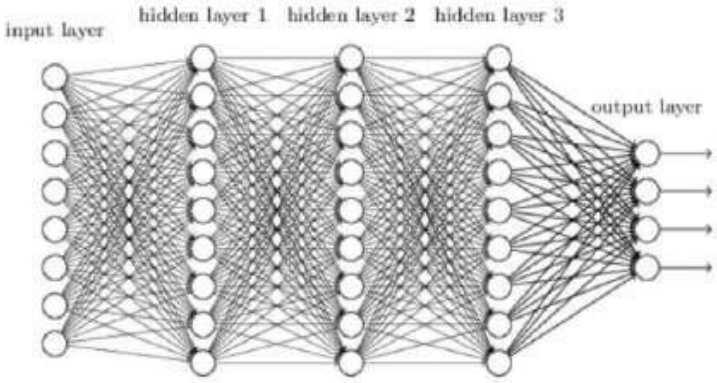

Figure 1. Deep Learning Architecture [3]

Using neuron algorithms, deep learning can determine and analyze the characteristics of a data set. The design of deep learning programs incorporates far more complex capabilities. The aim is for the program to learn, process, and classify data sets. Deep learning methods in natural language processing (NLP) perform text classification and text generation tasks using advanced models such as Long Short-Term Memory (LSTM) networks and transformers. One popular transformer model is BERT (Bidirectional Encoder Representation of Transformers). BERT improves text classification by comparing it with LSTM networks, using a simplified version called DistilBERT [4]. Generative platforms like Generative Pre-Training Transformer (GPT)-3 can create text that is difficult to distinguish from text written by humans.

2.2. Generative Language Model

The generative language model is a modeling language that generates new text based on the meaning of the provided training data [2]. Generally, to learn the patterns and structure of the given text, deep learning techniques, such as Recurrent Neural Networks (RNN), are used [4]. When the model grasps the context and relationships between words, it can generate text and discussion topics similar to its training data. This capability is useful in applications such as automatic writing and language translation. By comprehending the language structure from the training data, the model can generate new sentences or word sequences that align with learned patterns, resulting in responses that sound natural or human-like.

Three main factors drive the advancement of new generative models. First, the large amount of human language data on the internet improves model training. Second, enhancements to neural network models and algorithms improve their quality. Thirdly, the growth of computing power allows the creation of larger and more sophisticated models. Acquiring computing power to train the model is the most expensive aspect of current applications, and the model's capability directly correlates with the amount of computing power used [5].

2.3. Generative Pre-Training Transformer

OpenAI developed the GPT, a language model capable of producing virtually

indistinguishable response text from natural human language. GPT employs a machine learning approach known as transformers, allowing the model to understand and produce natural and responsive text. GPT is based on the transformer architecture's structure, which gives the model the ability to process and understand the relationships between words in the text. The model undergoes a training process using pre-training and fine-tuning techniques [6]. The Transformer model focuses on two types of tasks:

- The attention mechanism, known as self-attention, uses the position of each word to draw relationships between words in a sentence.
- The encoder and decoder are devices that convert data from one format into another. A decoder is a logic circuit that receives a binary input and activates one of the outputs based on the binary code input.

Using the attention mechanism helps transformers filter out the confusion and focus on what is relevant, such as linking two words in semantic relation to each other that have no markers pointing to each other. Transformers have a better understanding of the context of words in a sentence compared to other types of neural networks [7]. Most of the competing neural sequence transduction models have an encoder-decoder structure [5, 2, 29]. In this context, the encoder converts a sequence of input symbol representations $(x_1,..., x_n)$ into a sequence of continuous representations $z = (z_1,..., z_n)$. Given z, the decoder then generates the output sequence $(y_1,..., y_m)$ with one symbol at each step. This model is auto-regressive, where at each step, it uses the previously generated symbol as an additional input when generating the next symbol [8].

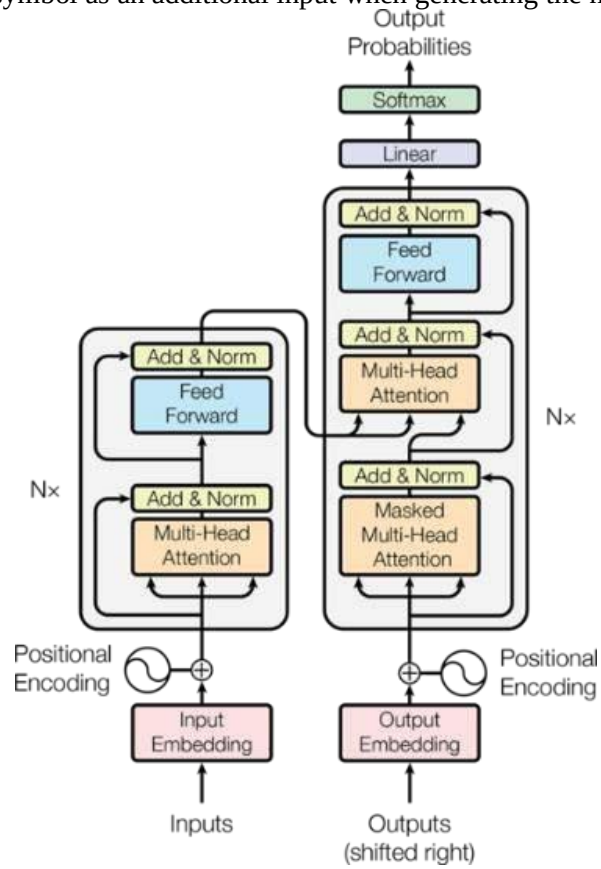

Figure 2. Transformer Architecture [9]

Figure 2 shows the transformer architecture. The element that is responsible for receiving input strings, i.e., text, is the encoder. It will then convert the input string into a more abstract and structured representation. The encoder consists of several iterative layers. In each layer, there are two main components, which are the multi-head attention layer and the feedforward layer. The multi-head attention layer enables the encoder to recognize the contextual relationships between words in the input string. It generates the 'context' representation, which enables the model to

comprehend the ‘meaning’ of words within their context.

In a transformer architecture, the encoder is in charge of taking an input, in the form of a string (such as text), and converting it into a more abstract and structured representation. The transformer encoder structure consists of several iterative layers. Each layer has two main components, namely:

a) Multi-Head Attention Layer, a component that allows the encoder to understand the contextual relationships between words in the input string. In this layer, a "context" representation is generated, thus allowing the model to understand the meaning of the words in context.

b) The Feedforward Layer produces a more abstract representation of the input.

Furthermore, in the transformer architecture, there is a decoder whose main function is to receive the output of the encoder (an abstract representation of the input) and produce a sequence of outputs, in the form of language translation or text generation. Similar to the encoder, the decoder also consists of several layers, they are the multi-head attention layer, a forward neural network layer, and an additional layer known as "masked multi-head attention". This layer reduces the risk of future information leakage into the decryption process.

GPT is a well-known example of a transformer architecture employed to generate text. However, there are differences between GPT and Transformer architectures, in which the GPT architecture alone employs a decoder, devoid of an encoder, to generate text by leveraging natural language processing [10]. Pre-training GPT involves learning the model on a large dataset that encompasses a variety of text types. Once trained, GPT can carry out tasks like text creation, sentence completion, and question answering.

GPT-3 is a natural language model designed to generate text responses that accurately match the information provided by a person, rather than simply eliciting binary responses such as yes or no. It can answer questions and provide question answering. GPT-3 can answer questions and provide answers that resemble the answers given by humans[11]. However, GPT-3 mainly emphasizes its text generation capabilities to solve complex questions, such as a chatbot that can provide simultaneous responses to questions about programming languages. In zero-shot and few-shot settings, GPT-3 works well on NLP stages [8]. GPT-3 can write text that is almost the same as human text writing. Furthermore, GPT-3 is capable of performing tasks for which it has never received explicit training, such as summarizing numbers, crafting SQL queries, and composing React and JavaScript code in English. Therefore, researchers use GPT-3 technology in the recommendation system so that the presentation of recommendation results is more personalized and contextual.

2.4. *Conceptual Framework*

The following is an image of the conceptual framework of the system that will be developed in this study. The explanation of the stages in the conceptual framework image is as follows:

a. **User**

Users, in this particular case, are students who seek recommendations for the system. The system requires a user to provide two types of input, namely major subject grades and additional textual information describing the user’s area of research interest.

b. **Semantic Search**

It is the search for information related to the meaning and relationships between keywords, entities, or information. Semantic search can be used in various contexts such as website searches, database searches, documents, and other applications that involve text information. Search engines will try to understand the context and meaning behind the keyword text entered by the user. In the recommendation system that is built, semantic search functions search for words based on the meaning in the vector database and will provide the most relevant recommendation results to the user based on the input or preferences provided by the user. In this study, an ontology-based approach is used to represent vocabulary and relationships

between semantic entities. Ontologies describe the elements that exist in each field or area to represent semantic relationships so that the information users want can be found more quickly and efficiently [12].

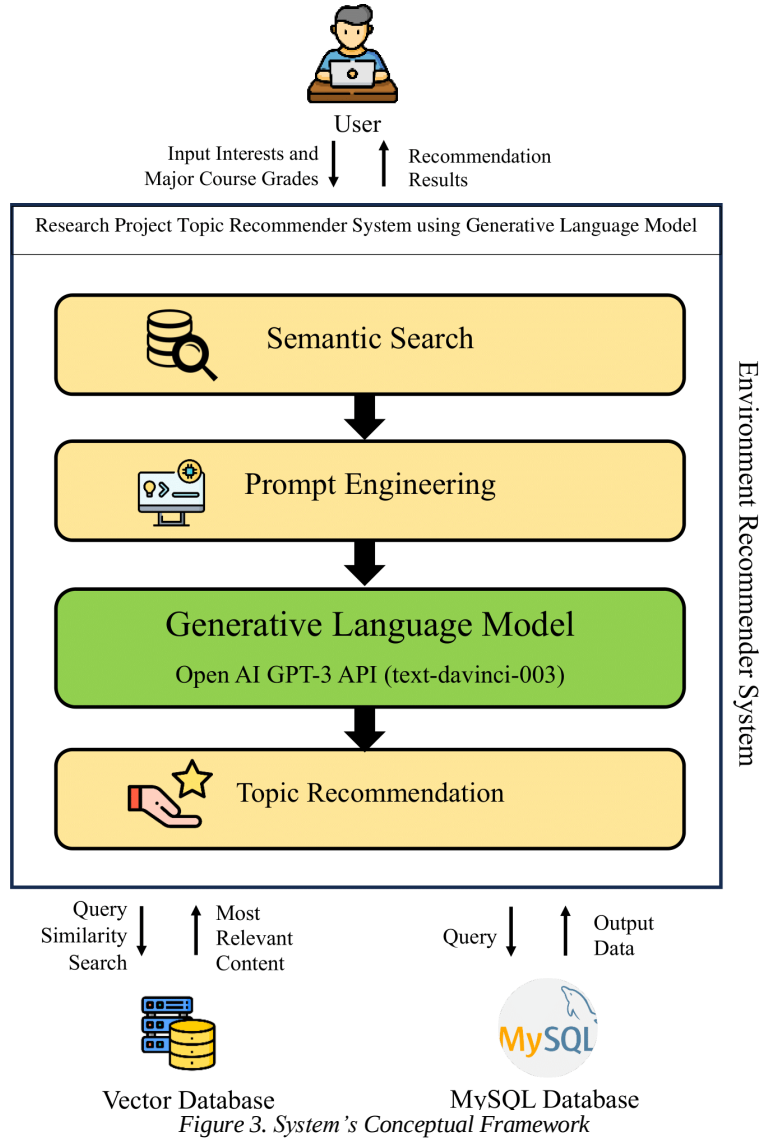

Figure 3. System's Conceptual Framework

c. **Prompt Engineering**

Prompt engineering is the process of designing, testing, and optimizing specific instructions or queries given to an AI model. Prompt engineering, also called "prompt design," "prompt programming," and "prompting" in short, is the practice of writing textual input for generative systems [13]. Most of the work in prompt engineering is concentrated on the problem of text generation from natural language processing [14]. Prompt engineering involves choosing the right words and formats to produce accurate and relevant results. The elements of a prompt are:

1) Instruction: the specific instruction that the model wants to perform.
2) Context: external information or additional context that provides knowledge to the model so that it can help produce more accurate and relevant responses.
3) Input data: input or questions you want to answer.
4) Output indicator that specifies the response format, whether the answer should be short, in one paragraph or more.

d. **Generative Language Model**

In this stage, the generative language model will generate text based on the textual information that describes the area of research interest provided by the user (previously described). In this study, a GPT-3 is employed to produce a response that fits the context of users' prompts.

e. **Topic Recommendation**

In this stage, as the outcome, the system will provide recommendations of some 'research project topics' that might fit the user. When the user does not provide enough input data (major subject grades and specific areas of research interests), the system will also provide the user with information about these limitations.

f. **Vector Database**

Vector database functioned as a database specifically designed for storing, managing, and analyzing vector data, data that consists of large digital vectors. In a vector database, these vector data are used to perform search operations based on vector similarity, recommendations, analyses, and others. In addition, vector databases are also equipped with vector indexes, optimized search algorithms, as well as support for complex vector processing operations, that make a vector database capable of managing and analyzing large-scale and highly complex vector data [15]. It is therefore not surprising that vector databases are used in a variety of applications, including product recommendations, image searches based on visual content, and text analysis. In this research, the vector database is utilized as a database for storing data in the form of vectors or data on recommendation topics.

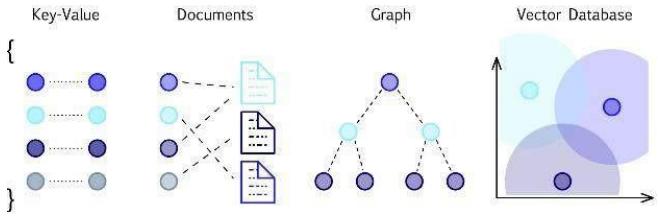

Figure 4. Vector Database

Among the various available Vector Storage Database systems, such as ChromaDB, Pinecone, and DeepLake [16], this research uses the ChromaDB vector database. ChromaDB is an open-source vector database that combines the k-means clustering algorithm with the ClickHouse database management system to retrieve portions of text that are semantically similar to the input query [17]. ChromaDB is a schema-free vector database specifically designed for artificial intelligence applications. ChromaDB, vector data can be easily managed to improve the performance and functionality of AI-based applications or systems [18] because it is lightweight and extremely powerful. Also, it allows efficient storage, retrieval, and management of vector data (embedding).

g. **MySQL**

MySQL is a Relational Data Base Management System (RDBMS) that uses the open-source Structure Query Language (SQL) with a client-server model. SQL is a standard language used to access database servers MySQL functions to create and manage various information contained in a database on a server with the SQL programming language. One of the advantages of MySQL is that it is easy, free, stable, and can be applied to several different operating systems [19]. MySQL utilizes indexes to increase the speed of searching for specific data within rows of information.

Each table in MySQL should generally have at least one index, which is often a primary key or unique identification to make it easier to track data [20]. MySQL is used in this research because MySQL has several advantages that can help the course of building a recommendation system in this research. The advantages of MySQL include, MySQL is available for free so that it can be easily obtained, MySQL is stable in its operation, MySQL has a fairly good security system, is very flexible with various programs and the development of MySQL is very fast [21].

3. RESEARCH METHODOLOGY

3.1. Research Method

Developing a suitable system requires the use of the right approach or method. Therefore, this research will use one of the models in the SDLC or System Development Life Cycle. This research will utilize Rapid Application Development (RAD), one of the many models in the SDLC, to aid in system development. The RAD method is an object-oriented approach to building systems whose main goal is to reduce application time and processes to create software systems as quickly and accurately as possible [22].

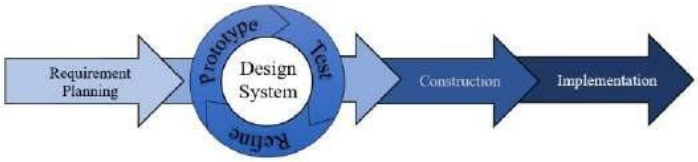

Figure 5. RAD

The stages of RAD process are described as follows:

1) **Requirement Planning**. Before designing and creating a system, researchers must analyze what problems are experienced by users and can later be resolved by the recommendation system. In this section, the researcher conducts a literature study.
2) **System Design**. At this stage, the design process will be carried out, and the design improvement process will be repeated. There are three parts that researchers must do: prototyping, testing, and refining.
    a. prototype, an early version or temporary embodiment of the system to be developed by researchers that aim to see feedback from users and minimize failure during further system development.
    b. testing, a testing phase that aims to identify problems and what improvements are needed.
    c. Refine, repeating the previous steps if there are still discrepancies that must be corrected again.
3) **Construction**. At this stage, the researcher will build a temporary system prototype into the final version. Where there will be a process of continuous improvement and development based on any feedback obtained from users.
4) **Implementation**. In this stage, the programmer will implement the previously approved system design. Then the testing process will be carried out on the program used to reduce errors in the system to be developed. At this stage, a decision will be made about whether the system is following the original objectives of the research or not.

4. DISCUSSION

4.1. Analysis

Researchers use the Unified Modeling Language (UML) to describe the work of the recommendation system, carrying out the system development using an object-oriented approach. Researchers use case diagrams to describe what kind of interaction will occur between the system and the user. Additionally, the use case diagram illustrates the features that the user can access in the future. Researchers developed a use-case diagram (as shown in Figure 6) for the Research Project Topic Recommender System.

Figure 6. Use Case Diagram

There are 12 use cases or functions, namely account registration, login, input of major subject grades and preferences, and recommendation results. If users do not fill in the major subject grades and preferences, they will not get the recommendation results. Next, users find a list of their major subjects and grades, navigate to the "about" section, and view their profile. Two more functions, "edit profile" and "edit password," complement these features. Next, the grading standard, the history, and the final function, which is logout.

5. IMPLEMENTATION

5.1. Design Implementation

The Research Project Topic Recommender System is shown in Figures 7 to 10. Figure 7 is the Login page, which indicates that a student user needs to have an account to access the system. Login requires the user to select his/her major from the list provided. In addition, a registration feature is provided for a new user who has no account yet. Another feature provided on this page is the password reset feature that allows existing users to regain access to their account when they have forgotten their password.

Figure 7. Login Page

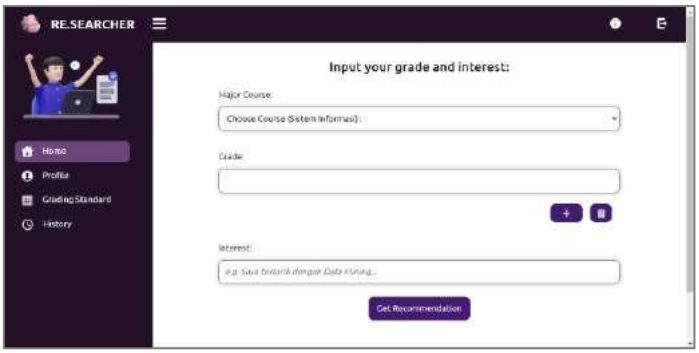

Figure 8. Home Page

Figure 8 depicts how the Home page of the Research Project Topic Recommender System is implemented. Through this page, the user will provide the major subjects and their grade information. A list of major subjects offered by the Faculty of Computer Science is provided to make it easier for the students to choose them, followed by entering the respective grades. The Add button functions to add a new major subject and its grade. Furthermore, there is another field for the user to enter his or her preferences or research field area of interest. This helps the user get recommendation results that are suitable and following the user's interests in computer science.

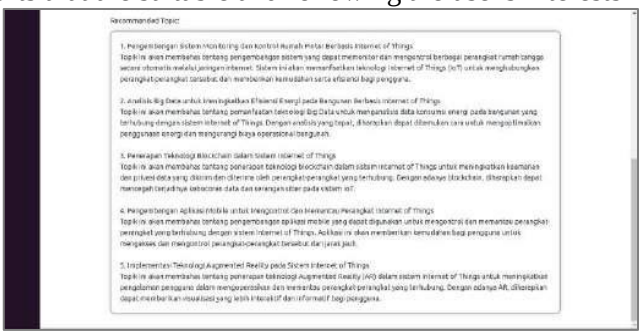

Figure 9. Recommendation Result

Figure 9 demonstrates the implementation of the Recommendation Result page within the Research Project Topic Recommender System. The system infers the recommended research project topic from the major subject grades and keywords (preferences or research field area of interest) on this page.

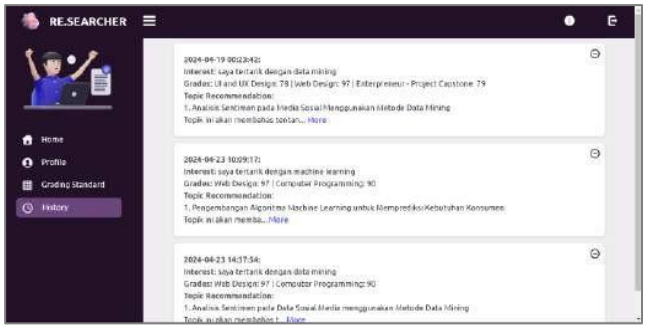

Figure 10. History Page

Figure 10 displays the implementation of the History page in the Research Project Topic Recommender system. This page showcases a user's search history, which includes their major subject grades and the keywords (preferences or research field area of interest) they've entered to receive recommendations for research project topics. This page also displays the previous recommendation results for each search, along with the date and time.

5.2. Black-box Testing

Testing is critical in developing a system to ensure that it conforms to expectations. Testing uses a black-box testing method that focuses on system functionality. This test evaluates whether the input and output processes of each system function run correctly. Table 1 shows the results of the validation process conducted by the user. The validation process aims to assess whether the system created is following user needs. We use the black box testing method to focus on system functionality during testing.

Table 1. Black-box testing

Input	Process	Expected output	Status
Account Registration	- Enter the registration page. - Select a major, input full name, username, email, and password. - Click the save button.	User's account was successfully created	Success
Login	- Enter the login page. - Select major, input full name, username, email, and password. - Click the login button.	Successfully login into the website	Success
Input Major Course Grade and Interest	- Enter the home page. - Select a course and enter the course's grade. - Click the button with the add symbol to add a course to the list. - Input the user's interest.	Major Course Grades and Interests were successfully inputted into the database	Success
View Major Course Grades	- Enter the home page. - Click the button with a grade symbol.	Display a list of Courses and Grades	Success
Recommendation Results	- After entering the course grades and interest, click the get recommendation button.	Display recommendations based on data provided or the user's input	Success
View About	- Enter the home page. - Click the About menu in the navbar.	Display the contents of the About page	Success
View Profile	- Enter the home page. - Click the About menu in the navbar.	Display the contents of the Profile's page	Success
Edit Profile	- Enter the profile page. - Click the edit button.	Profile data editable	Success
View Grading Standard	- Enter the home page. - Click the grading standard menu on the sidebar.	Display the contents of the Grading Standard's page	Success
View History	- Enter the home page. - Click the history menu in the navbar.	Display the content of History's page	Success
Logout	- Enter the home page. - Click logout in the navbar.	Exit the system successfully.	Success

6. CONCLUSION

6.1. Conclusion

This study successfully developed a web-based recommendation system to assist students in selecting suitable research topics for their final projects. The system can generate personalized topic suggestions based on students' academic performance (major subject grades) and areas of interest, as it utilizes AI technologies, particularly deep learning and the generative language model GPT-3. The integration of semantic search and vector databases ensures that the recommendations are relevant and contextually accurate. Despite the limitations related to data availability and user input variability, the system demonstrates significant potential for reducing the difficulties students face in choosing research topics. Future research should focus on refining the system's algorithms, expanding its dataset, and enhancing user interface functionalities to further improve its effectiveness and user experience.

6.2. Suggestion

We propose the following recommendations for future development to enhance the quality and effectiveness of AI-based recommendation systems:

a. Improving the variables and criteria for research topic recommendations can help improve the quality of research topic recommendations.
b. Development of language processing abilities. It is anticipated that this system will undergo further development to improve its language processing capabilities to support other languages, thereby expanding the application's user reach and relevance, although currently, the focus is on Indonesian.

By implementing the suggestions above, this research will continue to develop and make a significant contribution to the development and implementation of AI-based recommendation systems.

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