BrainWave Flashcards

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***Abstract*—BrainWave Flashcards is a web-based application designed to optimize the learning process. The app allows users to create personalized flashcards for efficient studying, organized into decks like 'Personal,' 'Academic,' and 'General.' Users can then review the flashcards for optimal knowledge retention. Thorough evaluations, including accessibility and usability tests, bug, error, and performance checking, along with user satisfaction and engagement, were conducted after development to ensure a seamless user experience. This application serves as the foundation for an intelligent, data-driven learning application, with details for implementation outlined in the 'Future Work' section.**

Index terms: Personalized learning, Flashcard creator, Multimedia content integration, Adaptive learning, Learning style customization, User engagement strategies

I. Introduction

In today's educational landscape, learning [9] often relies on standardized materials, providing identical references for all students without considering their needs and preferences. This uniform approach neglects crucial factors such as prior knowledge, learning styles, and personal interests, ultimately hindering students' potential and reducing the overall effectiveness of the learning process.

We proposed this project due to several important questions and were curious to find their answers. To answer some of these questions, we developed our flashcard application and conducted in-depth literature and industry reviews for others. For example, how can we revolutionize [10] the traditional one-size-fits-all learning approach and unlock the full potential of each student? What if flashcards could adapt to our unique learning styles, preferences, and prior knowledge, transforming how we study and retain information?

We also questioned why we are tired of generic learning materials that fail to engage us. How can we create a personalized, multimedia-rich learning experience tailored to our needs? Do learners struggle to find the time and motivation to review their study materials? How can smart technology streamline our learning process and make it more efficient? Another interesting question is about imagining a future where your flashcards not only store information but also intelligently generate content and adapt to our progress. How can we make this a reality?

II. Literature Review and Related Work

While the development of flashcard applications has stabilized in the industry, the domains of education and learning remain active areas of literature and research [2, 3, 4]. A significant amount of research has been conducted on optimizing learning [5], encompassing user experience (UX) design [6, 11] as well as the incorporation of AI features. For instance, the state-of-the-art multimodal DualGNN recommender systems [1] demonstrate the potential of AI in developing intelligent learning systems. However, despite numerous studies on education, development, psychology, and UX [7, 8], a major challenge remains: these findings are often not implemented in a unified application. Although creating a super-intelligent flashcard application is beyond the scope of this project, the report presents a literature review and step-by-step documentation for implementing a potential system, as outlined in the final section. This application can integrate the latest research to revolutionize learning styles using cutting-edge technologies, such as multimodal DualGNN recommenders, advanced cloud-based infrastructure (e.g., SageMaker) [24], and large language models (LLMs) like GPT.

III. Relation to Other Projects

While this project explores a unique idea within our Multimedia course, it draws inspiration from established applications in the field of spaced repetition learning, such as Quizlet [20], Anki [19], Memrise [21], Tinycards by Duolingo [22], and StudyBlue [23]. Each of these applications has its plus points and downsides.

IV. Development Work and Novelty

A. Data set

Since no machine learning models were incorporated into this project, we did not utilize any specific datasets. Instead, the application functions by leveraging user-provided information, which is inputted in the form of both the front and back sides of flashcards. This user-generated data serves as the foundation for the application's operations, allowing for a personalized and interactive experience.

B. Details of Packages and Libraries Used

In the development of our Online Flashcard Maker application, we utilized several key technologies to create a robust and user-friendly web-based solution. For the Front-End development, we employed HTML5, CSS3, and JavaScript [12, 13, 15, 16] to build the foundation of the application's user interface and interactivity. HTML5 provided the semantic structure and content of the web pages, allowing us to create a well-organized and accessible layout for the flashcard creation and management features. CSS3 was used to enhance the visual appeal and responsiveness of the application, enabling us to style the various UI components and ensure a consistent and aesthetically pleasing design across different devices and screen sizes. JavaScript, on the other hand, was instrumental in adding dynamic functionality to the application, enabling features such as interactive flashcard creation, real-time updates, and seamless user interactions.

To further streamline the Front-End development process, we incorporated the Bootstrap Front-End framework. Bootstrap offered a comprehensive set of pre-built UI components, layout options, and responsive design utilities, which significantly reduced the time and effort required to create a visually appealing and mobile-friendly user experience for our Online Flashcard Maker.

For the Back-End part of the application, we utilized the Flask Python web framework, which provided a lightweight and flexible foundation for our server-side logic. The Flask Ninja library, a third-party extension, was employed to enhance the functionality of Flask, potentially adding features like improved routing, middleware, or additional utility functions that were tailored to the specific requirements of our project. To manage the database for storing and retrieving user-generated flashcards, we opted for the SQLite database engine. SQLite's self-contained and serverless nature made it an ideal choice for our application, as it required minimal setup and configuration, while still providing the necessary data management capabilities.

Additionally, to ensure the consistency and portability of our Online Flashcard Maker application, we incorporated Docker, a containerization platform. Docker allowed us to package the entire application, including its dependencies, into isolated and reproducible containers. This simplified the deployment process, ensuring that the application would run consistently across different environments, from development to production, and streamlined the overall development and delivery workflow. By leveraging these cutting-edge technologies, we were able to build a robust and feature-rich Online Flashcard Maker application that offers a seamless user experience, efficient data management, and a scalable and maintainable infrastructure.

Lastly, for our future work, we have explored advanced technologies such as generative AI models, MultiModal Dual-GNN recommender systems, and cloud services like Amazon SageMaker. While we did not directly utilize them in the current implementation of our Online Flashcard Maker project, these technologies hold great potential to enhance our application's capabilities, enabling personalized content generation, intelligent recommendations, and seamless integration of AI functionalities. By continuing to research and experiment with these emerging technologies, we aim to incorporate them into future iterations of our Online Flashcard Maker, creating a more adaptive and feature-rich solution for our users.

V. Application Layout

Our application comprises several key components that provide users with a comprehensive set of features.

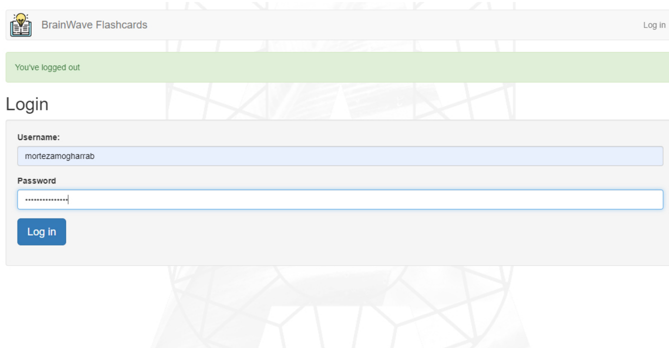

Fig. 1: The login page where users can enter the application by providing their username and password.

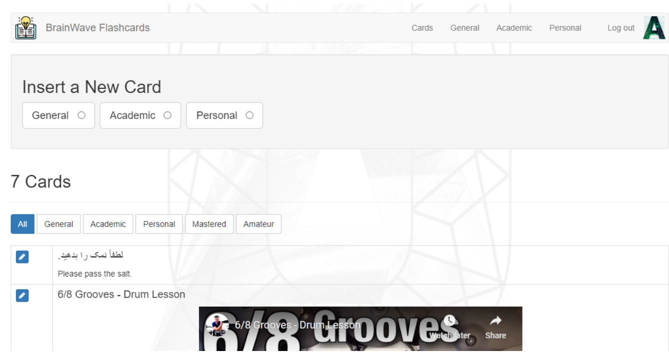

Fig. 2: The main page of the application, where users can add new cards, access their desired deck, start reviewing, and view all available cards based on tags (e.g., learned and unlearned flashcards).

VI. Team Work Contribution

In detailing the contributions of each team member, it's evident that the project progressed through several crucial stages, each requiring specific expertise and dedication. From the initial phase of research and planning, where the collective effort of the entire team solidified the project's foundation, to the subsequent phases of development, testing, and future planning, each member played a vital role in steering the project toward success. Below is a summarized table outlining the tasks, timeframes, and contributors for each stage of the project.

VII. Novel Aspects of the Project

This project focused on expanding our team's skillset by exploring technologies and tools like Docker and Flask (of which we had no prior knowledge) for building web

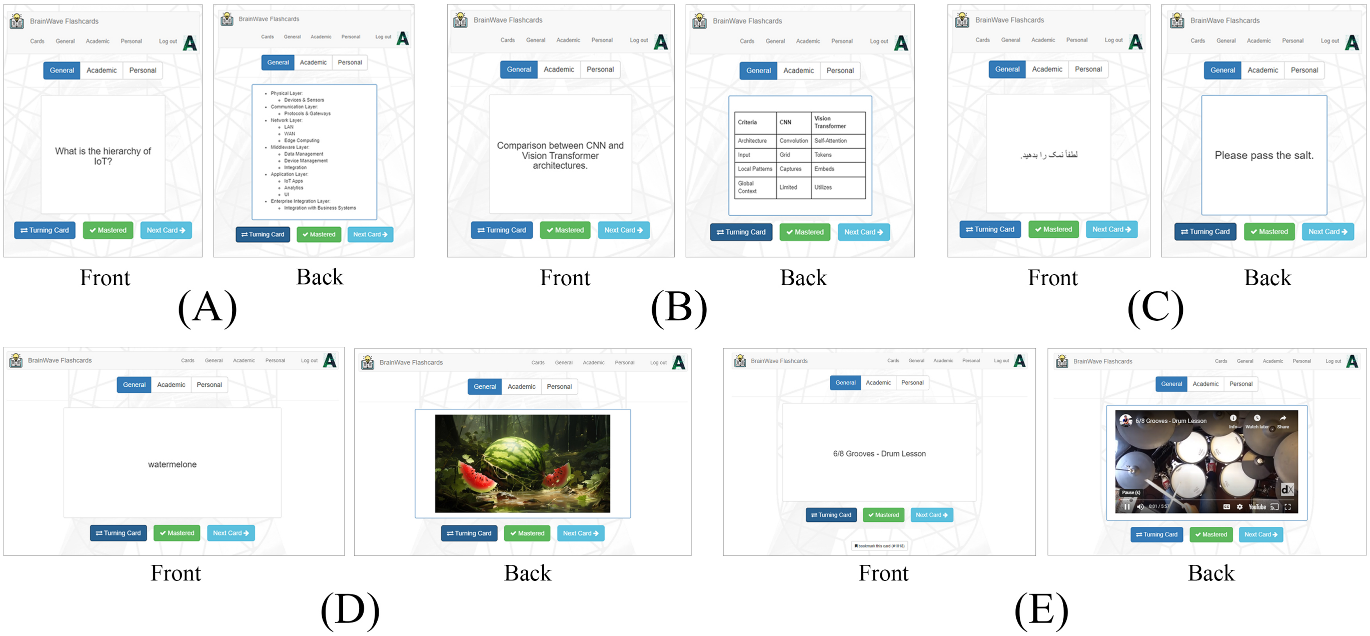

Fig. 3: Five different types of flashcards are supported in the application: Lists (A), Tables (B), Simple Text (C), Images (D), and Videos (E). The implementation of these features is based on compiling HTML code on the back side of the flashcards.

TABLE I: Task Time Allocation and Contributors

Task	Time Period	Contributors
Research and Planning	2 weeks	All team members
Front-End Development	3 weeks	Morteza, Ameer
Back-End Development	3 weeks	Nima, Morteza
Testing and Quality Assurance	1 week	Ameer
Searching for Future Work	1 week	All team members

applications. Through hands-on experimentation, we gained valuable experience in containerization and web framework development. For the novelty of our project, we conducted a comprehensive literature review to identify new approaches for developing intelligent applications with the potential to revolutionize future learning methods. The key details of this proposed approach are outlined in the 'Future Work' section.

VIII. Evaluation and Results

Our flashcard application has undergone a comprehensive evaluation process to ensure it meets the project goals and delivers a satisfactory user experience. The application has been thoroughly tested for accessibility based on WCAG 2.0 standards and accessibility checkers, with satisfactory results in areas such as color and contrast, and keyboard accessibility. This ensures the application is inclusive and usable for a wide range of users.

Additionally, a small-scale usability test [14, 17, 18] was conducted, providing valuable insights into user interactions. The feedback was positive, highlighting the app's intuitiveness, ease of navigation, and clarity of information, facilitating iterative improvements to enhance overall usability. Over 95% of users were able to complete specific actions like adding new flashcards and reviewing them in under a minute. Users also rated the app an average of 4.5 out of 5 on a Likert scale, demonstrating a high level of usability.

Regarding engagement metrics, the application has shown positive results, with users actively engaged and consistently returning to the application, indicating they find it valuable. Furthermore, user satisfaction metrics, measured through the Net Promoter Score (NPS) and Customer Satisfaction (CSAT) surveys, have been favorable, suggesting users are likely to recommend the application and are satisfied with its features and functionality. Any errors or bugs identified during the evaluation process have been promptly resolved to ensure a seamless user experience.

IX. Project Status

Overall, we reached our goals in developing the application for both the Front-End and Back-End components. However, due to our limited prior knowledge of the utilized technologies, such as handling the Back-End and Docker aspects, we encountered various challenges throughout the project. From the outset, our main objective was to work towards creating an intelligent, state-of-the-art application with the potential to revolutionize the education industry, considering recent leading AI companies that started discussing similar ideas in their public forums. However, as implementing such ideas is an ambitious goal that exceeds the scope of a single course, we are satisfied that we diligently searched the literature and identified potential solutions for developing such an application.

X. FUTURE WORK

The future work of this study involves expanding and refining our initial flashcard application into a comprehensive AI-driven platform. Our aim is to build upon the foundation laid here by integrating user preferences through interactive questioning, continuously updating content based on user feedback, and leveraging social media data for enhanced content generation. Key elements of this endeavor include developing a more powerful flashcard application, cloud-hosting the system, implementing Multimodal DualGNN and other recommender systems, incorporating PDF parsing techniques for tailored question generation, and devising a prompt-generation system to facilitate Text, Image, and Video generation through Generative-AI models [25, 26, 27]. Through these advancements, we aim to create an intelligent, data-driven application that revolutionizes personalized learning experiences. In the following sections, we will discuss the required steps and technologies for implementing our next step application from a high-level perspective.

A. Implementing the Core Application

The development of this application has the below main sections: Flashcard Creation and Customization, Spaced Repetition Algorithm, Study and Review Features, Synchronization and Cross-Platform Support, Reporting and Analytics, Customization and Extensibility, Community and Sharing, and Offline Availability

The initial step focuses on developing a user-friendly interface using HTML, CSS, and JavaScript, enabling users to input text, upload images, record audio, and insert diagrams or LaTeX equations. Image/audio processing libraries like Canvas API and Web Audio API ensure seamless multimedia integration. Functionalities for card layout customization and import features from various sources such as web pages and PDFs are incorporated, alongside a robust deck and subdeck management system for organizational efficiency. JavaScript, alongside data structures like trees and graphs, is utilized to implement the Leitner system and Mnemonic Major System in the Spaced Repetition Algorithm phase, dynamically adjusting review intervals based on user performance and difficulty. Study modes are created using JavaScript, DOM manipulation, and event handling, offering basic and cloze deletion options, with keyboard shortcuts and UI elements enhancing study efficiency. Utilizing web technologies and cloud storage APIs, a web-based platform (such as AnkiWeb) is developed for seamless sync across devices, complemented by mobile apps (such as AnkiDroid for Android, and Anki for iOS) featuring secure data synchronization. Data visualization libraries like D3.js and Chart.js, alongside custom reporting and analytics features, enable users to track learning trends and identify areas for improvement.

A modular architecture, leveraging plug-in frameworks and scripting languages, allows for customization and extensibility through custom add-ons and plugins. Web development technologies facilitate the creation of a community platform, enabling users to share decks, participate in discussions, and showcase their decks, with features integrated to encourage user engagement. Finally, an offline-first architecture ensures seamless operation of desktop software and mobile apps without an internet connection, optimizing application performance for offline usage and updating user progress and decks upon internet reconnection.

B. Creating a system to automatically generate questions and answers from a PDF book involves several steps

First, the text content is extracted from the PDF using a parsing library and preprocessed. This preprocessing involves tasks like segmenting sentences, tokenizing words, and recognizing named entities. Next, neural network-based models, such as Transformer architectures like BERT or GPT, are utilized to generate relevant questions from the text. These models are fine-tuned on question-answering datasets to learn question patterns and structure. The models analyze the text to identify key information and formulate questions answerable based on the content.

After question generation, similar neural network models are employed to extract the most relevant answer spans from the text for each generated question. These models scan the text to identify contextual information and extract appropriate answers. Confidence scores are assigned to the generated questions and answers based on the model's certainty, and those that do not meet a predefined confidence threshold are filtered out to ensure quality.

The generated questions are paired with their corresponding answers, and metadata such as page numbers or chapters from the original PDF book are attached to each pair. The pairs are indexed for efficient retrieval and future use. A user interface, either web-based or within a mobile app, is developed to allow users to access and interact with the generated question-answer pairs. The system is integrated with this interface, enabling users to search, browse, and study the content. Finally, mechanisms for user feedback are implemented to continuously improve the system's performance over time. Users can provide feedback on the quality and accuracy of the generated questions and answers, which is used to fine-tune the underlying AI models. This process harnesses natural language processing and generation techniques to create an interactive system that extracts relevant questions and answers from PDF book content, serving as a valuable educational or knowledge-sharing tool.

C. Implementing the Cloud infrastructure

In the grand scheme of implementing this complex AI-based application, cloud services play a pivotal role in ensuring scalability, reliability, and seamless integration of various components.

First and foremost, cloud computing platforms like AWS, Azure, or GCP are utilized to host the application's components. Cloud storage services such as AWS S3, Azure Blob Storage, or Google Cloud Storage are employed to store PDF books, user data, and generated content. Cloud-based databases like Amazon DynamoDB, Azure Cosmos DB, or

Google Cloud Datastore manage structured data such as user profiles and question-answer pairs.

The implementation of the Multimodal Dual GNN Recommender System, a critical component, involves leveraging cloud-based machine learning services such as AWS SageMaker or Azure Machine Learning for training and deployment. Integrating this recommender system with the application's user interface and content management system is also facilitated through cloud services. Various types of recommender systems are integrated to provide personalized recommendations, with cloud-based recommender system services simplifying the process.

To enable prompt-based interactions and content generation, integration with different API-based language models like OpenAI GPT is essential. This integration is made possible through cloud-based serverless functions, handling API calls and integrating language models into the application seamlessly. For PDF processing and question-answer generation, cloud-based document processing services such as AWS Textract or Azure Form Recognizer are utilized to extract text and metadata from PDF books. These capabilities are then integrated with question-answer generation models hosted on cloud-based machine-learning platforms.

Scalability and reliability are ensured through cloud autoscaling features, load balancing, and content delivery network services, which distribute resources and improve performance. Monitoring and logging services maintain the application's health and reliability, utilizing cloud-based tools like AWS CloudWatch or Azure Monitor. Security and compliance are paramount, with cloud-native security services like AWS IAM or Azure Security Center ensuring data encryption, network security, and access control. Compliance with regulations such as GDPR or HIPAA is maintained through cloud-based compliance solutions. Lastly, continuous integration and deployment are facilitated by cloud-based CI/CD pipelines and tools, automating the development, testing, and deployment processes. By harnessing the capabilities of cloud computing, this AI-based application can effectively handle user demands, adapt to changing requirements, and maintain high performance and availability.

D. Implementing the integration and prompt generation for generating AI-based contents

We discussed integrating our flashcard application with generative AI APIs across various modalities like text, video, and email generation. To achieve this, we need to develop a system that generates prompts based on user preferences, personalities, and characteristics, including age and gender. These prompts will be based on both the front and back sides of the flashcards, meaning questions and answers respectively. Subsequently, these prompts need to be fitted into AI generative models through APIs.

Here's a detailed breakdown of the steps involved: Firstly, we'll need to model and store flashcard data, including questions, answers, and metadata ((e.g., topic, difficulty level, user ratings)), in a cloud-based database. This database should be flexible to accommodate various content types such as text, images, audio, and video Next, we gather user information like age, gender, interests, and learning preferences to personalize the content generation process. This data is stored in user profiles and used to provide tailored flashcard recommendations. We then develop a robust prompt engineering system capable of generating prompts based on flashcard data and user preferences. This includes creating a library of predefined prompt templates (cases (e.g., text generation, image generation, video generation, email generation) customizable for different use cases and incorporating techniques like few-shot learning and prompt tuning.

Afterward, we research and evaluate different generative AI APIs ((e.g., OpenAI GPT, Anthropic Claude, Stability AI Dall-E, Google Imagen)) supporting desired content modalities. We then implement secure and scalable API integrations to access these capabilities within our application, ensuring optimization for performance and cost-effectiveness. Subsequently, we implement a content generation module that takes flashcard data and user preferences to generate content using the integrated generative AI APIs. Mechanisms are developed to ensure the generated content aligns with the flashcard context and user needs. To maintain content quality, we implement content curation workflows to review and validate generated content before presenting it to users. User feedback, ratings, and engagement metrics are leveraged to continuously improve the content generation process.

We then seamlessly integrate the generative AI-powered content creation system into the flashcard application's user interface and study workflows, ensuring a smooth and intuitive experience for users. Scalability and performance optimization are crucial, so we design the system architecture to scale efficiently as the user base and content volume grow. We optimize API integrations, prompt engineering, and content generation processes, leveraging cloud-based auto-scaling, load balancing, and caching mechanisms. Lastly, we implement feedback mechanisms to gather user insights and continuously refine the prompt engineering system, API integrations, and content generation algorithms. Regular monitoring and analysis of usage patterns, user engagement, and content performance help identify areas for improvement. By following these steps, we can seamlessly integrate a generative AI-based content creation system into our flashcard application, providing personalized and high-quality flashcard content to users.

E. Implementation of Multimodal DualGNN recommender system

The implementation of the Multimodal DualGNN recommender system for the flashcard maker application involves a comprehensive data collection and preprocessing stage. The system leverages both in-app user interactions and opt-in user surveys to gather valuable data on users' content preferences and learning styles. By tracking how users engage with different types of flashcard content, such as text, images, videos, and audio, the application can collect insights into their preferences. Additionally, the opt-in user surveys provide explicit information about the users' interests and other relevant factors. This data is then preprocessed to create the necessary inputs for the Multimodal DualGNN model, including processing user-item interactions, and item-item relationships, and extracting multimodal features from the flashcard content.

The core of the recommender system is the Multimodal DualGNN model, which combines the power of graph neural networks and multimodal learning. The model consists of several key components, including multimodal feature extraction modules to extract relevant features from the different content modalities, a dual graph construction process to build user-item and item-item graphs based on the collected data, and a multimodal fusion mechanism to combine the extracted features from the various modalities. The recommendation engine at the heart of the Multimodal DualGNN model then uses the learned representations and the constructed graphs to generate personalized recommendations for each user. This involves analyzing the user's preferences and learning styles, as well as the relationships between different flashcard content items, to identify the most relevant and effective content for that individual user.

To integrate the Multimodal DualGNN recommender system with the flashcard maker application, the system must be accessible through an API or integration layer. This allows the application to seamlessly send user data, such as user ID, content interactions, and preferences, to the recommender system and receive personalized recommendations in return. When a user interacts with the flashcard maker app, the relevant data is sent to the recommender system, which then uses the Multimodal DualGNN model to analyze the user's preferences and learning styles and generate personalized recommendations for flashcard content, such as images, videos, and audio. The recommended content is then integrated into the application, creating a seamless and personalized flashcard experience for the users.

To ensure the continued effectiveness of the Multimodal DualGNN recommender system, it is crucial to implement mechanisms for collecting user feedback and engagement data on the recommended flashcards. This feedback can be used to fine-tune and update the Multimodal DualGNN model, continuously improving the recommendations over time. Additionally, the performance of the recommender system should be regularly monitored, and updates or adjustments should be made as needed to optimize the user experience and learning outcomes. By establishing a robust feedback loop and continuous improvement process, the Multimodal DualGNN recommender system can remain highly effective and adaptive to the evolving needs and preferences of the users, providing them with the most relevant and impactful flashcard content to support their learning and growth.

XI. Conclusion

The BrainWave Flashcards application serves as a foundation for a more advanced, intelligent learning platform. While the current implementation provides a robust, user-friendly web-based flashcard creation and management system, the team has also explored and outlined future opportunities to further enhance the application's capabilities. The proposed future work involves integrating cutting-edge technologies such as generative AI models, multimodal dual general recommender systems, and cloud-based infrastructure, to revolutionize the way people learn and retain information. Though the implementation of this ambitious goal was not feasible within the scope of the current project, the team has laid the groundwork for developing a more adaptive and feature-rich solution that could ultimately transform the educational landscape. The comprehensive evaluation of the current application, including usability testing, accessibility checks, and engagement metrics, has demonstrated the strong foundation upon which the future intelligent learning application can be built.

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