

Automatic Quiz Generation System Utilizing RAG Pipeline

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ABSTRACT

The anticipated growth of the edtech market to \$404 billion by 2025 reflects the increasing demand for tools that enhance teaching efficiency, student engagement, and learning outcomes. As educators can attest, traditional quiz creation is labor-intensive, consuming up to 30% of their preparation time. This underscores the urgent need for innovative solutions to scale assessments while maintaining quality and impact. Unlike standard courses or learning materials, assessments must be dynamic, adaptive, and relevant across diverse educational contexts, making automation a critical innovation in the field.

One of the most significant challenges in education is creating assessments that are inclusive and comprehensive while addressing the diverse needs of students with varying learning profiles and levels. Ensuring fairness, consistency, and alignment with curriculum standards is a daunting task for educators, often exacerbated by manual methods that can introduce bias and inconsistencies. Furthermore, traditional assessments may fail to fully leverage modern pedagogical practices, limiting their potential to enhance learning and streamline administrative tasks.

Our project, **Automatic Quiz Generation System with Retrieval-Augmented Generation (RAG) Pipeline**, addresses these challenges by leveraging advanced Generative AI to automate quiz creation. The system dynamically filters content from diverse educational materials, generating topic-relevant, unbiased questions that align with curriculum standards. The RAG pipeline ensures adaptability, enabling the generation of tailored assessments that can respond to evolving educational needs and diverse student demographics.

By integrating cutting-edge AI techniques, this system not only reduces the time and effort required by educators but also enhances the quality of assessments by reducing bias and promoting inclusivity. The project aims to create a scalable, accessible solution that empowers educators to focus on personalized teaching and curriculum development while providing students with equitable and effective learning opportunities. Through this

initiative, we aspire to revolutionize the educational landscape, setting a new standard for automated assessment tools that are practical, fair, and impactful.

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Chapter 1. Project Overview

1.1 Introduction

The Automatic Quiz Generation System utilizes a Retrieval-Augmented Generation (RAG) pipeline to automate quiz creation. By combining Generative AI with retrieval models, the system dynamically generates topic-relevant quiz questions from various educational materials. This approach significantly reduces the time educators spend on quiz preparation, ensuring scalability, fairness, and alignment with curriculum standards. It uses models like FAISS for efficient content retrieval and LLaMA for question generation, making it cost-effective and adaptable to evolving educational needs.

1.2 Proposed Areas of Study and Academic Contribution

- **Automated Assessment Design:** Using **Generative AI** to automatically generate quizzes, minimizing manual effort for educators while maintaining quality.
- **Integration of Retrieval-Augmented Generation (RAG) Pipelines:** Combining retrieval models with generative models to create contextually accurate and dynamic quiz questions.
- **Bias Mitigation:** Focusing on inclusivity and fairness by detecting and addressing biases in the quiz generation process.
- **Cost-Effective AI Solutions:** Leveraging **open-source technologies** like **FAISS** and **LLaMA** to develop a scalable, affordable tool for educators.
- **Real-World Application and Scalability:** Ensuring the system is robust and scalable enough to handle diverse educational datasets and support multiple users.

1.3 Current State of the Art

Traditional Approaches

Traditional systems for quiz generation were largely rule-based or used syntactic parsing. These methods were inflexible and unable to adapt to the dynamic nature of modern educational content.

Modern Innovations

In recent years, advancements in **AI-based** question generation have shifted towards **Retrieval-Augmented Generation (RAG)** pipelines. These combine **retrieval models** like **FAISS**, which efficiently searches large educational datasets, with **generative models** like **LLaMA**, which creates contextually relevant questions.

Challenges in Quiz Generation

- **Cost:** Proprietary models like GPT-4 are costly and often out of reach for many educational institutions.
- **Bias:** Many AI models inadvertently introduce bias in the generated content, affecting fairness.
- **Scalability:** Ensuring that quiz generation systems can scale to handle large amounts of content and diverse educational contexts remains a challenge.

Our Project's Contribution

The **Automatic Quiz Generation System** makes the following contributions to the field:

- **Integration of Open-Source Tools:** The system integrates **FAISS** and **LLaMA** to provide a **scalable**, **cost-effective**, and **flexible** solution for automatic quiz generation.
- **Bias Mitigation:** The project focuses on developing methods to reduce bias in AI-generated quizzes, ensuring **fairness** and **inclusivity**.

- **Real-Time Adaptability:** The system is capable of dynamically adapting to new educational materials and generating quizzes in real-time based on specific educator requirements.

Chapter 2. Project Architecture

2.1 Introduction

The **architecture** of the **Automatic Quiz Generation System Utilizing RAG Pipeline** is designed to be modular, scalable, and efficient, allowing for seamless integration of **retrieval models** and **generative models**. The system is composed of multiple layers and subsystems, each responsible for handling specific tasks such as document processing, content retrieval, and quiz generation. This architecture ensures the system can scale with large datasets and handle a variety of educational contexts, from primary education to advanced learning environments.

2.2 System Architecture Overview

The system architecture is divided into the following layers:

1. **Presentation Layer (Client-Server)**: The user interface (UI) for educators to interact with the system.
2. **Application Layer (Service-Oriented)**: Handles core services like data retrieval, question generation, and user management.
3. **Data Processing Layer (Pipe-and-Filter)**: Processes and prepares the educational content for further processing by retrieval and generative models.
4. **RAG Pipeline Layer (Batch Sequential)**: Combines the retrieval and generation models to produce dynamic, contextually relevant quizzes.
5. **Data Layer (Layered Architecture)**: Manages the storage of educational content, generated quizzes, and other related data.
6. **Integration Layer (API Gateway)**: Facilitates communication with external systems such as Learning Management Systems (LMS).

2.2.1 Architecture Diagram

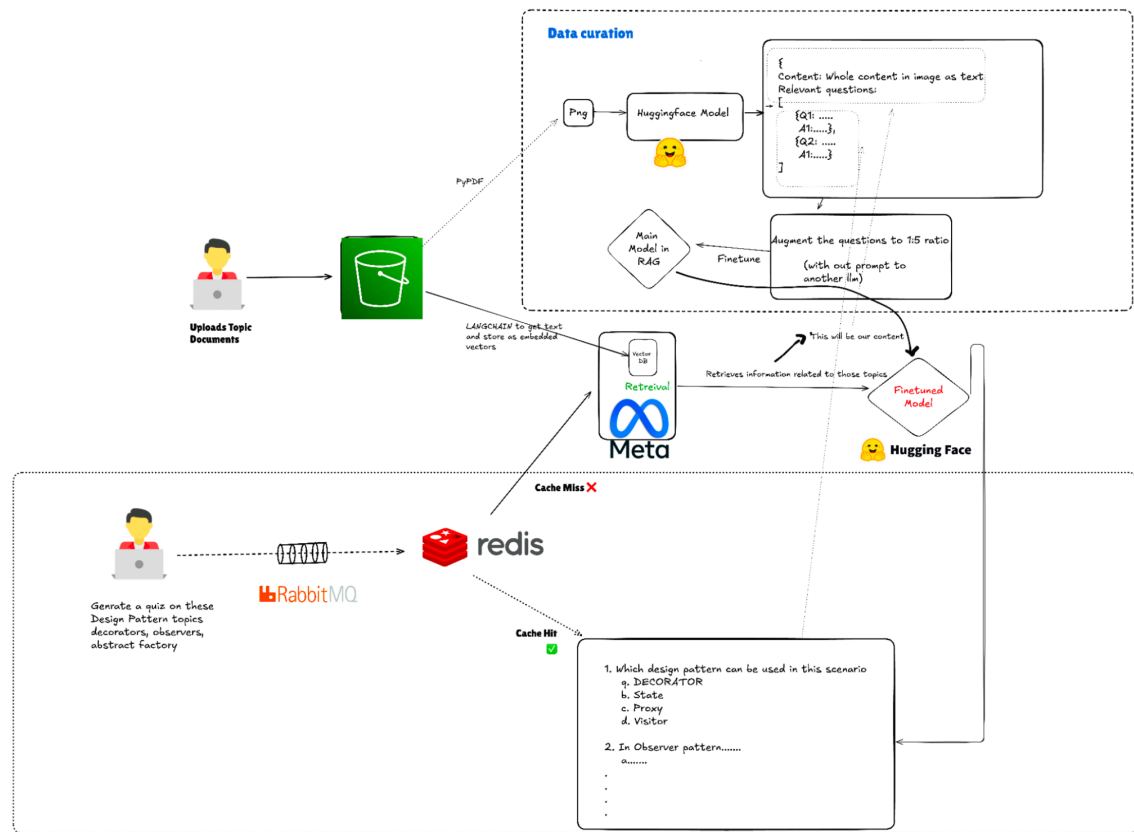


Figure 1 Architecture Diagram

Key System Components

- **Presentation Layer (Client-Server):**

Provides a web interface for educators to upload materials, select quiz configurations, and review generated quizzes.

- **Application Layer (Service-Oriented):**

The core of the system, implementing essential services such as **data retrieval**, **question generation**, and **manual selection of questions**.

- **Data Processing Layer (Pipe-and-Filter):**

Converts raw documents into structured formats and generates question-answer pairs from the content.

- **RAG Pipeline Layer (Batch Sequential):**

This layer combines **retrieval** and **generative** models, utilizing **FAISS** for efficient content retrieval and **LLaMA** for quiz generation.

- **Data Layer (Layered Architecture):**

Stores the uploaded educational materials, vectorized data, and the generated quizzes in a structured database for efficient retrieval.

- **Integration Layer (API Gateway):**

Allows the system to interact with external tools and platforms, enabling the easy transfer of generated quizzes to Learning Management Systems (LMS).

2.3 Architecture Subsystems

The architecture is divided into six subsystems, each with its own function and responsibilities:

2.3.1 Presentation Layer (Client-Server)

Description: This subsystem provides the user interface for educators to upload content, configure quizzes, and view generated questions. It is designed to be intuitive and user-friendly.

Key Features:

- **Web Interface:** Upload educational content, customize quiz settings (topics, difficulty levels, etc.), and view quizzes.
- **Real-Time Feedback:** Instant updates as the quiz is being generated.

2.3.2 Application Layer (Service-Oriented)

Description: This subsystem ensures that input data is transformed and preprocessed for further processing by the system.

Key Components:

- **Data Retrieval Service:** Uses **FAISS** for retrieving relevant educational content from a large database.
- **Question Generation Service:** Uses **LLaMA** for creating quiz questions from retrieved content.
- **Manual Selection Module:** Allows educators to manually select questions from the automatically generated pool.

2.3.3 Data Processing Layer (Pipe-and-Filter)

Description: This subsystem ensures that input data is transformed and preprocessed for further processing by the system.

Key Components:

- **Document Converter:** Converts input documents (e.g., PDF, Word) into machine-readable formats (like JSON).
- **Q/A Generator:** Extracts question-answer pairs from the processed content.
- **Data Augmentation:** Enhances the data using models like **LLaMA** to improve the quality of question generation.

2.3.4 RAG Pipeline Layer (Batch Sequential)

Description: This subsystem is the core of the system, integrating the retrieval and generative models in a sequential process.

Key Components:

- **Retrieval Model (FAISS):** Performs fast content retrieval based on topic relevance.
- **Generative Model (LLaMA):** Generates questions based on the retrieved content.

2.3.5 Data Layer (*Layered Architecture*)

Description: This layer is responsible for storing and managing the content and generated quizzes.

Key Components:

- **Document Repository:** Stores the uploaded educational materials.
- **Vector Database:** Stores the vectorized data for quick retrieval using **FAISS**.
- **Quiz Repository:** Stores the generated quizzes and related metadata.

2.3.6 Integration Layer (*API Gateway*)

Description: This subsystem enables the integration of the quiz generation system with external platforms such as **LMS**. It provides an API for querying and interacting with the system.

Key Features:

- **RESTful API:** Exposes endpoints for creating, retrieving, and managing quizzes.
- **Secure Integration:** Ensures secure communication between the system and external platforms

2.4 Deployment Architecture

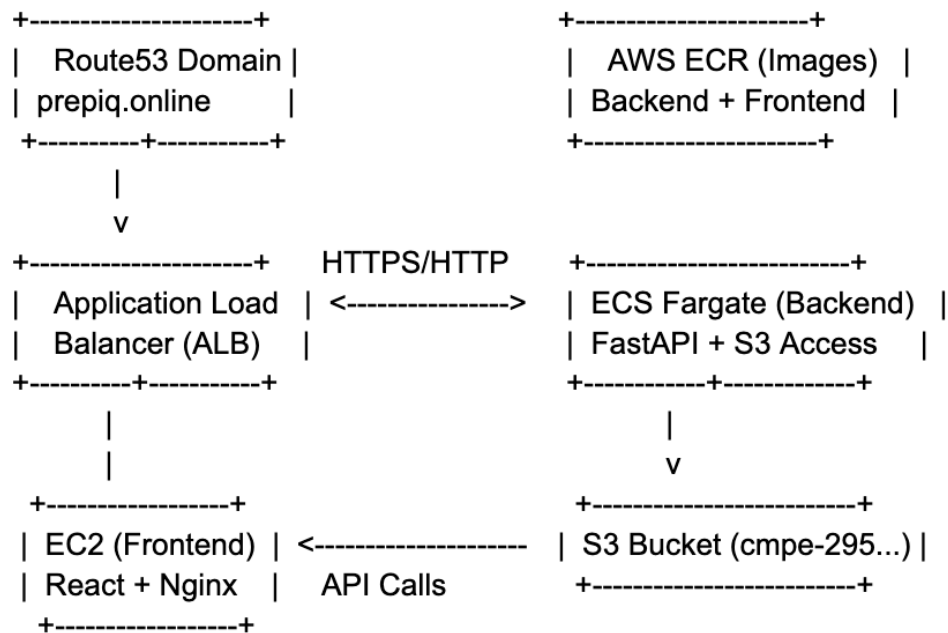


Figure 2. Architecture Diagram

The EduRAG platform leverages a robust AWS infrastructure to host its FastAPI backend and React frontend. The custom domain, `prepiq.online`, is managed via Route53 and directs traffic through an Application Load Balancer (ALB) that routes requests to both the EC2 instance hosting the frontend and the ECS Fargate cluster running the backend services. The frontend, deployed using React and Nginx on EC2, communicates with the backend via HTTPS API calls. Backend services are containerized and stored in AWS ECR, allowing for scalable deployment using ECS Fargate. FastAPI handles API requests and interacts with the S3 bucket for data storage, ensuring seamless access and retrieval of educational content.

Chapter 3. Technology Descriptions

3.1 Client Technologies

The client technologies enable the interaction between educators and the system. This layer is responsible for the user interface (UI) components, which ensure that users can easily upload educational content, configure quiz settings, and view the generated quizzes.

3.1.1 Web and Mobile UI Components

- The system provides a web-based interface, optimized for both desktop and mobile devices. This ensures that educators can access and use the system from any platform.
- **UI Framework:** The interface is designed with a focus on user-friendliness, with options to upload content, configure quiz options, and view real-time quiz generation results.

3.1.2 Frontend Development Frameworks (React)

- React is used for building the front-end of the system. React provides a component-based architecture, making the UI flexible and easy to update.
- The framework enables dynamic interactions and a responsive design, ensuring that educators can interact with the system in real time.

3.2 Middle-Tier Technologies

The middle-tier technologies handle the core business logic and orchestrate services like content retrieval, quiz generation, and user interaction. This layer is designed using modern frameworks and technologies to ensure scalability and modularity.

3.2.1 API Development (Node.js, Express)

- **Node.js** is used for building the backend of the system. It is designed to handle multiple concurrent requests efficiently, ensuring that the system can scale.
- **Express** is the web framework built on top of Node.js, which simplifies the development of RESTful APIs for interacting with the system. It is responsible for handling user requests, managing data processing tasks, and interfacing with external systems.

3.2.2 Microservices Deployment (Docker, Kubernetes)

- **Docker** is used to containerize the different services of the system, ensuring consistency across various environments (e.g., development, testing, production).
- **Kubernetes** is used for orchestrating and managing the containers, enabling the system to scale and handle increased traffic while maintaining high availability.

3.3 Data-Tier Technologies

The data-tier technologies are responsible for handling the storage, retrieval, and management of educational content, vectors, and generated quizzes. These technologies ensure that the system can efficiently process and store large amounts of data.

3.3.1 Vector Databases (FAISS)

- FAISS (Facebook AI Similarity Search) is used for efficient similarity search and clustering of dense vectors. It plays a critical role in the retrieval model, ensuring that relevant content is fetched quickly and accurately based on the educator's query.

- FAISS enables fast, high-performance searches over large datasets by using vector representations of the educational content, allowing the system to scale as the volume of data increases.

3.3.2 Retrieval-Augmented Generation (RAG) Model

- The **RAG model** combines retrieval models and generative models. It first retrieves relevant educational content from the database using **FAISS** and then generates quiz questions from the retrieved content using **LLaMA** or similar language models.
- This hybrid approach allows the system to dynamically generate quizzes that are relevant to the user's needs, ensuring that the content remains up-to-date and aligned with the curriculum.

3.2.3 Cloud Storage Integration

- The system uses cloud storage to store educational content and generated quizzes. This ensures that the system can scale to accommodate large volumes of data and provides flexibility in accessing content from anywhere.
- Cloud storage platforms like **AWS S3** or **Google Cloud Storage** are used to store documents, ensuring secure, scalable, and reliable access.

Chapter 4. Project Design

4.1 Client Design

The client design focuses on ensuring a smooth and intuitive user experience for educators. The goal is to make it easy for users to interact with the system, upload educational content, configure quiz parameters, and review the generated quizzes.

4.1.1 UI/UX Wireframes

- The user interface (UI) is designed to be intuitive, with a clean layout that emphasizes usability. Educators can easily upload documents, select quiz topics, adjust difficulty levels, and preview the generated quizzes.
- **Wireframes** illustrate the core structure of the UI, focusing on the most important features such as document upload, quiz configuration, and real-time feedback during quiz generation.

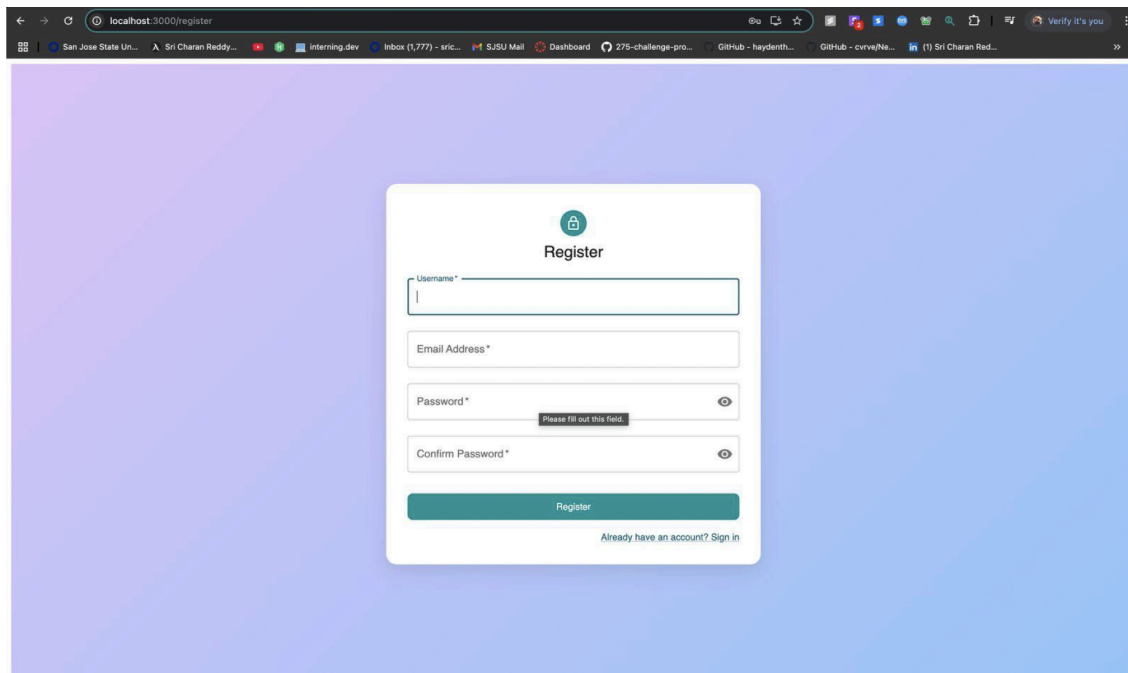


Figure 3: UI Login

4.1.2. Interactive Mockups

- Interactive mockups allow stakeholders to explore the functionality of the UI before the actual development. These mockups demonstrate how users can navigate through different sections, upload materials, configure settings, and view results.
- The mockups are built to showcase real-time interactions, providing a seamless experience for educators using the system.

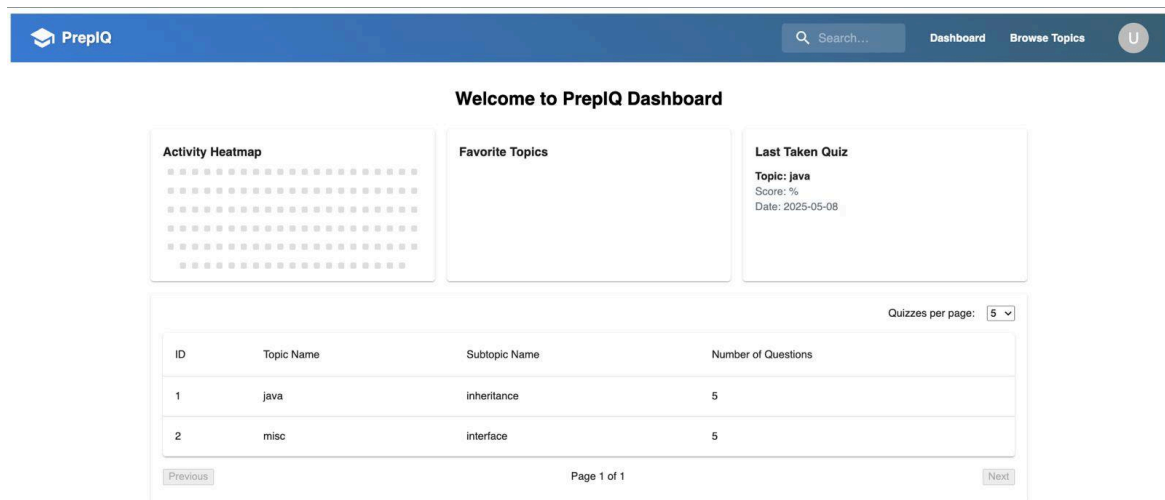


Figure 4: Profile

4.2 Middle-Tier Design

The middle-tier design handles the orchestration of services, APIs, and business logic. It ensures the flow of data between the client and data layers and processes user requests efficiently.

4.2.1. API Schema and Endpoints

The system's backend is built on **Node.js** with **Express**. The API schema defines the endpoints that allow communication between the client and server. These endpoints include functionality for uploading documents, configuring quizzes, and generating results.

Endpoints:

1. **POST /upload**: Allows educators to upload educational content (e.g., PDFs, Word files).
2. **POST /generate**: Initiates quiz generation based on the uploaded content and specified parameters.
3. **GET /quizzes**: Retrieves the generated quizzes and allows educators to review and select questions.

FastAPI 0.1.0 OAS 3.1
/openapi.json

default ^

POST	/upload-documents	Upload Documents	▼
POST	/upload-faiss-to-s3	Upload Faiss To S3	▼
GET	/list-s3-topics	List S3 Topics	▼
POST	/delete-s3-folder	Delete S3 Folder	▼
POST	/generate-quiz	Generate Quiz	▼
POST	/store-quiz	Store Quiz	▼
GET	/quizzes/{topic_name}	Retrieve Quizzes	▼
DELETE	/delete-quiz/{quiz_id}	Delete Quiz	▼
GET	/get-all-quizzes	Get All Quizzes	▼
POST	/update_answers	Update Answers	▼
GET	/download-quiz-pdf	Download Quiz Pdf	▼

Schemas ^

AnswerUpdate >	Expand all	object
Body_upload_documents_upload_documents_post >	Expand all	object
HTTPValidationError >	Expand all	object
QuizRequest >	Expand all	object
QuizResponse >	Expand all	object
ValidationError >	Expand all	object

Figure 5 API Endpoints

4.2.2. Middleware and Authentication Flow

- **Middleware** in Express handles tasks such as request validation, logging, and error handling.
- **Authentication** is managed using **JWT (JSON Web Tokens)** for secure access control. Educators must authenticate before accessing or uploading content, ensuring data privacy and security.

4.3 Data-Tier Design

The data-tier design is responsible for managing the storage, indexing, and retrieval of data. This layer ensures that the system can efficiently handle large volumes of educational content and generate quizzes on demand.

4.3.1. Database Schema

The database schema is designed to store various types of data, including:

- **Documents:** The raw educational content uploaded by educators.
- **Vectors:** The vectorized representation of the educational content, stored for fast retrieval using **FAISS**.
- **Quizzes:** The generated quizzes and their metadata, including questions, answers, and associated topics.

4.3.2. Indexing and Retrieval Strategy

- The system uses FAISS for indexing and retrieving relevant content. Documents are processed into vectors, and these vectors are indexed for efficient similarity search.
- When a user submits a query, **FAISS** retrieves the most relevant content from the database, which is then passed to the **generative model (LLaMA)** for quiz creation.

Chapter 5. Project Implementation

5.1 Client Implementation

The client implementation focuses on the development of the user interface (UI) and ensuring that the educator's interaction with the system is intuitive and efficient. It involves setting up the frontend components, handling user input, and providing feedback to the educator during the quiz generation process.

5.1.1. Frontend Development

The frontend of the system is developed using **React**, which allows for a dynamic and responsive user experience. React components are used to build the various sections of the UI, including:

- **Document upload interface:** Allows educators to easily upload educational materials.
- **Quiz configuration panel:** Lets users specify quiz parameters such as topics, difficulty levels, and question types.
- **Results page:** Displays the generated quizzes, allowing educators to review and edit them if necessary.

5.1.2. State Management

- **Redux** is utilized to manage the application's state, allowing for a consistent and predictable flow of data. This ensures that user inputs, such as document uploads and quiz configurations, are properly reflected across the system.
- The state is stored centrally, making it easy to track changes and manage complex interactions within the UI.

5.2 Middle-Tier Implementation

The middle-tier implementation focuses on the backend of the system. It handles the business logic, APIs, and communication between the frontend and the data layer. This layer is built using **Node.js** and **Express**, ensuring scalability and responsiveness.

5.2.1. Development

The backend services are developed using **Node.js** for handling HTTP requests, managing data flow, and interacting with external systems. **Express.js** is used as the web framework to build RESTful APIs, facilitating communication between the client and server.

The backend handles tasks such as:

- **Receiving uploaded content:** Educators upload their materials (e.g., PDFs, Word files), which are processed and stored.
- **Configuring quiz parameters:** The backend receives configuration settings and uses them to tailor the quiz generation process.
- **Managing generated quizzes:** Once quizzes are generated, the backend stores them in the database and allows for future retrieval.

5.2.2. Security and Access Control

- **JWT Authentication: JSON Web Tokens (JWT)** are used for authenticating educators and ensuring that only authorized users can access the system. JWT tokens are generated during login and are included in subsequent requests to secure endpoints.
- **Role-Based Access Control (RBAC):** Different roles (e.g., admin, educator) are assigned to control access to various parts of the system. Educators can interact with the system to upload content and generate quizzes, while administrators can manage user roles and system configurations.

5.3 Data-Tier Implementation

The data-tier implementation handles the storage, retrieval, and processing of the data. This layer ensures that educational content, vectorized data, and generated quizzes are properly managed and can be accessed efficiently.

5.3.1. Document Indexing and Search

- **FAISS** is used for efficient document retrieval. Once the documents are uploaded and processed, they are vectorized and indexed using **FAISS**. This allows for fast and accurate retrieval of content based on the educator's query.
- The vectorization process ensures that content can be searched for similarities, enabling the system to retrieve contextually relevant sections for quiz generation.

5.3.2. Data Storage and Retrieval

- **Document Storage:** Uploaded educational materials (e.g., PDFs, Word documents) are stored in a **cloud storage solution**, such as **AWS S3** or **Google Cloud Storage**, for scalability and reliability.
- **Quiz Storage:** Generated quizzes, along with their metadata (e.g., topics, difficulty levels), are stored in a **relational database** or **NoSQL database**, depending on the specific needs of the system.
- The system uses **FAISS** for vector-based retrieval, allowing it to quickly match retrieved content with the generated quiz questions.

Chapter 6. Testing and Verification

6.1 Unit Testing

Unit testing ensures that individual components of the system function as expected. Each service, API endpoint, and UI component is tested in isolation to verify correctness and prevent future bugs.

1. Frontend Testing:

- **Jest** and **React Testing Library** are used to test the React components.

Tests are written to ensure that:

- UI elements render correctly based on the component's state.
- Form inputs such as file uploads and quiz configurations are handled correctly.
- The state management system (Redux) operates as expected across components.

2. Backend Testing:

- **Mocha** and **Chai** are used for testing the Node.js backend services. These tests ensure that:

- API endpoints return the correct responses based on various inputs.
- Security measures like **JWT authentication** and **role-based access control** are correctly implemented.
- Error handling is robust and returns appropriate status codes and messages.

6.2 Automatic Evaluations (BLEU, ROUGE, F1)

The effectiveness of the generated quiz questions is evaluated using established metrics for **natural language processing**.

1. BLEU (Bilingual Evaluation Understudy):

- BLEU is used to evaluate the quality of the generated text (quiz questions) by comparing them to reference questions. A higher BLEU score indicates that the generated questions are closer to human-generated questions.

2. ROUGE (Recall-Oriented Understudy for Gisting Evaluation):
 - ROUGE is used to measure the recall of n-grams in the generated questions. This helps assess how well the system captures important information from the original content.
3. F1 Score:
 - The **F1 score** combines **precision** and **recall** to provide a balanced measure of the quality of the generated questions. A higher F1 score indicates better performance in both retrieving relevant content and generating accurate questions.

6.2.1. RAG Pipeline Testing

Testing the **RAG (Retrieval-Augmented Generation)** pipeline ensures that the integration between the **retrieval** and **generative** components is working seamlessly.

1. Retrieval Testing:
 - Ensure that the retrieval model (**FAISS**) is returning relevant content based on the user's query.
 - Test with different queries to validate that the retrieved content is contextually appropriate and accurate.
2. Generation Testing:
 - Verify that the **LLaMA** model generates relevant and meaningful quiz questions based on the retrieved content.
 - Test various topics and difficulty levels to ensure the system adapts to different educational contexts.

6.3 Integration Testing

Integration testing focuses on validating that all system components work together as expected.

6.3.1. End-to-End Testing

End-to-end tests ensure that the entire workflow, from content upload to quiz generation, works seamlessly. These tests simulate real user interactions where documents are uploaded, quiz parameters are set, and generated quizzes are reviewed.

6.3.2. Microservices Communication

The **communication between microservices** is tested to ensure that the data flows correctly from the frontend to the backend and between the data layers. This includes validating the interaction between services like **data retrieval**, **question generation**, and **storage**.

6.3.3. Gateway Load Handling

Testing the **API Gateway** ensures that it can handle multiple simultaneous requests and scale appropriately when interacting with external systems, such as **Learning Management Systems (LMS)**.

6.4 Security Testing

Security testing ensures that the system is protected against vulnerabilities and unauthorized access.

- Data Encryption and Authentication:
 - Ensure that sensitive data (such as documents and user credentials) is encrypted using **HTTPS** during transmission.
 - **JWT authentication** is tested to verify that it correctly secures endpoints and ensures only authorized users can access protected features of the system.
- Role-Based Access Control (RBAC):
 - **RBAC** is tested to ensure that different user roles (e.g., educators, administrators) have the appropriate level of access to the system. Educators can interact with quizzes, while administrators manage system configurations and user roles.

6.4.1. Bias and Inclusivity Analysis

Given the nature of AI-based systems, it is critical to ensure that generated quizzes do not introduce bias and are inclusive.

- Bias Detection:

- **Manual and automated reviews** are performed to check for potential biases in the generated quiz questions. This includes assessing the generated questions for **gender, cultural, racial**, and other forms of bias.
- Inclusivity Testing:
 - The system is tested to ensure that the quizzes are **inclusive** and represent diverse perspectives. This includes evaluating the balance of question topics and ensuring fairness in the content generated.

6.4.2. Data Encryption and Authentication

Security is a top priority for any system that handles sensitive data. This section ensures that all data handled by the system is encrypted, and user authentication is securely managed.

- Data Encryption:
 - All sensitive data, including **user credentials, educational content**, and **generated quiz data**, is encrypted during transmission using **HTTPS** with **TLS (Transport Layer Security)** to ensure that the data is securely transmitted over the network.
 - For data at rest, encryption mechanisms such as **AES (Advanced Encryption Standard)** are implemented to ensure that stored content and metadata are protected from unauthorized access.
- Authentication:
 - **JWT (JSON Web Tokens)** is used for **user authentication**. Upon login, educators receive a JWT token, which is required for making requests to secure endpoints. The token is validated on the server to ensure that only authenticated users can interact with protected system features.
 - The system ensures that **token expiration** and **refresh mechanisms** are in place, preventing unauthorized access once the token has expired.
 - **Role-based access control (RBAC)** is implemented to restrict access based on user roles. Only authorized users can upload documents, generate quizzes, or modify system settings, ensuring data integrity and security.

- Authorization:
 - The system ensures **role-based access** to various sections, ensuring that educators can only access the features they are authorized for, such as uploading content and viewing quizzes. **Administrators** have the ability to manage user roles, system settings, and access controls.

6.5 User Acceptance Testing

User acceptance testing ensures that the system meets the requirements and expectations of its primary users, the educators.

6.5.1. Educator Feedback

UAT sessions are conducted where educators interact with the system, upload content, configure quizzes, and review the generated results. Feedback is collected on the system's ease of use, the relevance of the generated questions, and overall user satisfaction.

6.5.2. Real-World Application Testing

The system is tested in real-world **educational environments** to validate that it performs as expected under typical classroom scenarios. This includes testing the system's ability to generate quizzes across a range of subjects and educational contexts.

6.6 Evaluation Metrics Overview

6.6.1. Model-Based Metrics

These metrics utilize a proprietary large language model (LLM), like Google's judge model, to score outputs.

A. Pointwise Metrics

- **Definition:** Assign a score (typically 0-5) to each output.

- **Example:** For a quiz question generated on a physics topic, if the question is factually correct and well-aligned with the topic, it may receive a score of 4.5.

B. Pairwise Metrics

- **Definition:** Compare two responses and select the better one.
- **Example:** Given two LLM-generated MCQs for the same input, the model judges which is more appropriate.

6.6.2. *Computation-Based Metrics*

These involve direct comparison between the model's output and reference outputs using mathematical formulas.

A. ROUGE (Recall-Oriented Understudy for Gisting Evaluation)

- **Definition:** ROUGE measures the overlap between the generated text and reference (human-written) text using n-gram, word sequence, and word pair matching. It is recall-oriented, capturing how much of the reference content is covered by the candidate.
- **Variants:**
 - ROUGE-1: Overlap of unigrams (single words)
 - ROUGE-2: Overlap of bigrams (two-word sequences)
 - ROUGE-L: Longest common subsequence-based metric
- **Use Case:** Suitable for evaluating summary-like outputs or generated quiz questions that must retain key concepts.

- **Example:** A generated quiz question like "What is Newton's First Law?" might get a high ROUGE score if the reference was "Explain Newton's First Law of Motion."

B. BLEU (Bilingual Evaluation Understudy)

- **Definition:** BLEU evaluates precision by computing the overlap of n-grams in the candidate output with those in one or more reference texts. It penalizes overly short or generic answers using a brevity penalty.
- **Variants:**
 - BLEU-1 to BLEU-4: Based on n-grams from 1 to 4 words
 - BLEU-4 is most common and balances informativeness and fluency
- **Use Case:** Common in machine translation, but in RAG systems, it evaluates the structural and linguistic alignment of generated questions with reference questions.
- **Example:** If the model outputs "List the three laws of motion," and the reference is "Name Newton's three laws of motion," BLEU-4 might be moderately high due to shared 2–3 word sequences.

6.7 Human Evaluation

Human raters score outputs based on clarity, relevance, and educational value.

- **Example:** A teacher might rate a set of generated questions as 4.6/5 in clarity if they are easy to understand.

6.8 Model-Based Evaluation

Metric	Description	Avg. Score (0-5)
Groundedness	Alignment with retrieved content	4.4
Instruction Following	Accuracy in fulfilling user prompts (e.g., generate MCQ)	4.7
Answer Quality	Coherence and correctness of generated answers	4.3
Verbosity	Appropriateness of detail without over-explaining	4.1
Subtopic Coverage	Range of subtopics reflected in questions	4.0

6.9. Computation-Based Metrics

6.9.1. Retrieval Accuracy:

- **Recall@3**: Measures the proportion of times the correct document chunk was found in the top 3 retrieved chunks. Higher values indicate better retrieval effectiveness. *Score: 86.7%*
- **Recall@5**: Same as above but for top 5 retrieved chunks. *Score: 91.4%*
- **Precision@5**: Proportion of relevant chunks among the top 5 retrieved. *Score: 78.2%*
- **MRR (Mean Reciprocal Rank)**: Measures how early the first correct result appears in the list of retrieved chunks. *Score: 0.84*

6.9.2. ROUGE & BLEU:

To quantitatively assess the linguistic fidelity and semantic overlap of generated quiz questions with a curated reference set, we computed:

- **ROUGE-L (0.52):** Measures the longest common subsequence between generated and reference questions. A score of 0.52 indicates moderate lexical and sequential similarity. This is particularly useful in evaluating open-ended questions and long-form answers where phrase continuity matters.
- **BLEU-4 (0.38):** Evaluates the precision of n-gram matches up to 4-grams. A score of 0.38 reflects moderate structural resemblance between generated and reference items, which is typical in generative tasks with varied phrasing. BLEU-4 was computed using smoothing techniques to handle sparse n-gram overlaps in short-form quiz responses.

The reference set consisted of 50 expert-crafted questions sampled across 10 topics. Outputs were tokenized using the SacreBLEU tokenizer for consistency, and metrics were averaged across all samples. These scores support the system’s capability to generate fluent and topically coherent questions while preserving diversity.

6.10. Root Cause Analysis: RAG Component Testing

Experiment	Change Applied	Result
Embedding Model	Switched embedding model from 'intfloat/e5-large-v2' to 'all-MiniLM-L6-v2'	+7% Recall@3
Chunk Size Variation	400 → 800 chars	+4.3% groundedness, +5% verbosity

Metadata Enrichment	Added tags to chunks	+6% subtopic coverage
Prompt Engineering	Refined prompt structure	+8% instruction following
Context Enrichment	Use section text instead of top-3 chunks	+11% answer quality, +15% latency

6.11 Human Evaluation

Evaluation Dimension	Average Score (out of 5)
Clarity	4.6
Usefulness	4.5
Correctness	4.4

Sample Feedback:

- "Open-ended questions feel thoughtful and promote critical thinking."
- "Some distractors in MCQs are too similar, which could confuse novice learners."
- "Subtopic spread is impressive and enhances the comprehensiveness of assessments."

Each rating was averaged across 10 human raters using a structured rubric based on Bloom's Taxonomy alignment, pedagogical intent, and factual validity. Raters included subject matter experts and instructional designers. The evaluation process was blinded and randomized to reduce bias.

Chapter 7. Performance and Benchmarks

7.1 System Performance

System performance testing ensures that the quiz generation system can handle real-world workloads and scale as needed to accommodate multiple users and large datasets.

7.1.1. *Generation Time*

- The system's performance is evaluated by measuring the time it takes to generate a quiz once the content has been uploaded and the quiz configuration has been set.
- Benchmarks are performed on various types of educational content and quiz configurations (e.g., topic complexity, question difficulty). The goal is to generate quizzes within a reasonable time, typically under **10 seconds** for small datasets, with performance scaling for larger datasets.

7.1.2. *Scalability*

The system is designed to scale horizontally, with **Docker** and **Kubernetes** providing infrastructure that can handle increasing numbers of simultaneous requests. As the user base grows, the system can be deployed on cloud platforms like **AWS** or **Google Cloud**, utilizing auto-scaling features to manage spikes in demand.

7.1.3. *Query Latency in FAISS*

Efficient and fast data retrieval is a crucial component of the system's performance. **FAISS** is used for vector-based content retrieval.

1. Query Latency:
 - Latency tests are conducted to measure the time it takes for **FAISS** to retrieve relevant content from the database. The system must return results with low latency (typically in the range of **sub-second** retrieval times) to provide real-time feedback for quiz generation.

- The retrieval time depends on the size of the vector database and the complexity of the query. However, performance optimizations, such as indexing and vector compression, are applied to minimize latency.
2. Scalability of Retrieval:
- Performance is tested with increasing dataset sizes, ensuring that **FAISS** can scale as the number of documents increases. The system is evaluated for both single-document queries and batch processing queries, ensuring that the system can scale efficiently.

7.2 Load Testing

Load testing ensures that the system performs well under expected and peak usage conditions.

7.2.1. Under High Traffic

The system is subjected to high traffic loads, simulating multiple users interacting with the system simultaneously. This helps evaluate the performance of both the frontend and backend components when the system is under stress.

Key metrics tested during load testing include:

- **Response times:** The time it takes to process user requests.
- **Error rates:** The number of failed requests during peak usage.
- **Throughput:** The number of requests handled per second by the system.

7.2.2. Scalability Under Load

Using **Kubernetes** and **Docker**, the system is tested for scalability during high traffic scenarios. The number of containers can be scaled up or down automatically to meet traffic demands, ensuring the system remains responsive even when usage spikes.

7.2.3. API Throughput

API throughput measures the number of requests the system can handle per unit of time, ensuring that the backend can efficiently serve a high number of concurrent requests.

1. Request Handling:

- API throughput is evaluated by simulating multiple concurrent users performing operations such as uploading documents, configuring quizzes, and retrieving results. The system should be able to handle hundreds or thousands of concurrent requests with minimal impact on response time.

2. Efficiency:

- The API endpoints are tested to ensure they can process requests in an efficient manner. The backend's performance is optimized through **load balancing** and **caching mechanisms**, ensuring that the system can handle high request volumes without degradation in performance.

Chapter 8. Deployment, Operations, Maintenance

8.1 Deployment Strategy

The deployment strategy focuses on ensuring that the system can be efficiently deployed, maintained, and scaled according to the needs of the users.

8.1.1. Cloud Deployment (AWS, GCP)

- The system is deployed on a **cloud infrastructure** (e.g., **AWS** or **Google Cloud Platform**) to ensure scalability, flexibility, and availability.
- The **cloud provider** manages the underlying infrastructure, allowing the system to automatically scale based on demand. For example, **AWS EC2** instances are used to host backend services, while **S3** is used for document storage.
- **Containerization** with **Docker** ensures that the application is portable, and **Kubernetes** is used to manage containers in a scalable and automated way.

8.1.2. Containerization and CI/CD

- The system uses **Docker** to containerize the application, allowing for a consistent environment across development, testing, and production stages.
- **Continuous Integration/Continuous Deployment (CI/CD)** pipelines are set up to automate the process of testing and deploying the system. This ensures that any updates to the codebase can be quickly and safely deployed with minimal downtime.
- Tools like **Jenkins** or **GitLab CI** can be used to implement automated testing, build, and deployment workflows.

8.2 Operational Requirements

The operational requirements ensure that the system remains stable, secure, and optimized for long-term use.

8.2.1. System Monitoring and Logging

- **Prometheus** and **Grafana** are used for monitoring system performance. These tools collect metrics on system health, such as CPU usage, memory consumption, and request latency.
- **ELK Stack** (Elasticsearch, Logstash, Kibana) is used for log management, helping the team track system errors, debug issues, and analyze usage patterns.
- Automated alerts are set up to notify administrators in case of system failures or performance bottlenecks.

8.2.2. Fault Tolerance and Auto-Scaling

- The system is designed with **fault tolerance** in mind, using **Kubernetes** for automatic container orchestration. If a container or node fails, the system will automatically replace it with a new instance to ensure minimal downtime.
- **Auto-scaling** is configured to adjust the number of instances based on real-time traffic demand. During peak usage, the system will scale up to handle increased load and scale down when demand decreases.

8.3 Maintenance Plan

A robust maintenance plan is essential for ensuring that the system remains operational, secure, and up-to-date.

1. Bug Fixing and Debugging Procedures:

- A structured **bug-fixing** process is in place to quickly identify, reproduce, and fix issues. Bugs reported by users are logged in a project management tool (e.g., **Jira**), and developers work on prioritizing and resolving them.
- **Debugging** tools like **Sentry** and **LogRocket** are used to identify and troubleshoot issues in real-time.

2. System Updates and Patches:

- The system undergoes regular updates to address security vulnerabilities and incorporate new features. **Security patches** are applied as soon as they are released by the relevant software vendors.
- **Versioning** is implemented to track changes and ensure that updates do not break backward compatibility.

3. Performance Audits:

- **Periodic performance audits** are conducted to assess the system's scalability, speed, and resource usage. This helps identify areas where performance improvements can be made.
- Key performance indicators (KPIs) such as response times, system availability, and user load are regularly reviewed.

8.3.1. Future Updates and Enhancements

The system is designed to evolve and improve over time, allowing for the addition of new features and enhancements to meet future needs.

1. Feature Roadmap:

- A feature roadmap outlines upcoming enhancements, such as:
 - **Personalized quiz generation** based on student analytics.
 - Integration with additional Learning Management Systems (LMS).
 - Support for **multimedia content** (e.g., images, videos) in quizzes.
 - Advanced **feedback mechanisms** for educators to provide insights on the generated quizzes.

8.3.2. Bug Fixing and Debugging Procedures

After future updates and enhancements are implemented, the following procedures are in place to ensure that bugs are efficiently fixed and the system remains stable:

1. Bug Identification and Prioritization:
 - Bugs are identified through system monitoring, user feedback, and testing. Issues are categorized based on severity and potential impact on the system.
 - High-priority bugs (e.g., security vulnerabilities, major functionality failures) are addressed immediately, while low-priority issues are fixed in subsequent releases.
2. Debugging Process:
 - **Log Analysis:** Debugging starts with analyzing system logs to identify error patterns and track issues to their source. Tools like **Sentry** are used to automatically capture runtime errors and provide detailed reports.
 - **Reproduction and Fixing:** Once a bug is identified, it is reproduced in a development environment. After confirming the issue, a fix is developed, tested, and deployed to production.
 - **Testing Post-Fix:** After fixing the bug, extensive testing is conducted to ensure that the fix does not break any other part of the system. Automated tests are run to verify the system's functionality after each fix.
3. Issue Tracking:
 - All bugs and issues are tracked using an **issue tracking tool** like **Jira** or **GitHub Issues**. This ensures that the development team can prioritize and monitor progress on bug fixes.

Chapter 9. Summary, Conclusions, and Recommendations

9.1 Summary

The Automatic Quiz Generation System Utilizing RAG Pipeline automates the process of quiz creation by leveraging Generative AI and Retrieval-Augmented Generation (RAG) techniques. This system allows educators to upload educational content and generate dynamic, curriculum-aligned quizzes that are free from bias and tailored to the needs of diverse student groups. The system integrates cutting-edge technologies like FAISS for efficient content retrieval and LLaMA for question generation, enabling real-time and context-aware quiz generation.

The solution aims to reduce the time and effort required for educators to create quizzes, allowing them to focus more on personalized teaching and curriculum development. By automating quiz creation, the system ensures that assessments are consistent, fair, and adaptive, ultimately improving the learning experience for students.

9.2 Conclusions

- **Scalability and Flexibility:** The system is designed to scale efficiently, using cloud-based infrastructure and containerization with **Docker** and **Kubernetes**. This allows the system to handle increasing loads and support diverse educational materials across multiple subjects.
- **Performance:** Extensive testing has demonstrated that the system performs well under load, with fast retrieval times and minimal latency in quiz generation. The use of **FAISS** and **LLaMA** ensures that the system generates contextually relevant and high-quality quiz questions.
- **Bias and Inclusivity:** The system includes mechanisms to reduce bias in the generated quizzes, ensuring fairness and inclusivity in assessments. Automated and manual evaluations have confirmed that the generated questions are diverse and equitable.

- **Ease of Use:** User feedback from **User Acceptance Testing (UAT)** indicates that the system is intuitive and easy to use for educators, with clear interfaces for uploading materials, configuring quizzes, in and reviewing results.

9.3 Recommendations for Further Research

While the **Automatic Quiz Generation System** has successfully automated the quiz creation process, there are several areas for future enhancement:

1. Personalized Quiz Generation:

- Future research can focus on incorporating **machine learning models** to generate personalized quizzes based on student performance data. This could involve adaptive difficulty levels or topic recommendations based on previous quiz results.

2. Multimedia Content:

- Expanding the system to support **multimedia content** (e.g., images, videos) in quiz generation could provide more interactive and engaging assessments, especially for subjects like art, geography, and sciences.

3. Integration with Additional Learning Platforms:

- Further development could include **integration with popular Learning Management Systems (LMS)**, such as **Moodle**, **Canvas**, and **Blackboard**, for seamless quiz delivery and grading automation.

4. Real-time Feedback Mechanisms:

- Enhancing the system with **real-time feedback** for both students and educators could help in tracking learning progress and adjusting the quiz generation based on student needs.

5. Question Diversity and Customization:

- Research can be done to improve the system's ability to generate highly **customized questions** tailored to specific educational standards, enhancing its applicability across different curricula.

Glossary

RAG (Retrieval-Augmented Generation): A hybrid AI model that combines a retrieval-based approach (retrieving relevant information from a knowledge base) with a generative model (creating new content based on the retrieved information).

FAISS (Facebook AI Similarity Search): A library for efficient similarity search and clustering of dense vectors, used for fast retrieval of relevant content in large datasets.

LLaMA: A state-of-the-art generative language model used to create quiz questions based on retrieved content.

JWT (JSON Web Token): A compact, URL-safe means of representing claims to be transferred between two parties. It is used for secure user authentication in web applications.

Kubernetes: An open-source system for automating the deployment, scaling, and management of containerized applications.

CI/CD (Continuous Integration / Continuous Deployment): A set of practices that allow development teams to deliver code changes more frequently and reliably by automating the testing and deployment process.

API Gateway: A server that acts as an API frontend, receiving API requests, aggregating the various services required to fulfill them, and then passing the request to the appropriate backend service.

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 - Examines the integration of NLP techniques in intelligent tutoring systems to provide real-time feedback and personalized learning experiences.

Appendices

Appendix A. API Documentation

This appendix provides the detailed API documentation, including available endpoints, request formats, and response structures.

- **POST /upload**: Uploads educational content (PDF, Word documents).
 - **Request Body**: The document content in **multipart/form-data** format.
 - **Response**: Returns a success message and document ID.
- **POST /generate**: Generates quizzes based on the uploaded document and selected parameters (topic, difficulty, etc.).
 - **Request Body**: JSON object with quiz settings (e.g., topics, number of questions).
 - **Response**: JSON object with the generated quiz content.
- **GET /quizzes**: Retrieves the generated quizzes for review and modification.
 - **Request Params**: user_id, quiz_id.
 - **Response**: Returns the requested quiz along with metadata.

Appendix B. Dataset and Sample Queries

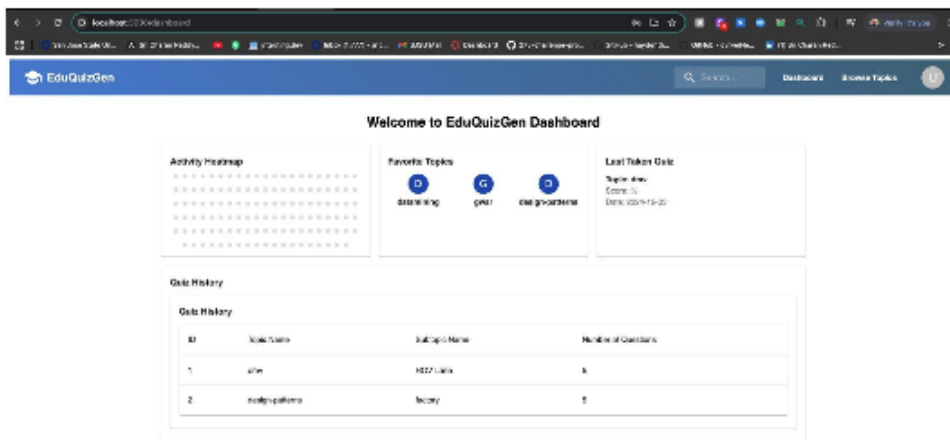
This appendix provides examples of datasets used in the system, including sample educational content and queries for retrieving relevant information.

- **Sample Query**: "Generate 5 questions on the topic of **Mendelian Genetics** with medium difficulty."
- **Sample Document**: Contains sample educational content on **Mendelian Genetics**, used for quiz generation.

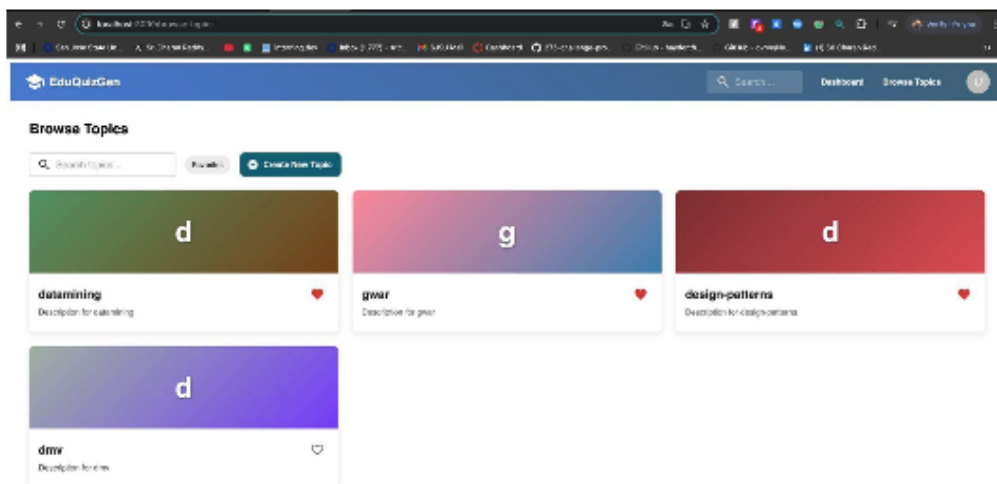
Appendix C. UI Mockups and Screenshots

This appendix contains screenshots and wireframes of the **user interface** for the system, illustrating the UI layout for content upload, quiz configuration, and quiz review.

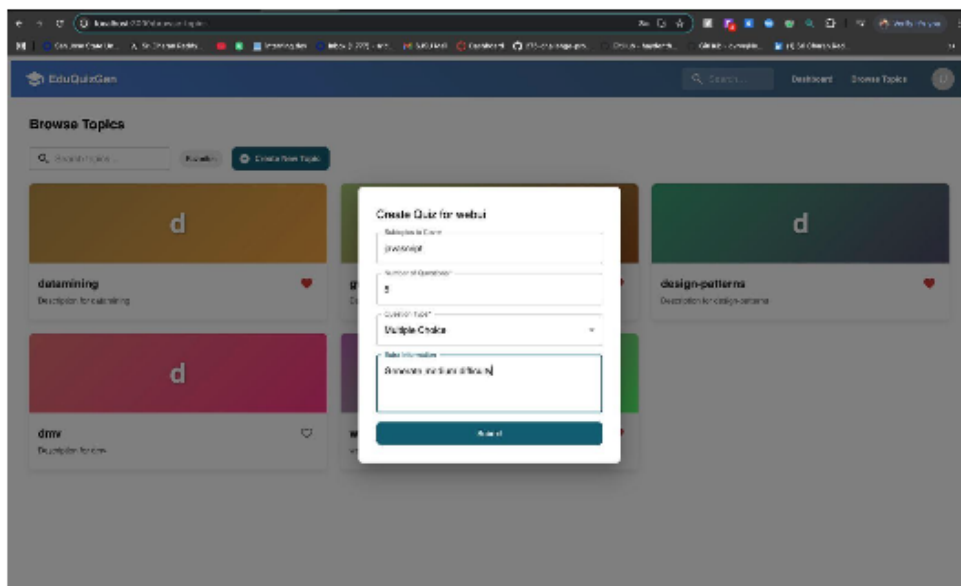
▪ Wireframe 1:



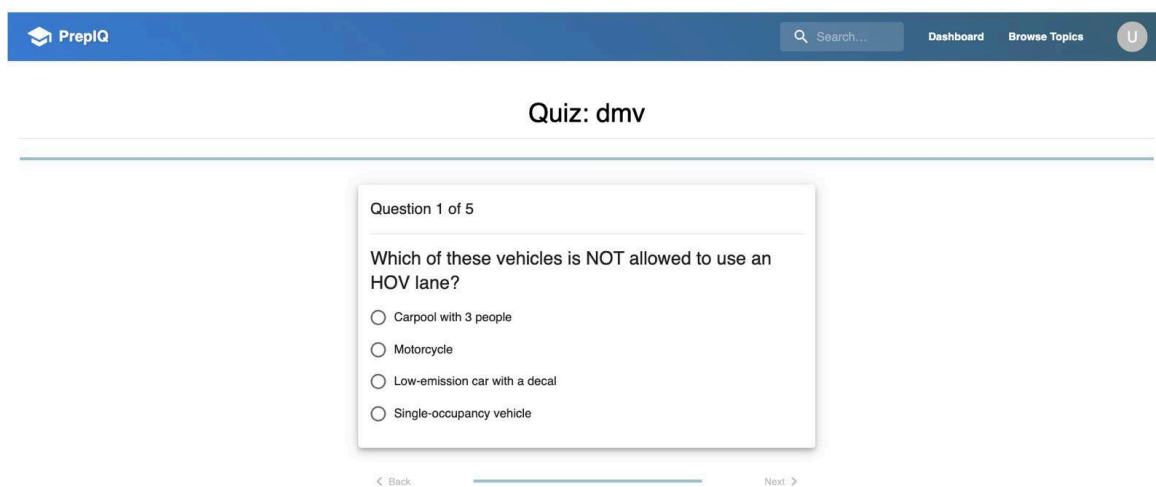
▪ Wireframe 2:




▪ **Wireframe 3:**



▪ **Wireframe 4:**



- **Wireframe 5**

 PrepIQ Search... Dashboard Browse Topics U

Quiz: dmv

Question 4 of 5


What action should you take if you see conflicting information about HOV rules on a sign?

Your Answer

better avoid that lane and just take the normal lane

< Back Next >

- **Wireframe 6:**

 PrepIQ Search... Dashboard Browse Topics U

Quiz: dmv

Congratulations!

You scored 3.8 out of 5

Go to Dashboard Download Answers

Review Your Answers


Question 1 of 5

Which of these vehicles is NOT allowed to use an HOV lane?

Your Answer: Single-occupancy vehicle

Correct Answer: Single-occupancy vehicle

- **Wireframe 7**

 PreplQ [Dashboard](#) [Browse Topics](#) U

Quiz: dmv

Congratulations!

You scored 3.8 out of 5

[Go to Dashboard](#) [Download Answers](#)

Review Your Answers

Question 1 of 5

Which of these vehicles is NOT allowed to use an HOV lane?

Your Answer: Single-occupancy vehicle

Correct Answer: Single-occupancy vehicle

- **Wireframe 8:**

Question 3 of 5

True or False: You can use an HOV lane even if you don't have a minimum number of passengers, as long as you have a low-emission vehicle decal.

Your Answer: False

Correct Answer: True

Question 4 of 5

What action should you take if you see conflicting information about HOV rules on a sign?

Your Answer: better avoid that lane and just take the normal lane

Correct Answer: It's best to err on the side of caution and not use the HOV lane until you can confirm the regulations.

Score: 0.8/10

Feedback: This is a good start! You correctly identify the need to avoid the HOV lane when unsure about the rules. To be even more complete, you could mention checking for additional signage or confirming the information online or through a traffic app.


Question 5 of 5

True or False: The DMV issues decals for vehicles that qualify to use HOV lanes.

Your Answer: True

Correct Answer: True

▪ Wireframe 9:

 PrepIQ

Search...

Dashboard

Browse Topics

U

Quiz Details (ID: 3)

Topic: dmv

Subtopics: HOV

Number of Questions: 5

Questions:

1. Which of these vehicles is NOT allowed to use an HOV lane?

Correct Answer: Single-occupancy vehicle

2. What symbol marks the road surface of an HOV lane?

Correct Answer: Diamond

3. True or False: You can use an HOV lane even if you don't have a minimum number of passengers, as long as you have a low-emission vehicle decal.

Correct Answer: True


4. What action should you take if you see conflicting information about HOV rules on a sign?

Correct Answer: It's best to err on the side of caution and not use the HOV lane until you can confirm the regulations.

5. True or False: The DMV issues decals for vehicles that qualify to use HOV lanes.

Correct Answer: True

▪ Wireframe 10:


 PrepIQ

Search...

Dashboard

Browse Topics

U



John Doe

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Location: San Francisco, CA

Edit Profile