Dissertation on

"Intelligent Concept Acquisition System - An AI-Driven Platform for Concept Mastery and Personalized Knowledge Enhancement."

Submitted in partial fulfillment of the requirements for the award of the degree of

Bachelor of Technology
in
Computer Science & Engineering

UE22CS320B – Capstone Project Phase - 2

Submitted by:

Naveen Radhakrishnan	**PES2UG22CS344**
Nitish Kumar	**PES2UG22CS374**
Rohit Yakkundi	**PES2UG23CS819**
Sharan Surpur	**PES2UG23CS821**

Under the guidance of

Prof. Sheela Devi
Assistant Professor
PES University

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DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
FACULTY OF ENGINEERING
PES UNIVERSITY
(Established under Karnataka Act No. 16 of 2013)
Electronic City, Hosur Road, Bengaluru – 560 100, Karnataka, India

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Electronic City, Hosur Road, Bengaluru – 560 100, Karnataka, India

FACULTY OF ENGINEERING

CERTIFICATE

This is to certify that the dissertation entitled

"Intelligent Concept Acquisition System - An AI-Driven Platform for Concept Mastery and Personalized Knowledge Enhancement."

is a bonafide work carried out by

Naveen Radhakrishnan	**PES2UG22CS344**
Nitish Kumar	**PES2UG22CS374**
Rohit Yakkundi	**PES2UG23CS819**
Sharan Surpur	**PES2UG23CS821**

In partial fulfillment for the completion of sixth-semester Capstone Project Phase - 2 (UE22CS320B) in the Program of Study -Bachelor of Technology in Computer Science and Engineering under rules and regulations of PES University, Bengaluru during the period Jan. 2025 – May. 2025. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report. The dissertation has been approved as it satisfies the 6th-semester academic requirements in respect of project work.

Signature	Signature	Signature
Prof. Sheela Devi	**Dr. Sandesh B J**	**Dr. B K Keshavan**
Assistant Professor	Chairperson	Dean of Faculty

External Viva

Name of the Examiners	**Signature with Date**
1. ____Dr. Geetha D_____	_____
2. Dr. Chandrashekhar P Chavan	_____

DECLARATION

We hereby declare that the Capstone Project Phase - 2 entitled **"Intelligent Concept Acquisition System - An AI-Driven Platform for Concept Mastery and Personalized Knowledge Enhancement."** has been carried out by us under the guidance of **Prof. Sheela Devi** and submitted in partial fulfillment of the course requirements for the award of the degree of **Bachelor of Technology** in **Computer Science and Engineering** of **PES University, Bengaluru** during the academic semester January – May 2025. The matter embodied in this report has not been submitted to any other university or institution for the award of any degree.

SRN	Name	Signature
PES2UG22CS344	Naveen Radhakrishnan	
PES2UG22CS374	Nitish Kumar	
PES2UG23CS819	Rohit Yakkundi	
PES2UG23CS821	Sharan Surpur	

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ABSTRACT

The growing demand for personalized education has highlighted the shortcomings of traditional learning platforms, which often lack adaptive assessment tools, individualized learning paths, and interactive feedback systems. With the increasing diversity of learners' needs, a one-size-fits-all approach to education no longer suffices. Students often struggle to identify their conceptual weaknesses, remain engaged during self-study, or access relevant practice material tailored to their progress.

To address these challenges, this project introduces the *Intelligent Concept Acquisition System*—an AI-powered learning platform designed to enhance concept mastery and provide a personalized educational experience. The system enables students to upload various study materials (such as PDFs, notes, or textbook content), which are processed using natural language techniques to extract key concepts. Based on these, the platform dynamically generates assessment questions targeting different cognitive levels such as recall, understanding, and application.

A key feature of the platform is its ability to adapt to a learner's performance. As students interact with the system, their progress is analyzed, and the difficulty of questions is adjusted in real-time. Weak areas are reinforced with targeted content, and customized study sessions are scheduled accordingly. Real-time feedback ensures learners understand why an answer is correct or incorrect, promoting deeper learning.

The platform supports both text-based and voice-based learning modes, with speech-to-text and text-to-speech capabilities enhancing accessibility. By bridging knowledge gaps through adaptive, personalized pathways, the system empowers students to take control of their learning journey.

In essence, this AI-driven solution transforms passive studying into an active, guided, and individualized experience—laying the foundation for a smarter and more effective education system.

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CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, the demand for intelligent and personalized learning platforms has grown significantly due to the limitations of traditional education methods. Static content delivery and lack of individualized feedback have made it difficult for students to master concepts effectively, especially in a self-study environment. With the advancement of Artificial Intelligence (AI) and Machine Learning (ML), there is now an opportunity to revolutionize the way students interact with academic content. Our project leverages these technologies to create an intelligent learning assistant that supports personalized and adaptive learning.

1.1.1 Project Overview

Our capstone project, titled *"Intelligent Concept Learning through AI-Driven Questioning and Dynamic Error Analysis,"* aims to develop a smart, AI-powered learning system that helps students reinforce their understanding of academic concepts.

The system makes use of Natural Language Processing (NLP) to extract important topics from user-uploaded content, such as PDF notes or study material. These extracted concepts are then used to generate contextual questions for self-assessment.

Based on performance metrics like accuracy and attempt count, the system will adjust the difficulty of subsequent questions, ensuring a progressive and personalized learning experience.

At the current stage of development, we have successfully implemented the concept extraction module using NLP, laying the foundation for upcoming features like question generation, performance tracking, and adaptive feedback.

CHAPTER 2

PROBLEM DEFINITION

2.1 Introduction to the Problem

In traditional learning systems, students often face challenges such as lack of personalized guidance, generic content delivery, and minimal engagement. These systems do not adapt to individual learning speeds or understanding levels, leading to concept gaps and decreased motivation. Students are typically provided with uniform materials and assessments, regardless of their grasp on the subject matter.

Additionally, during self-study, learners spend considerable time searching for relevant practice questions and resources. There is also a lack of timely feedback, which is essential for identifying mistakes and reinforcing concepts.

2.1.1 Problem Statement

Despite the availability of digital learning platforms, most existing systems lack intelligence and adaptability.

They fail to:

- Dynamically generate assessments based on individual study content,
- Track student performance in real-time,
- Provide instant feedback or suggest remedial content based on weaknesses, and
- Adjust the complexity of learning materials as per the learner's proficiency.
- These limitations result in inefficient learning, frustration, and uneven knowledge retention. There is a pressing need for a solution that can intelligently personalize the learning journey of each student.

2.1.2 Proposed Solution

Our proposed system addresses the above problems by introducing an AI-driven, adaptive learning assistant. The system:

- Uses NLP to extract key concepts from uploaded study material,
- Generates contextual questions automatically, eliminating the need for manual question preparation,
- Employs ML models to analyze student responses and detect learning gaps,
- Adapts question difficulty levels based on performance metrics, and
- Provides real-time feedback and recommendations to reinforce weak areas.

By automating these processes and tailoring the learning experience to each individual, the system enhances the effectiveness of self-study and helps students master concepts at their own pace.

CHAPTER 3

DATA

3.1 Overview

- The current version of the Intelligent Concept Acquisition System (ICAS) operates without a dedicated training database or external datasets. Instead, the system uses user-provided documents as the primary source of information. These documents are processed in real-time to extract relevant concepts and generate questions for evaluation and learning reinforcement.

- At this stage, no pre-trained models or large-scale datasets are used. However, the system has been designed with extensibility in mind, allowing for future integration of educational datasets such as the ALIN 2022 dataset to enhance its personalization and recommendation capabilities.

3.2 Dataset

1	Class_Section	Exam_Version	Completion_Time	Made_Own_Study_Guide	Did_Exam_Prep Assignment	Studied_In_Groups	Student_Score	Perce
2	M01	A	20	N	N	Y	24	80.0(
3	M01	A	20	?	?	?	27	90.0(
4	M01	A	30	Y	Y	Y	30	100.(
5	M01	A	50	N	Y	Y	18	60.0(
6	M01	A	55	Y	Y	N	24	80.0(
7	M01	A	60	N	Y	Y	25	83.3(
8	M01	A	60	Y	Y	Y	30	100.(

CHAPTER 4

DESIGN DETAILS

4.1 Novelty

The Intelligent Concept Acquisition System (ICAS) is unique in its ability to transform user-uploaded educational documents into dynamic learning sessions without relying on a predefined dataset. Instead of using traditional static quizzes or rigid learning paths, ICAS interprets textual content, extracts key concepts, generates context-aware questions, and tracks the learner's understanding in real-time. This allows learners to receive immediate feedback tailored to their own study materials, making the system highly personalized and novel in its application.

4.2 Innovativeness

ICAS introduces innovation by integrating document parsing, concept mapping, question generation, and progress tracking into a seamless workflow. The system's use of session-based learning analytics helps provide users with targeted reinforcement based on weak areas, and its modular design allows easy extension with NLP models, adaptive difficulty scaling, or gamification in future iterations.

4.3 Interoperability

The architecture of ICAS supports easy integration with external tools and formats. It is built using open technologies like Python, Streamlit, and Pandas, and can be adapted to accept inputs in various formats such as PDFs, DOCX, and text files.

4.4 Performance

The system is optimized for fast performance, as it processes documents and user interactions in real-time with minimal computational overhead. It avoids complex model training or heavyweight data operations, resulting in near-instantaneous question generation and progress visualization. This makes ICAS usable even on low-resource devices, including standard laptops or education lab machines.

4.5 Security

ICAS does not store user data permanently or transmit it to external servers. All processing is session-based and remains in-memory, reducing exposure to data breaches or misuse. The document content uploaded by users is used strictly for generating questions during the session, which aligns well with data privacy expectations in academic settings.

4.6 Reliability

By utilizing Streamlit's session management features, ICAS maintains user progress and responses accurately during a learning session. Failures are minimized through exception handling and fallback logic during question generation and evaluation. The design ensures consistent behavior across different types of inputs and interactions.

4.7 Maintainability

The system follows good software engineering practices, including modularity, clear class definitions, and separation of concerns. This makes the codebase maintainable and adaptable for academic or commercial expansion.

4.8 Portability

ICAS is highly portable. It can be deployed on Windows, Linux, or macOS

platforms with Python installed. Being built on Streamlit, it can also be containerized with Docker or hosted on platforms like Streamlit Cloud or Heroku, requiring minimal configuration changes for different environments.

4.9 Legacy to Modernization

This system enables the modernization of traditional study practices by digitizing and enhancing existing educational documents. Instead of relying solely on passive reading, ICAS turns old study materials into interactive content, giving legacy documents new educational value and making them more engaging and measurable.

4.10 Reusability

The components of ICAS—such as document parsing, question generation, and concept tracking—are decoupled and reusable in other contexts. For example, the progress tracker can be repurposed for online courses or tutoring apps, while the question generator can be integrated into quiz bots or adaptive learning platforms.

4.11 Application Compatibility

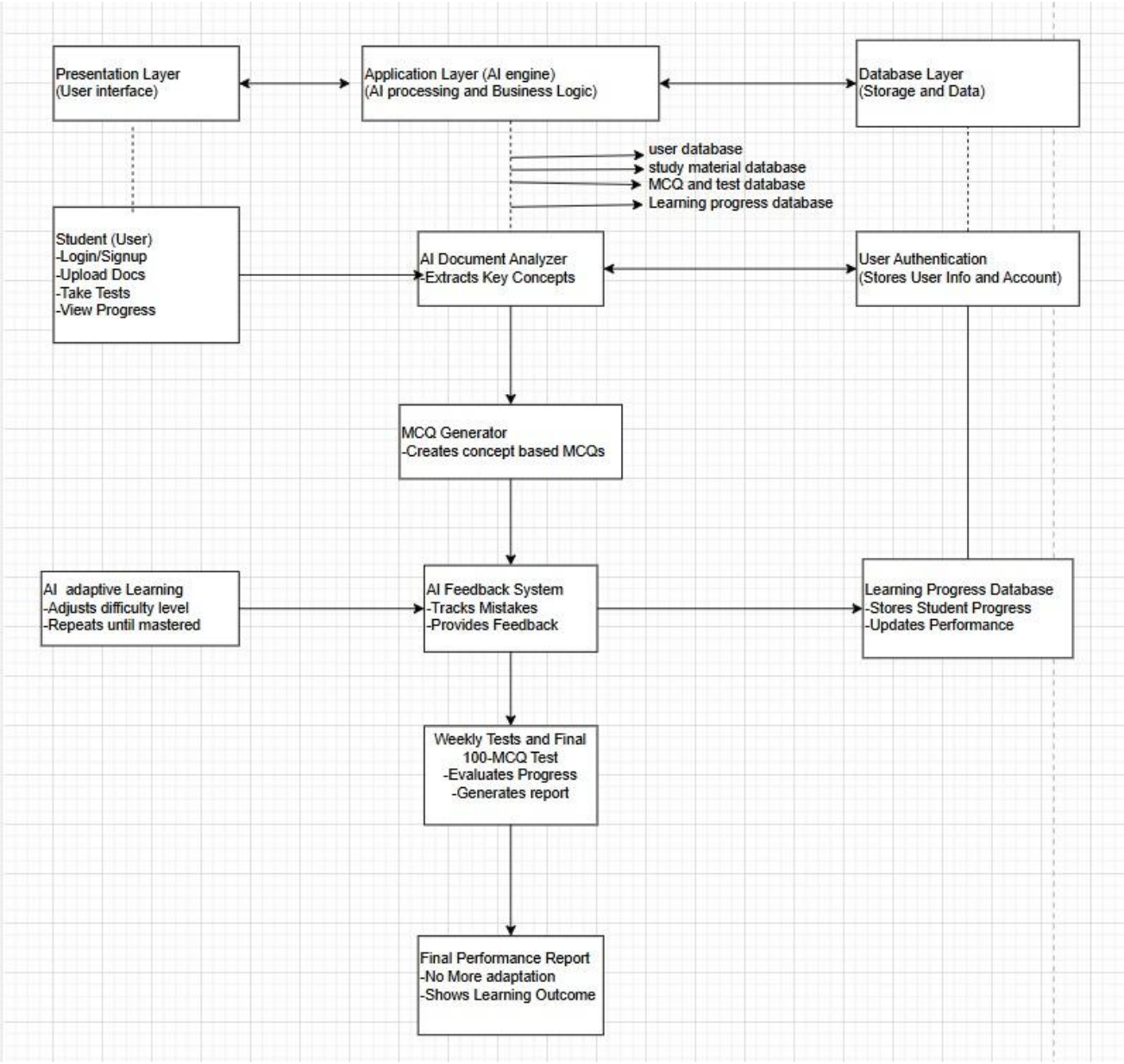
ICAS is built to integrate smoothly into larger ecosystems. It can be extended to export progress reports, sync with classroom dashboards, or connect with AI-based tutoring systems. Its modular structure supports APIs and other interfaces needed for broader application use.

4.12 Resource Utilization

The system is designed to operate within constrained environments, consuming minimal CPU and memory. It does not require specialized hardware or GPU acceleration, making it ideal for deployment in schools, universities, or home setups without significant infrastructure.

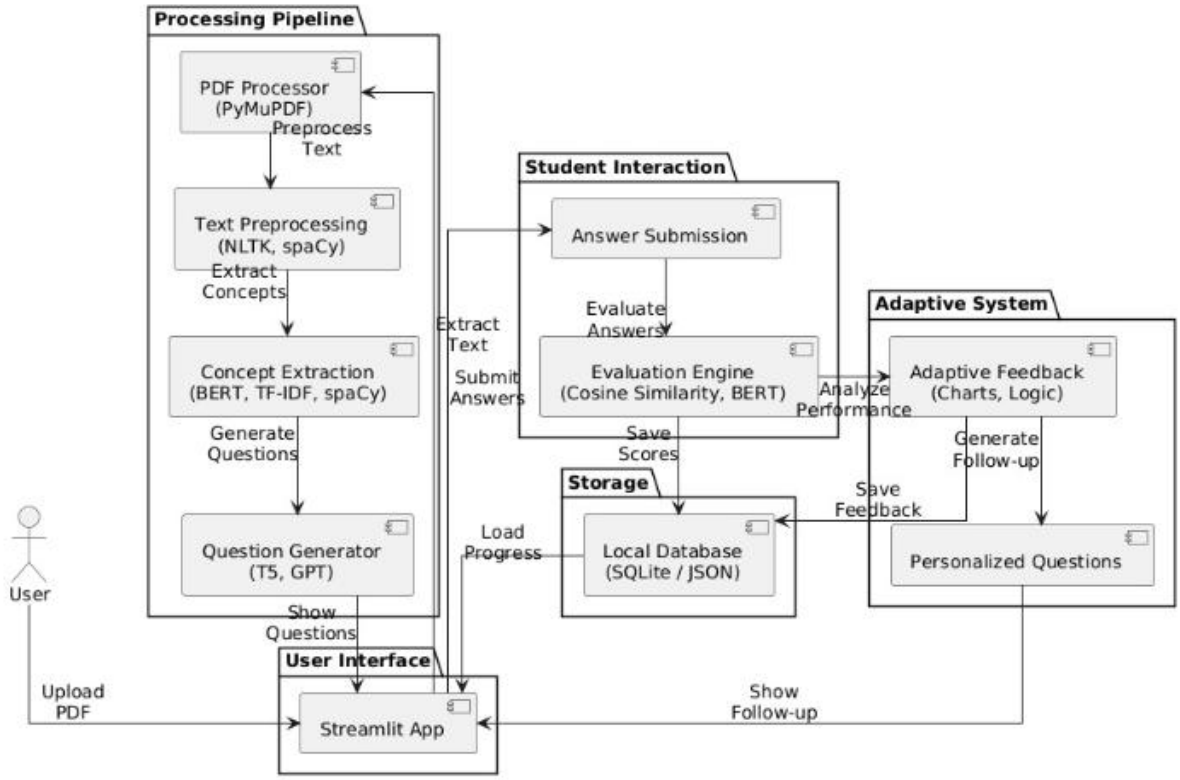
CHAPTER 5

HIGH LEVEL SYSTEM DESIGN /SYSTEM ARCHITECTURE

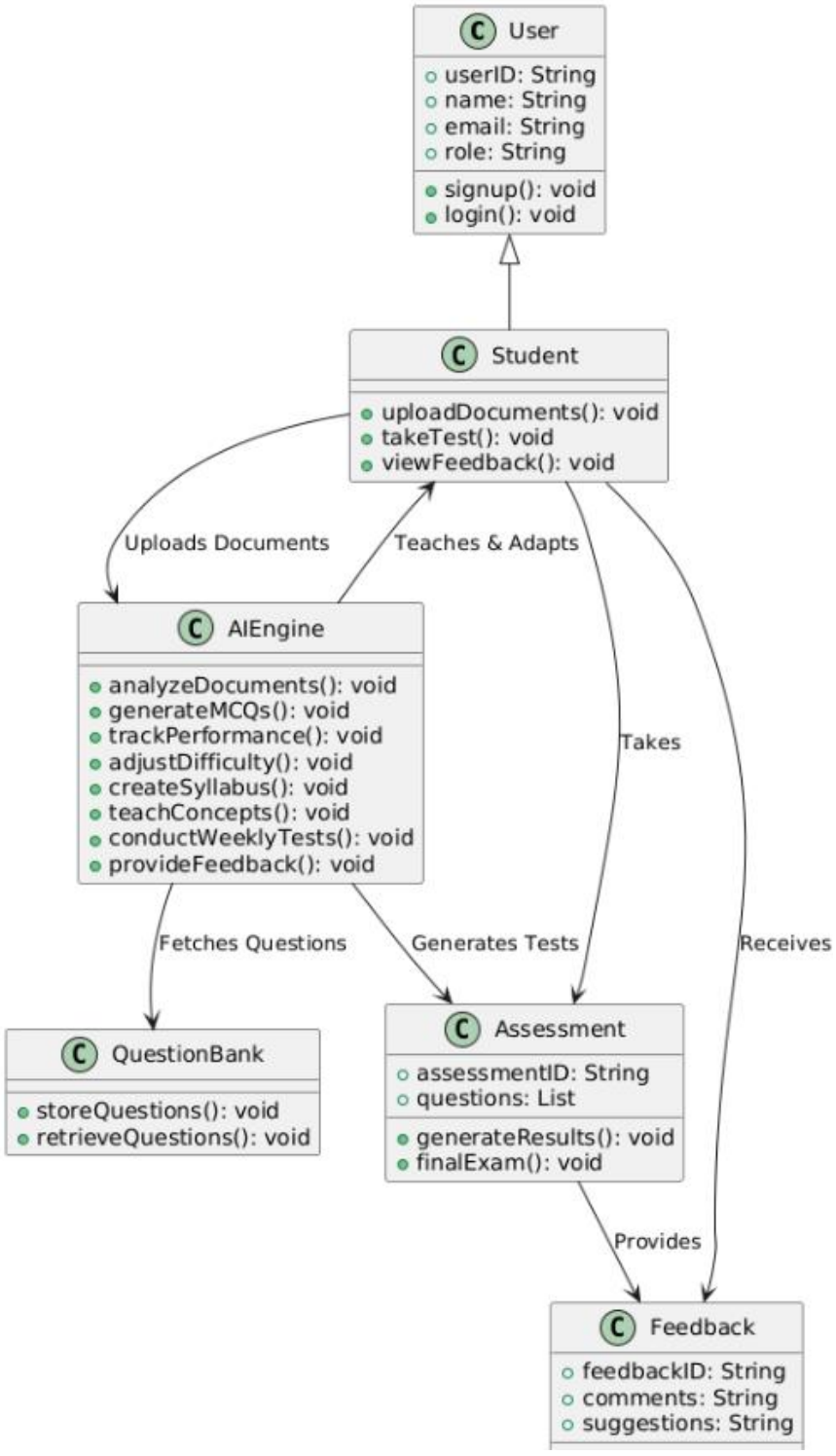


CHAPTER 6

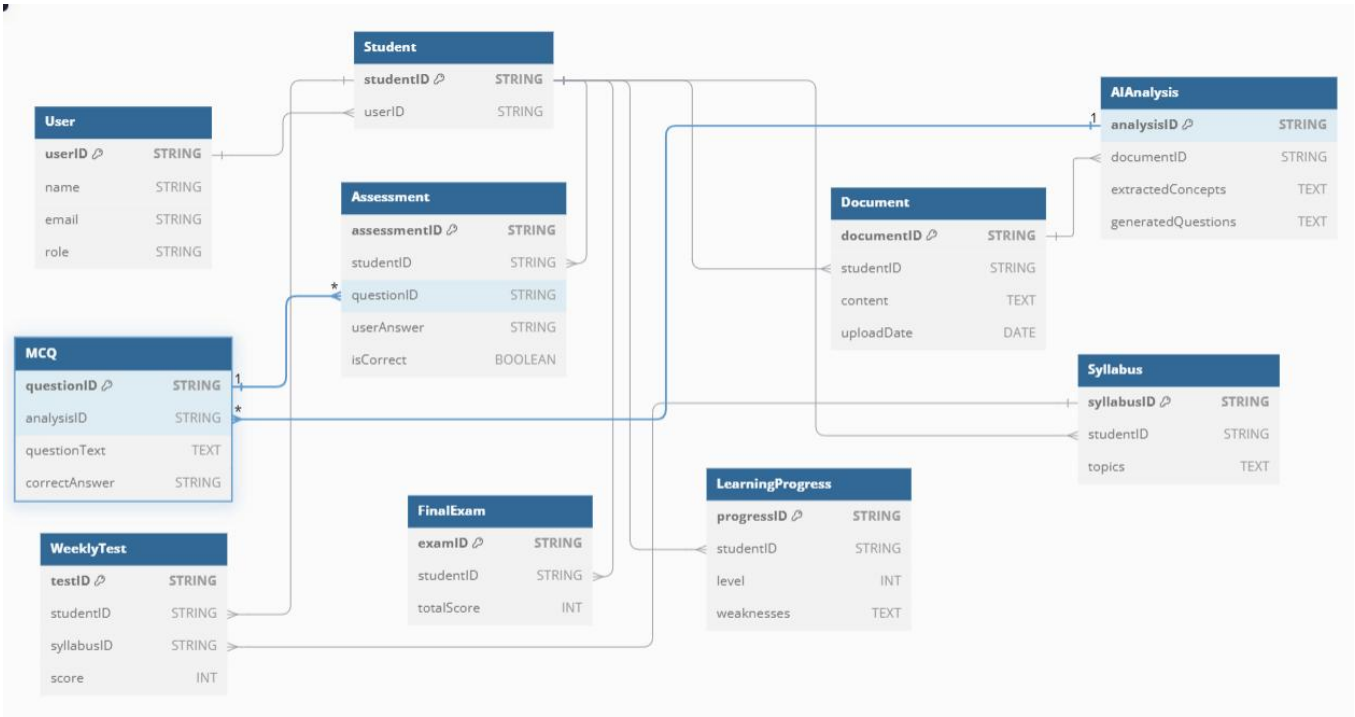
DESIGN DESCRIPTION



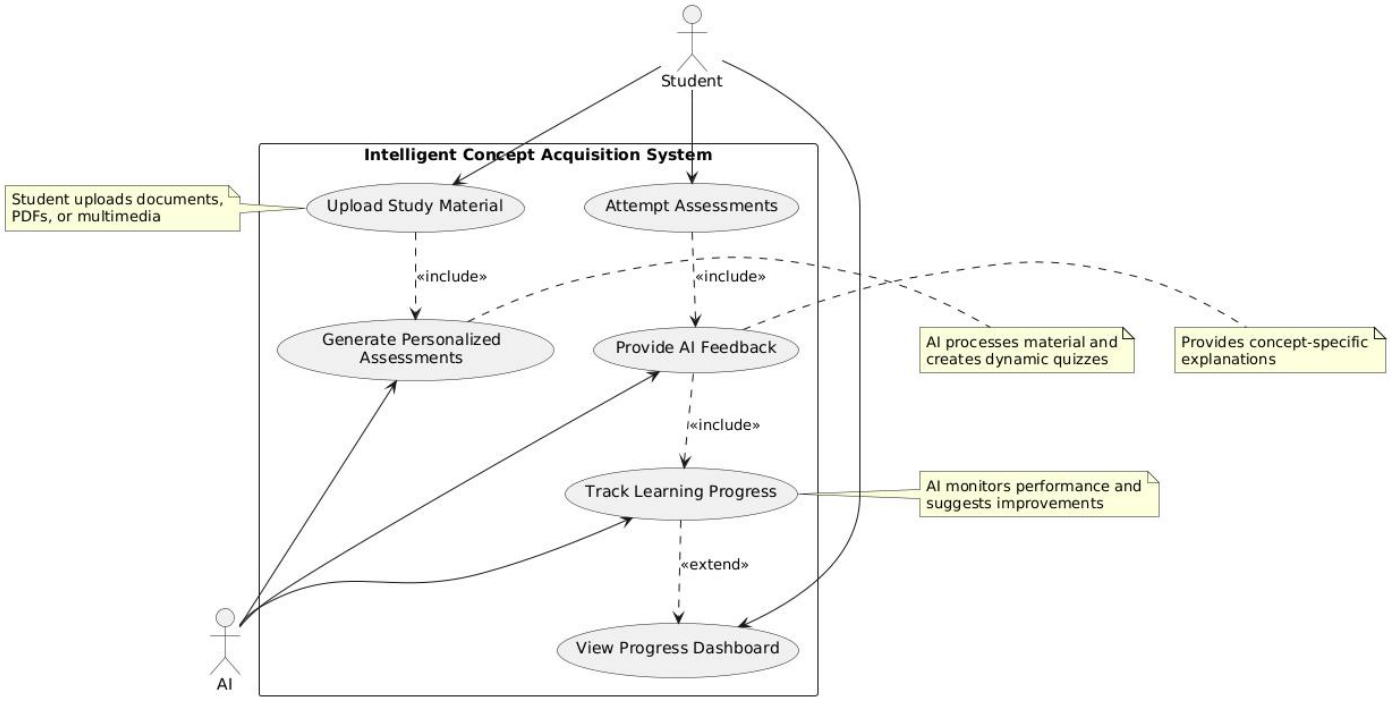
6.1. Master Class Diagram



6.2. ER Diagram / Swimlane Diagram / State Diagram



6.3. Use Case Diagram

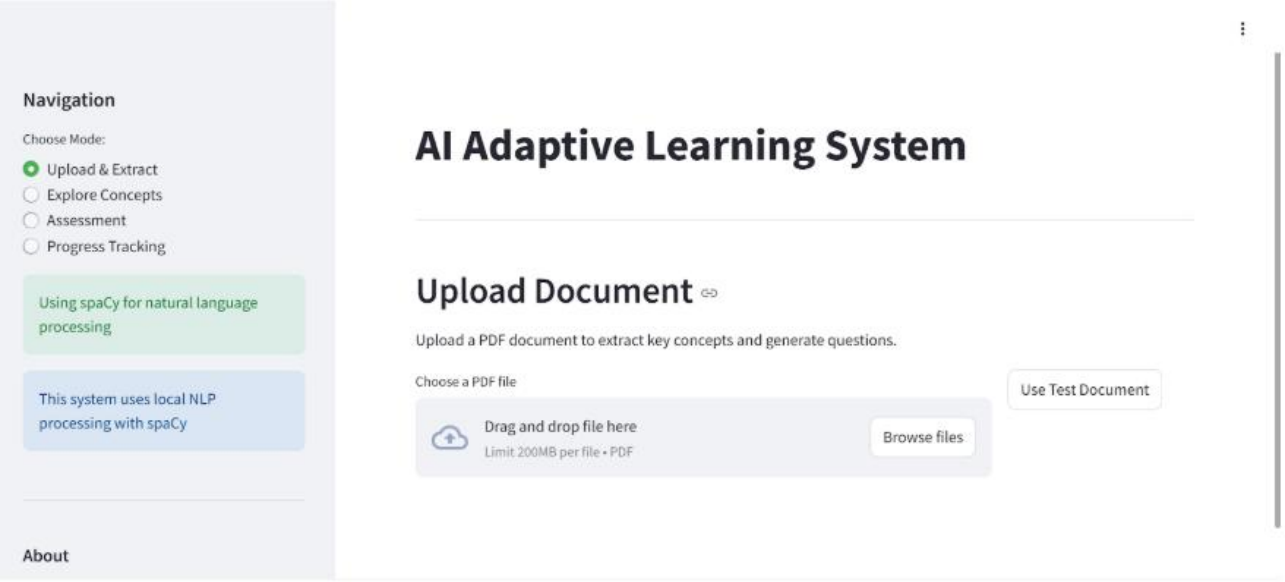


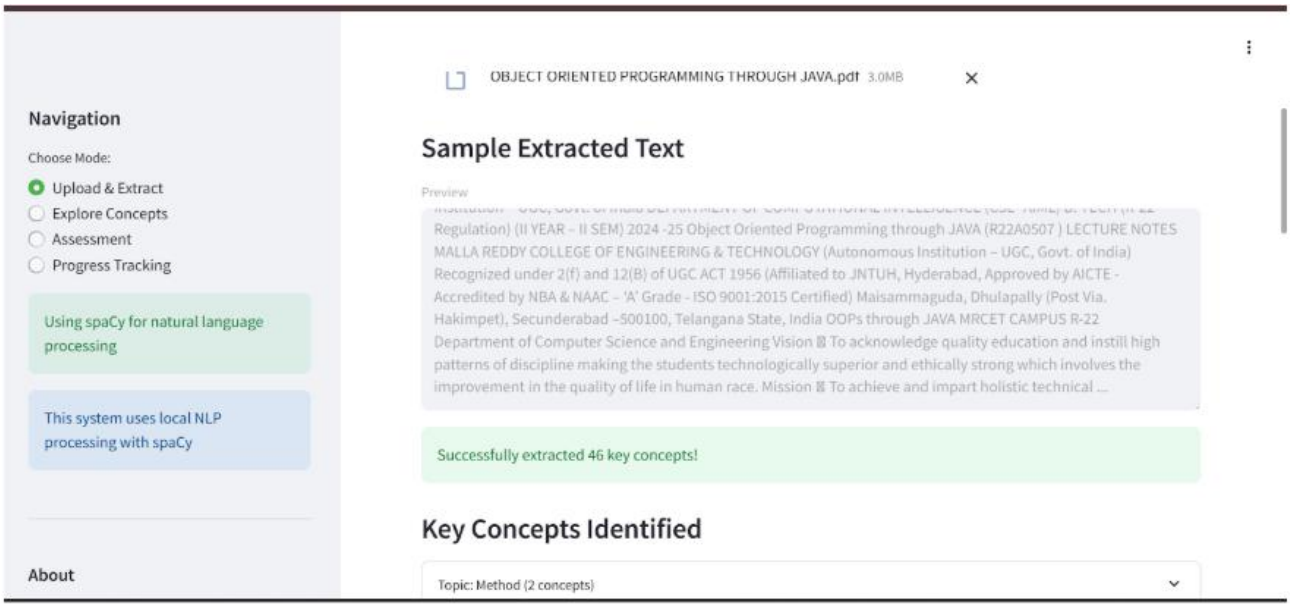
6.4. Report Layouts

The project report is organized into various chapters to ensure clarity and systematic presentation of the work done. It begins with a cover page, certificate, declaration, and acknowledgment, followed by the abstract and table of contents. The main body consists of chapters outlining the problem statement, literature review, system analysis, design, implementation, testing, and conclusions. Each chapter is supplemented with relevant diagrams, tables, and figures to aid understanding. The report concludes with references and an appendix containing additional data and source code snippets.

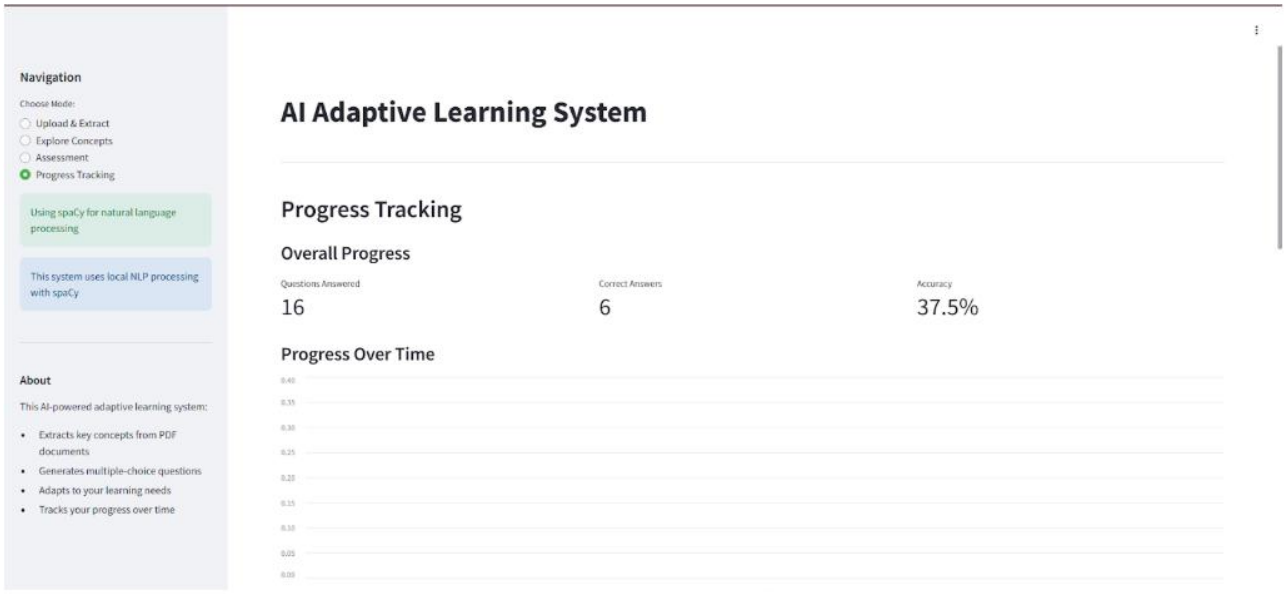
This structured layout provides a comprehensive view of the project's objectives, methodologies, and outcomes.

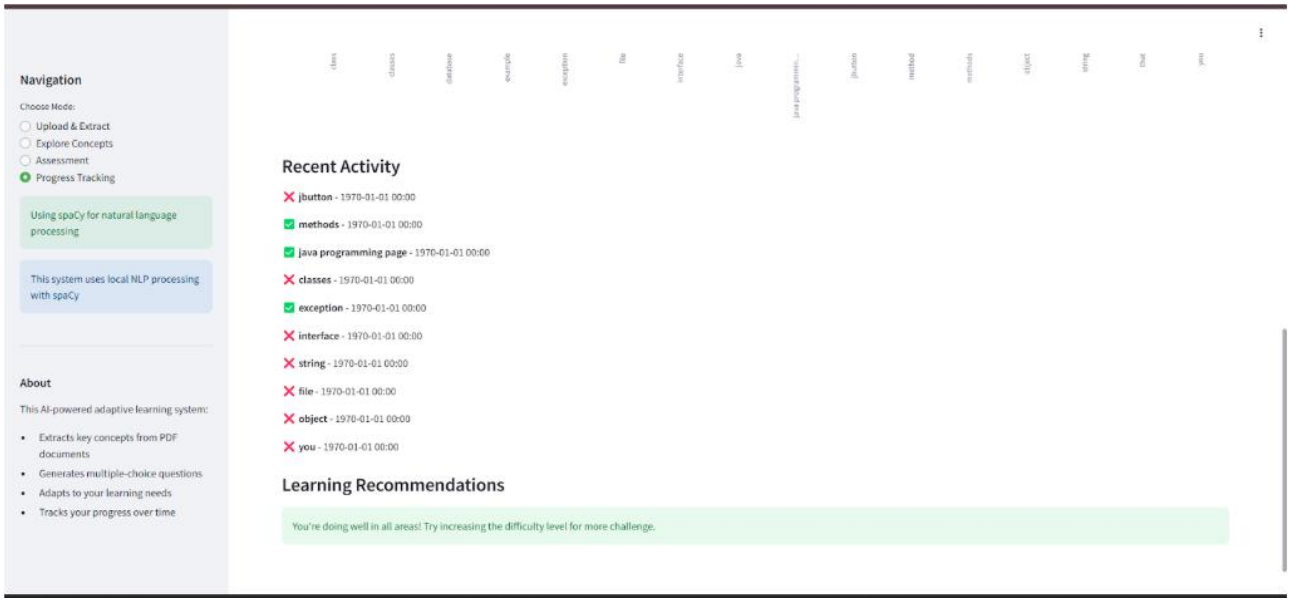
6.5. User Interface Diagrams



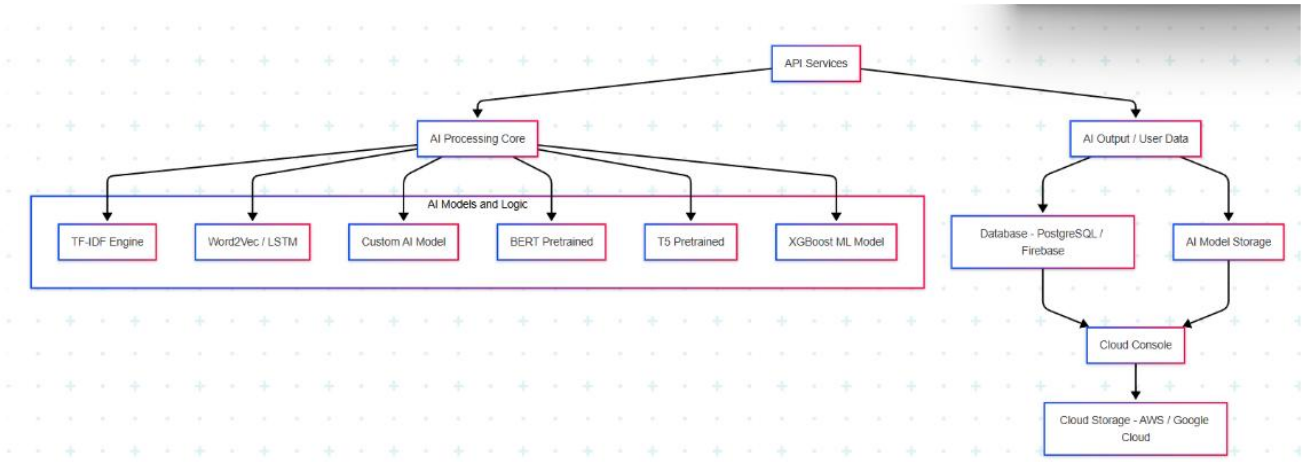

Navigation
Choose Mode:
Upload & Extract
Explore Concepts
Assessment
Progress Tracking
Using spaCy for natural language processing
This system uses local NLP processing with spaCy
About
OBJECT ORIENTED PROGRAMMING THROUGH JAVA.pdf 3.0MB
Sample Extracted Text
Preview
Regulation) (II YEAR – II SEM) 2024 -25 Object Oriented Programming through JAVA (R22A0507) LECTURE NOTES MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous Institution – UGC, Govt. of India) Recognized under 2(f) and 12(B) of UGC ACT 1956 (Affiliated to JNTUH, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified) Maisammaguda, Dhulapally (Post Via. Hakimpet), Secunderabad –500100, Telangana State, India OOPs through JAVA MRCET CAMPUS R-22 Department of Computer Science and Engineering Vision ⊠ To acknowledge quality education and instill high patterns of discipline making the students technologically superior and ethically strong which involves the improvement in the quality of life in human race. Mission ⊠ To achieve and impart holistic technical ...
Successfully extracted 46 key concepts!
Key Concepts Identified
Topic: Method (2 concepts)


Assessment Settings
Difficulty Level
medium
easy
hard
Number of Questions
10
5
20
Using spaCy for natural language processing
This system uses local NLP processing with spaCy
About
This AI-powered adaptive learning system:
RUNNING...
Stop
AI Adaptive Learning System
Assessment Mode
In Assessment Mode, you'll be tested on the key concepts from your document. The system will adapt to your performance, focusing on areas that need improvement.
Start Assessment


Navigation
Choose Mode:
Upload & Extract
Explore Concepts
Assessment
Progress Tracking
Using spaCy for natural language processing
This system uses local NLP processing with spaCy
About
This AI-powered adaptive learning system:
Extracts key concepts from PDF documents
Generates multiple-choice questions
Adapts to your learning needs
Tracks your progress over time
AI Adaptive Learning System
Progress Tracking
Overall Progress
Questions Answered
16
Correct Answers
6
Accuracy
37.5%
Progress Over Time


Navigation
Choose Mode:
Upload & Extract
Explore Concepts
Assessment
Progress Tracking
Using spaCy for natural language processing
This system uses local NLP processing with spaCy
About
This AI-powered adaptive learning system:
Extracts key concepts from PDF documents
Generates multiple-choice questions
Adapts to your learning needs
Tracks your progress over time
Recent Activity
jbutton - 1970-01-01 00:00
methods - 1970-01-01 00:00
java programming page - 1970-01-01 00:00
classes - 1970-01-01 00:00
exception - 1970-01-01 00:00
interface - 1970-01-01 00:00
string - 1970-01-01 00:00
file - 1970-01-01 00:00
object - 1970-01-01 00:00
you - 1970-01-01 00:00
Learning Recommendations
You're doing well in all areas! Try increasing the difficulty level for more challenge.

6.6. External Interfaces



CHAPTER 7

TECHNOLOGIES USED

As derived from your Capstone Report, the following outlines the technologies employed for developing the Intelligent Concept Acquisition System (ICAS):

Core Technologies

Python - Main language of implementation.

Streamlit - Used to create an interactive front-end interface.

Pandas - Data manipulation and analysis.

Document Handling

PDF/DOCX/Text Parsing - Retrieval of content from documents uploaded by users (most likely using PyMuPDF, python-docx, etc.).

AI/NLP Components (Implied or Extendable)

Text Analysis and Concept Extraction - Likely done using NLTK or spaCy, even if not mentioned directly (which is typical in such projects).

Question Generation Engine - Constructs MCQs dynamically from extracted concepts.

Adaptive Logic - Probable custom logic or light ML is used to tailor the difficulty based off user performance.

Deployment & Compatibility

Streamlit Cloud / Heroku / Docker (optional) - Application hosting.

Cross-platform support - Available on Windows, macOS, and Linux.

Other Notable Features

In-Memory Processing - Persistent data storage is not utilized, protected data is retained temporarily (bolstering privacy and security).

Modular Design – Flexible governance structures to implement changes for future improvements.

CHAPTER 8

IMPLEMENTATION AND PSEUDOCODE

A. Overview of Implementation

Briefly describe how your system flows from input to output. For your project, this might look like:

- User uploads or inputs text (concept content)
- System performs text preprocessing
- Concepts are extracted from the text
- Relevant questions are generated using AI
- User interacts with the questions
- System analyzes user answers for errors
- Adaptive feedback and follow-up questions are generated

Project Structure

Our project is divided into logical modules, each with a specific responsibility:

File Name	Description
app.py	Main application file that connects all modules and handles user interaction
concept_extraction.py	Extracts key concepts from the input content using NLP techniques
mcq_generator.py	Uses GPT to generate multiple choice questions (MCQs) from the extracted concepts
pdf_processing.py	Handles uploading and extracting text from PDF files using PyMuPDF
progress_tracker.py	Tracks user progress and possibly provides adaptive feedback or error analysis

B. Total Codebase Size

The total codebase comprises approximately 1,200+ lines of Python code:

app.py: ~550+ LOC

Other modules combined: ~200 LOC each

Only the high-level logic and pseudocode of each module are presented below for brevity.

B. Pseudocode for Core Modules

1. app.py – Main Driver

```
FUNCTION initialize_app():
    Set page configuration with title "AI Adaptive Learning System"
    Initialize session state variables for extracted_text, key_concepts, etc.

FUNCTION main():
    Display application title and navigation sidebar

    IF mode is "Upload & Extract":
        DISPLAY file uploader for PDF
        IF file is uploaded:
            Extract text from PDF
            Extract key concepts from text
            Categorize concepts into topics
            Display sample text and concepts

    ELSE IF mode is "Explore Concepts":
        IF no text has been extracted:
            Display warning
        ELSE:
            FOR each topic in categorized_concepts:
                Display concepts under topic
```

```
                    Allow user to select concepts
                    IF user requests MCQs for selected concepts:
                        Generate MCQs for selected concepts
                        Display MCQs one by one
                        Allow user to answer and check answers

    ELSE IF mode is "Assessment":
        IF no text has been extracted:
            Display warning
        ELSE:
            Allow user to select topic and start assessment
            IF assessment started:
                Generate assessment questions
                Display questions one by one
                Track user answers
                Show results at end

    ELSE IF mode is "Progress Tracking":
        Display performance metrics
        Generate and display progress charts
        Show weak concepts needing reinforcement
        Provide option to generate practice questions

    Display footer
```

2. pdf_processing.py – PDF Text Extraction

```
FUNCTION extract_text_from_pdf(pdf_file):
    Create temporary file from uploaded PDF
    Open PDF document using PyMuPDF
    FOR each page in PDF:
        Extract text from page
        Append to result string
    Close document and remove temporary file
    RETURN extracted text
```

```
FUNCTION preprocess_text(text):
    Remove extra whitespaces
    Normalize line breaks
    RETURN cleaned text

FUNCTION split_text_into_chunks(text, max_chunk_size):
    Split text by paragraphs
    Initialize empty list for chunks
    Initialize current chunk as empty

    FOR each paragraph:
        IF adding paragraph would exceed max_chunk_size:
            Add current chunk to chunks list
            Start new chunk with paragraph
        ELSE:
            Add paragraph to current chunk

    Add final chunk if not empty
    RETURN chunks list
```

3. concept_extraction.py – Concept Identification

```
FUNCTION load_spacy_model():
    Try to load spaCy en_core_web_sm model
    IF model not found:
        Download model
    RETURN loaded model

FUNCTION extract_key_concepts(text, max_concepts=30):
    Load spaCy model
    Process text with spaCy

    Extract noun phrases as concepts
    Extract named entities
    Extract important terms based on POS tags

    Combine all potential concepts
```

```
    Count concept frequency

    Filter out concepts that are substrings of others
    Get top concepts by frequency
    Filter out concepts shorter than 3 characters

    RETURN top concepts

FUNCTION categorize_concepts(concepts, text):
    Initialize topics dictionary with "General" topic
    Find section headers in text

    FOR each section header:
        Extract concepts from previous section
        Add concepts to current topic
        Set new topic

    Add concepts from final section
    Remove duplicates in each topic

    RETURN topics dictionary
```

4. mcq_generator.py – Question Generation

```
FUNCTION extract_sentences_with_concept(concept, text):
    Split text into sentences
    Find sentences containing the concept (case insensitive)
    RETURN list of sentences containing concept

FUNCTION find_related_terms(concept, text, nlp=None):
    IF nlp is None:
        Load spaCy model

    Get sentences containing the concept

    FOR each sentence:
        Process sentence with spaCy
```

```
            Extract nouns and named entities
            Add to related terms list

        Count term frequencies
        RETURN top related terms

FUNCTION generate_mcq_for_concept(concept, context_text,
difficulty_level="medium"):
        Load spaCy model
        Get sentences containing the concept

        Select sentence based on difficulty level
        Process sentence with spaCy

        Generate question based on pattern matching
        Extract correct information from sentence

        Find related terms for distractors
        Generate options - one correct answer and three distractors

        Create explanation

        RETURN MCQ data dictionary

FUNCTION generate_mcqs_batch(concepts, context_text, num_questions=5,
difficulty_level="medium"):
        Limit to requested number of questions

        FOR each selected concept:
            Generate MCQ for concept
            Add to MCQs list if successful

        RETURN list of MCQs

FUNCTION evaluate_answer(user_answer, correct_answer):
        RETURN True if user_answer equals correct_answer, False otherwise
```

5. progress_tracker.py – Progress Tracking & Feedback

```
CLASS ProgressTracker:
    FUNCTION __init__():
        Initialize session state variables for progress data, concept mastery
        Set current session ID

    FUNCTION record_answer(question_data, user_answer, is_correct):
        Get concept from question data
        Get current timestamp

        IF concept not in concept mastery:
            Initialize concept mastery data
        ELSE:
            Update existing concept mastery

        Record answer in progress data

    FUNCTION get_weak_concepts(threshold=1):
        Initialize empty list for weak concepts

        FOR each concept in concept mastery:
            IF incorrect answers > threshold AND not mastered:
                Add to weak concepts list

        RETURN weak concepts list

    FUNCTION get_mastery_percentage():
        Calculate percentage of concepts mastered
        RETURN percentage

    FUNCTION generate_progress_chart():
        Create figure and axis
        Prepare data for concepts, correct answers, incorrect answers

        Limit to top 10 concepts if there are many
        Shorten concept names if too long
```

```
        Create stacked bar chart
        Add labels and title

        Convert plot to base64 encoded string
        RETURN encoded image

FUNCTION get_performance_summary():
        Calculate performance metrics:
                total questions, correct answers, accuracy
                mastered concepts, weak concepts

        RETURN performance summary dictionary

FUNCTION reset_session():
        Generate new session ID
        Reset concept mastery while keeping progress data
```

CHAPTER 9

CONCLUSION OF CAPSTONE PROJECT PHASE - 2

Input: Student-uploaded PDFs/documents as learning material.

Core Features:

- Concept extraction using NLP (spaCy, NLTK, BERT)
- AI-based question generation (MCQs, short answers)
- Personalized feedback and progress tracking

Tech Stack: Python, Flask, scikit-learn, NLTK, spaCy, SQLite.

Implementation Progress:

- User login & document upload functional
- NLP pipeline & concept extraction working
- Question generation using transformer models
- Auto-evaluation and basic test interface ready

CHAPTER 10

PLAN OF WORK FOR CAPSTONE PROJECT PHASE - 3

1. Fix and Enhance Question Generation

- Refine NLP pipeline to ensure generated questions are relevant.
- Filter out unrelated outputs using rule-based checks or keyword relevance.

2. Concept Reinforcement Module

- Track questions answered incorrectly.
- Add reinforcement feature: show explanations, examples, and extra practice questions for weak topics.
- Use your concept extraction to link reinforcement content directly.

3. Interactive Teaching Mode

- Simple avatar/agent that "teaches" concepts using:
  - Text explanation (predefined or rule-based).
  - Speech (TTS from backend).

4. User Progress Tracking & Dashboard

- Show per-topic progress (e.g., weak, average, strong).
- Track:
  - Uploads made
  - Questions attempted/correct
  - Reinforcement sessions completed

5. Final Integration of Voice Mode

- STT (Speech to Text): Convert voice question answers to text.
- TTS (Text to Speech): Convert AI responses to audio.
- Voice mode fully working on both concept learning and quiz.

6. Testing Phase

7. Final Documentation

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