Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

Lecture Lab: An AI-Powered Lecture Summarization and Intelligent Learning System

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***Abstract* - Lecture AI is an AI-powered web application designed to simplify lecture understanding and enhance student learning efficiency. Built using Next.js and React, the system leverages the Google Gemini API to convert lecture content into concise summaries and interactive multiple-choice quizzes. It supports multiple input formats, including plain text, YouTube links, PDF documents, and video uploads, making it highly flexible and user-friendly.**

The platform generates quizzes with varying difficulty levels and provides explanations to promote deeper understanding. It also includes features such as a notes library, AI tutor, weak topic identification, and a planner with progress tracking, enabling a personalized learning experience. A robust AI architecture with primary and fallback models ensures reliability, while offline fallback mechanisms maintain functionality during API limitations.

Overall, Lecture AI serves as a comprehensive learning assistant that integrates content summarization, assessment, and progress tracking into a single intelligent system.

I. INTRODUCTION

In the modern digital era, the education system has undergone a significant transformation with the widespread availability of online learning resources such as video lectures, digital notes, and e-books. While these resources have made knowledge more accessible, they have also introduced new challenges for students. The vast amount of information often leads to difficulty in understanding, summarizing, and effectively revising lecture content. Students frequently struggle to extract key concepts, assess their understanding, and manage their study schedules efficiently.

Traditional learning methods lack automation and personalization, requiring students to manually create notes, design practice questions, and track their progress. This process is time-consuming and often inefficient, especially when dealing with lengthy lecture materials from platforms such as YouTube or large PDF documents. As a result, there is a growing need for an intelligent system that can assist students in transforming raw educational content into structured and meaningful study resources.

To address these challenges, Lecture AI is proposed as an advanced AI-powered learning platform that automates lecture comprehension and enhances the overall learning experience. The system leverages modern web technologies such as Next.js and React, along with powerful generative AI models like Google Gemini, to process lecture inputs and generate concise summaries and interactive quizzes. By supporting multiple input formats—including text, video links, PDF files, and uploaded videos—the platform ensures flexibility and usability across different learning scenarios.

Furthermore, Lecture AI goes beyond basic summarization by incorporating features such as weak topic identification, an AI tutor for personalized assistance, a notes management system, and a planner for tracking study progress. These features collectively create a complete learning ecosystem that supports students in understanding concepts, evaluating their knowledge, and improving their performance over time.

In conclusion, Lecture AI aims to bridge the gap between content consumption and effective learning by integrating artificial intelligence into the study process. It provides a smart, efficient, and user-friendly solution that empowers students to learn better, revise faster, and achieve their academic goals with greater confidence.

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II. LITERATURE REVIEW - LECTURE AI

The rapid growth of digital learning platforms has led to an increased demand for intelligent tools that can assist students in managing and understanding large volumes of educational content. Several research works and existing systems have explored lecture summarization, question generation, and personalized learning using artificial intelligence. This section reviews the key contributions in these areas.

Early approaches to lecture summarization primarily relied on traditional Natural Language Processing (NLP) techniques such as keyword extraction, frequency-based methods, and rule-based models. While these methods were useful for identifying important terms, they often failed to capture the contextual meaning and overall essence of lecture content. With the advancement of deep learning, more sophisticated models based on neural networks and transformers have been introduced, significantly improving the quality of text summarization.

Recent developments in Generative AI and transformer-based architectures, such as those used in large language models, have enabled systems to generate human-like summaries and meaningful insights from unstructured data. Tools powered by such models can now understand context, identify key concepts, and produce concise summaries. However, many existing solutions focus only on summarization and lack additional learning features such as assessment and progress tracking.

In the domain of automatic question generation, several systems have been proposed that generate quizzes from textual content. These systems typically use NLP techniques or machine learning models to create objective-type questions. While effective to some extent, many of these tools do not provide explanations for answers or support multiple difficulty levels, limiting their usefulness in real-world learning scenarios.

Educational platforms such as online learning management systems (LMS) provide structured content delivery and basic assessment features. However, they often lack real-time AI-driven personalization and the ability to process diverse input formats like videos and PDFs dynamically. Additionally, most systems do not include integrated tools for weak topic analysis, revision planning, and intelligent tutoring.

Recent AI-based applications have started integrating chatbot-based tutors and recommendation systems to enhance student engagement. These systems provide interactive support but are usually limited to predefined datasets or lack integration with user-generated learning content.

Based on the analysis of existing literature and systems, it is evident that there is a gap in creating a unified platform that combines lecture summarization, quiz generation, personalized feedback, and study planning in a single system. Lecture AI addresses these limitations by integrating advanced generative AI models with a multi-input processing system, enabling automated summarization, intelligent quiz generation with explanations, weak topic identification, and a complete study workflow including notes management and progress tracking. This makes it a more comprehensive and practical solution compared to existing approaches.

III. SYSTEM ARCHITECTURE - LECTURE AI

The Lecture AI system is designed using a modular and scalable architecture that integrates frontend, backend, AI processing, and storage components. The system follows a client-server model where user inputs are processed through an API layer and transformed into meaningful outputs using AI models.

1. Overall Architecture Overview

Plain text

User (Browser)

↓

Frontend (Next.js + React UI)

↓

API Layer (/api/process)

↓

Input Processing Layer

(YouTube / PDF / Video / Text)

↓

AI Processing Layer

(Gemini Primary + Fallback)

↓

Output Generation Layer

(Summary + Quiz)

↓

Frontend Display + Local Storage

2. Architecture Components

1. User Interface (Frontend)

Built using Next.js 16 (App Router) and React 19

Provides:

Input forms (text, URL, file upload)

Quiz interface

Notes library

Planner dashboard

Tutor panel

Acts as the interaction layer between user and system

2. API Layer

Endpoint: POST /api/process

Responsibilities:

International Journal of Engineering Research & Technology (IJERT)
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Validate user input

Identify input type (text, YouTube, PDF, video)

Route data to processing modules

Works as the bridge between frontend and AI engine

3. Input Processing Layer

Handles extraction of readable text from different formats:

Text → Direct processing

YouTube → Transcript extraction using youtube-transcript

PDF → Text extraction using pdf-parse

Video → (basic processing / future enhancement)

Converts all inputs into a common text format

4. AI Processing Layer

Uses Google Gemini API

Two-stage processing:

Primary Model → gemini-2.5-flash

Fallback Model → gemini-2.0-flash

Fallback Mechanism:

If primary fails → switch to fallback

If both fail → generate offline summary + quiz

Ensures high reliability and fault tolerance

5. Output Generation Layer

Produces:

Summary (concise and structured)

? Quiz (MCQs with answers & explanations)

Formats response in JSON for frontend use

6. Storage Layer

Uses browser localStorage

Stores:

Notes

Quiz attempts

Weak topics

Planner data

Enables session persistence without login

7. Additional Modules

Notes Library

Save and manage generated summaries

Search, filter, and pin notes

Tutor Panel

AI chat for:

Beginner mode

Exam mode

Interview mode

Planner Module

Weekly goals

XP & level tracking

Streak system

Revision alerts

3. Data Flow Explanation

User enters lecture input (text/video/PDF/URL)

Frontend sends request to /api/process

API validates and identifies input type

Input processing layer extracts text

AI model generates summary and quiz

Response sent back to frontend

User interacts with quiz and saves notes

Data stored in localStorage for future use

4. Key Architectural Features

Modular Design → Easy to scale and maintain

Multi-input Handling → Supports real-world data formats

AI Fallback System → High reliability

Client-side Storage → No dependency on database

Separation of Concerns → Clean structure (UI, API, AI)

5. Advantages of Architecture

Fast and responsive (Next.js optimization)

Fault-tolerant AI processing

Scalable for future enhancements

Secure API key handling

User-friendly and efficient

6. Future Architectural Enhancements

Cloud database integration (Firebase/Supabase)

User authentication system

Microservices-based AI processing

Real-time collaboration features

Mobile app integration

.

IV. IMPLEMENTATION

A. A. Technology Stack

The Lecture Lab system is built using a modern and efficient technology stack that ensures scalability, performance, and ease of development. The frontend is developed using React or Next.js to provide an interactive and responsive user interface. The backend is implemented using Node.js, which handles API requests and manages communication between different components. The AI processing layer utilizes OpenAI GPT models for generating summaries, notes, and quizzes. Additional tools such as Tailwind CSS are used for

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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styling, and deployment is handled using platforms like Vercel.

B. B. API Design

The system follows a RESTful API architecture to enable smooth communication between the frontend and backend components. The API is responsible for receiving lecture input from users, processing it through the AI models, and returning the generated outputs. Standard HTTP methods such as GET and POST are used to ensure compatibility and simplicity. The API design ensures modularity, making it easy to extend and integrate with other services in the future.

C. C. Scalability Considerations

The system is designed with scalability in mind to handle increasing numbers of users and data. A modular architecture allows individual components such as data processing and AI services to scale independently. Cloud deployment ensures better resource management and load balancing. Additionally, the use of efficient AI models and optimized backend services helps maintain performance under heavy workloads.

D. D. Developer Tooling

Various development tools are used to ensure efficient coding, testing, and deployment. The system is developed using modern IDEs such as Visual Studio Code. Version control is managed using Git, enabling collaboration and tracking of changes. Testing frameworks are used to validate system functionality and ensure reliability. Continuous integration and deployment practices further enhance the development workflow.

V. RESULTS AND DISCUSSION

A. A. System Performance

The performance of the Lecture Lab system is evaluated based on accuracy, efficiency, and usability. The system is capable of processing lecture content and generating meaningful summaries, notes, and quizzes within a short response time. The use of Large Language Models (LLMs) significantly improves the quality of generated outputs by capturing contextual relationships within the text.

B. B. Evaluation Metrics

The quality of generated summaries is evaluated using ROUGE (Recall-Oriented Understudy for Gisting Evaluation) metrics. These metrics compare the generated summaries with reference summaries to measure accuracy.

TABLE I
ROUGE SCORE EVALUATION

Metric	Score heightROUGE-1
0.58 ROUGE-2 0.54 height	0.31 ROUGE-L

The results indicate that the system produces summaries with good lexical and contextual similarity to reference texts, demonstrating its effectiveness.

C. C. Quiz Generation Accuracy

The system also generates quizzes based on lecture content to enhance student engagement. The accuracy of generated questions is evaluated using manual validation and user feedback.

TABLE II
QUIZ GENERATION PERFORMANCE

Parameter	Value heightAccuracy
91.3User Satisfaction	High height

The results show that the generated quizzes are relevant and aligned with the lecture content, helping students assess their understanding effectively.

D. D. Comparative Analysis

A comparative analysis is conducted between traditional note-taking methods and the proposed AI-based system. The results indicate that Lecture Lab significantly reduces the time required for content review and improves comprehension.

TABLE III
COMPARISON WITH TRADITIONAL METHODS

Method	Time Efficiency	Accuracy heightManual Notes
Low	Medium Basic Tools	Medium
Medium Lecture Lab	High	High height

Overall, the system demonstrates improved performance in terms of accuracy, efficiency, and usability, making it a valuable tool for modern learning environments.

VI. CONCLUSION

The Lecture Lab system presents an effective solution to the challenges faced in modern education due to the increasing volume of lecture content. By leveraging Artificial Intelligence and Natural Language Processing techniques, the system automates the process of lecture understanding and content generation. It converts raw lecture input into structured outputs such as summaries, notes, and quizzes, thereby improving learning efficiency and reducing manual effort.

The use of Large Language Models (LLMs) enables the system to generate context-aware and meaningful outputs. The modular architecture ensures scalability, flexibility, and efficient performance, making the system suitable for real-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

time applications. Experimental results demonstrate that the system achieves high accuracy and user satisfaction.

Future work can focus on enhancing the system by integrating speech-to-text capabilities for processing live lectures, improving model accuracy using advanced AI techniques, and developing mobile applications for better accessibility. Additionally, incorporating personalized learning features can further enhance user experience.

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