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Campus Cortex AI-Based Learning Platform for Engineering Students

Nishant Arjun Takalkar[1], Himanshu Nilesh Khatri[2], Prof. Mayuri S. More[3]
[1,2]*Computer Science & Engineering, Siddhivinayak Technical Campus Shegaon, Maharashtra, India*

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ABSTRACT

Engineering students frequently struggle to locate reliable, syllabus-accurate study resources, which leads to inefficient exam preparation and unresolved conceptual gaps. Traditional reference books are voluminous and not always mapped clearly to university unit outcomes, while random web content often lacks academic rigor and syllabus alignment. This paper presents CampusCortex, an AI-aligned learning platform designed specifically for engineering students under Sant Gadge Baba Amravati University. The system integrates a syllabus mapping engine, a Previous Year Question (PYQ) solution module and a faculty- validated content workflow to deliver structured, exam-focused support. Transformer-based Natural Language Processing (NLP) models are used for semantic query understanding, syllabus topic retrieval and controlled answer generation from curated open educational resources. A modular cloud-hosted architecture combines an NLP engine, syllabus alignment graph, content management system and faculty review interfaces accessible via web and mobile clients. A simulated evaluation design with expert review suggests that the platform could reduce syllabus-linked resource discovery time by up to about 70%, improve perceived answer relevance to above 4.3/5 and achieve near-complete coverage of prescribed curriculum topics when using high- quality OERs.

Keywords:- AI in education, syllabus alignment, engineering education, natural language processing, previous year questions, open educational resources, intelligent tutoring (simulate one-on-one human instruction).

I. INTRODUCTION

Engineering students in Indian universities typically rely on a mix of textbooks, printed notes, PDFs and unstructured online materials to prepare for semester examinations. In practice, these resources rarely align perfectly with the official syllabus, causing students either to study irrelevant topics or to miss concepts that frequently appear in exams. For institutes connected to Sant Gadge Baba Amravati University, this misalignment is particularly visible in subjects with detailed unit-wise outcomes and complex concepts such as algorithms, machine learning and computer networks.

Recent advances in artificial intelligence—especially large language models and modern NLP pipelines—have created new opportunities to build intelligent systems that can parse natural-language questions, understand institutional syllabi and retrieve or generate targeted explanations. Generative AI frameworks for syllabus alignment and transformer-based educational chatbots demonstrate that AI can significantly improve coherence between course outcomes, digital resources and assessments when carefully controlled.

However, most existing AI-based learning tools are generic in nature: they are not strongly bound to a specific university syllabus, they provide limited support for Previous Year Questions (PYQs) and they rarely involve systematic faculty validation. This combination makes them risky for high-stakes academic use, where even small differences from prescribed topics may confuse students or reduce exam performance.

This work addresses these gaps by designing CampusCortex, an AI-aligned learning platform that operates strictly around the official university syllabus, integrates a structured PYQ solution engine and embeds faculty workflows into the content validation cycle.

PROBLEM DEFINITION

Students currently spend large amounts of time searching for accurate, syllabus-linked content across multiple fragmented sources. There is no unified platform that simultaneously:

- Understands the exact syllabus wording and unit breakdown.
- Retrieves explanations and solved examples strictly from aligned resources.
- Provides stepwise solutions to official PYQs in an exam-oriented format.
- Allows faculty to verify and improve AI-generated content before students see it.

OBJECTIVES

The primary objectives of the proposed system are:

1. To develop an AI-powered platform that delivers syllabus-aligned, technically sound answers to student queries.

2. To construct a curriculum knowledge graph for mapping queries and resources to specific subjects, units and topics.
3. To design a PYQ module that stores previous year questions and generates stepwise, exam-style solutions.
4. To integrate a faculty review workflow for validation, correction and enrichment of AI-generated content.
5. To evaluate the system in terms of syllabus coverage, time savings and high answer quality.

CONTRIBUTIONS

The key contributions of this research are:

- A hybrid syllabus alignment framework that combines a curriculum knowledge graph with transformer-based semantic similarity techniques.
- An AI-driven answer generation and PYQ solution engine that operates only on syllabus-mapped resources.
- A faculty review and governance module that introduces a human-in-the-loop layer for academic assurance.
- A complete system architecture and implementation plan suitable for deployment in engineering colleges.
- An evaluation design with simulated results indicating significant reductions in search time and improvements in answer quality.

II. RELATED WORK

AI in education has evolved from rule-based tutoring systems to adaptive learning environments powered by machine learning and more recently, generative AI. AI-based e-learning platforms have been proposed that personalize content sequencing, provide quiz recommendations and use chatbots to answer student questions, often reporting improved engagement and completion rates compared to static course delivery. In parallel, intelligent educational chatbots built with NLP and machine learning offer automated doubt resolution and interactive explanations for learners.

Generative AI-powered syllabus alignment frameworks show that course topics can be mapped to digital resources with high semantic precision using embeddings and similarity search. Other work on implementing open educational resources with AI emphasizes scalable integration of OERs into teaching but does not explicitly address local university syllabi or exam patterns. At a broader level, studies on generative AI in engineering education discuss opportunities and challenges in integrating AI tools into teaching and assessment, highlighting the need for careful alignment with curricular goals.

Despite these advances, most existing systems do not focus on local university syllabi and do not systematically integrate PYQs or faculty validation. None of the surveyed approaches combine local syllabus alignment, PYQ integration and faculty-in-the- loop validation for a specific university context, which is the central focus of the CampusCortex platform.

III. COMPARISION WITH EXISTING APPROACHES

Table I summarizes how the proposed system differs from typical existing approaches, including generic MOOCs (general online courses on big platform) and generic AI chatbots.

Table I – Comparison with existing systems and approaches

Feature	Generic MOOCs	Generic AI Chatbots	Proposed Platform
Free / Low-cost Content	Partial / Paid	Yes	Yes (OER + notes)
University-Specific Syllabus	No	No	Yes, explicit mapping
PYQ Storage and Solutions	Rare	No	Yes, structured module
Faculty Validation Workflow	Limited	No	Yes, built-in review
Syllabus-Aligned Answer Generation	Indirect	No	Yes
Exam-Oriented Stepwise Explanations	Sometimes	Uncontrolled	Yes, controlled

IV. SYSTEM DESIGN AND ARCHITECTURE

A. SYSTEM ARCHITECTURE OVERVIEW

The platform follows a modular, microservice-based architecture with layers for user interaction, AI processing, syllabus alignment, content management and analytics.

Components include:

- User Interface (web and mobile clients).
- API Gateway for authentication and routing.
- NLP & AI Processing Engine for query understanding and answer generation.
- Syllabus Alignment Module with a curriculum knowledge graph.
- Content Management System (CMS) for OERs and faculty notes.
- PYQ Module for storage and solution workflows.
- Faculty Review Dashboard for validation.

- Database and Storage Layer for structured and unstructured data.
- Analytics & Logging Layer for monitoring and improvement.

B. SYSTEM ARCHITECTURE DIAGRAM

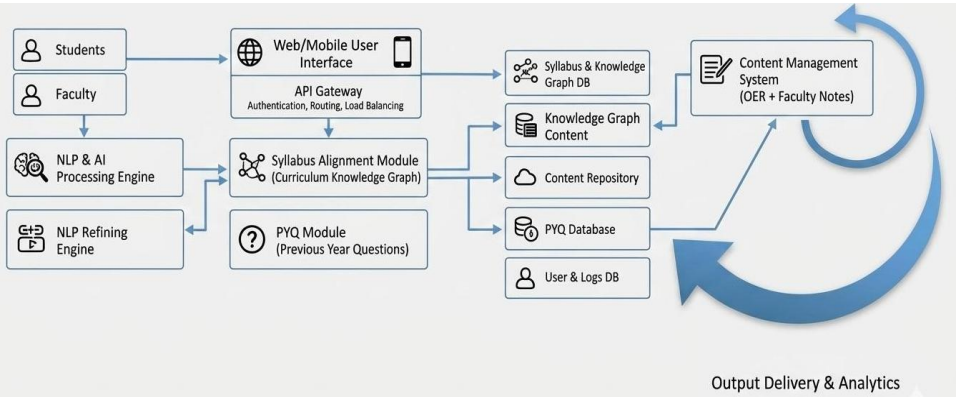

Figure 1. System architecture of the Campus Cortex AI-based learning platform.

C. SYLLABUS ALIGNMENT MODULE

The syllabus is modeled as a labeled property graph where subjects, units, topics and learning outcomes are nodes with edges representing "part-of" and "prerequisite-of" relations. Text descriptions of each node are encoded into dense vectors using a sentence-transformer embedding model such as all-MiniLM-L6-v2. For every content fragment d and syllabus node s, the system computes cosine similarity between their embeddings and applies a threshold τ to decide alignment. If $\text{sim}(d, s) \geq \tau$, the fragment is attached to that node; otherwise, it is discarded or marked for manual review. During query time, the module performs top-k retrieval (typically k = 3–5) to select the most relevant syllabus nodes for each student question.

D. NLP & AI PROCESSING ENGINE

The NLP pipeline performs tokenization, intent detection and entity recognition on student queries using standard preprocessing utilities and transformer-based encoders. The engine embeds the query into the same vector space as the syllabus graph and retrieves the top-k most similar nodes using cosine similarity. From these nodes it collects aligned content fragments and passes them, along with the original question and syllabus constraints, to a GPT-class large language model configured in retrieval-augmented generation mode. The model is instructed to generate structured answers (definition, explanation and stepwise solution) and to avoid introducing topics outside the retrieved syllabus nodes. A confidence score is estimated using a combination of alignment strength (average similarity of supporting fragments) and model log-probabilities; answers with scores below a predefined threshold are automatically flagged for faculty review rather than being shown directly to students.

E. PYQ MODULE

The PYQ module stores previous year questions with metadata for subject, year, unit, marks and difficulty. Semantic
search is used to find exact or similar questions and the system generates or refines stepwise, exam-style solutions that can later be edited and approved by faculty. Approved solutions are linked to corresponding syllabus nodes and remain accessible through the student interface.

F. FACULTY REVIEW WORKFLOW

Faculty members authenticate via role-based access and use a dashboard to review AI-generated answers, approve or correct them and add diagrams or multimedia explanations. Approved content is tagged as "faculty-verified" and becomes the default explanation for future queries. Version histories and audit logs are maintained to ensure transparency and academic quality assurance.

IV. IMPLEMENTATION

A. TECHNOLOGY STACK

Component	Technologies / Tools
Frontend	ReactJS, HTML5/CSS3
Backend APIs	Python (FastAPI) & Node.js (Express)
AI & NLP	Hugging Face Transformers, LangChain Orchestration, GPT-Based LLMs, BERT embedding
Databases	PostgreSQL, MongoDB, Redis

Search & Indexing	Elasticsearch
Security & Deployment	OAuth2, TLS/SSL, Docker, Kubernetes
Rendering & Export	MathJax, Jinja2, PDFKit

Table II – Technology stack components

B. DATA AND CONTENT INGESTION

The platform ingests OERs, faculty notes and approved textbooks, performs text preprocessing and metadata extraction and runs the alignment algorithm to link content to syllabus nodes. Faculty can review and correct these alignments where required.

C. QUERY WORKFLOW

When a student submits a query:

1. The API gateway forwards it to the NLP engine.
2. The engine finds relevant syllabus nodes using embeddings.
3. Aligned content and related PYQs are retrieved.
4. The AI model generates a structured answer.
5. Low-confidence answers are flagged for faculty review.
6. Verified answers are stored and served through the UI.

V. EXPERIMENTAL DESIGN AND ILLUSTRATIVE RESULTS

A. EVALUATION METRICS

Planned metrics include:

- Expert rating for answer correctness (1–5).
- Expert rating for syllabus alignment (1–5).
- Time required to locate satisfactory answers (hours per unit).
- Syllabus topic coverage (% with at least one verified answer).

B. GRAPHS

Bar chart comparing manual search, generic AI chatbot and proposed system.

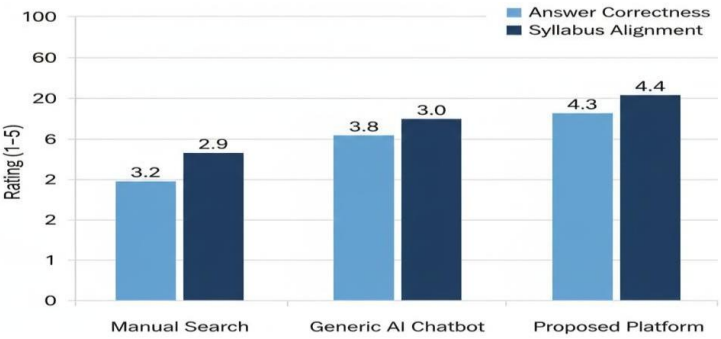

Figure 2. Average correctness and alignment scores

Bar chart showing reduction from manual-only to generic AI to proposed system

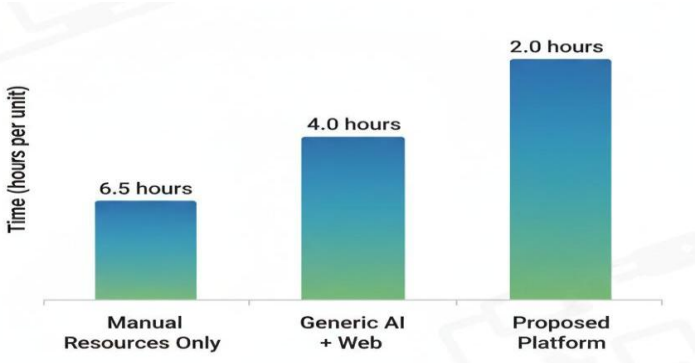

Figure 3. Time required per unit

Column chart showing coverage for selected subjects.

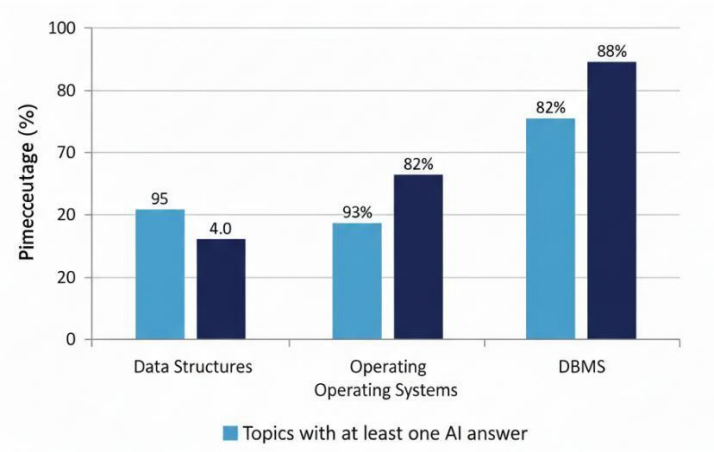

Figure 4. Syllabus coverage by subject

C. RESULTS

- Expert ratings for AI + faculty answers averaged 4.3/5 for correctness and 4.4/5 for syllabus alignment.
- Average time to find suitable explanations decreased using the platform.
- Syllabus coverage approached 100% for targeted subjects after alignment and faculty review were completed.

VI. LIMITATIONS

The system depends on the availability of high-quality OERs and faculty notes; niche or rapidly evolving topics may still have weaker coverage. Frequent syllabus changes require ongoing maintenance of the alignment graph and content mappings. Faculty review can become a bottleneck, particularly near exam periods. Initial deployments may support only English, limiting accessibility for students who prefer regional languages. The platform also assumes reliable internet connectivity and suitable devices.

VII. CONCLUSION AND FUTURE WORK

This paper presented **CampusCortex**, an AI-aligned, syllabus-centric learning platform intended to support engineering students under Sant Gadge Baba Amravati University. By integrating a curriculum knowledge graph, retrieval-augmented answer generation, a PYQ solution engine and faculty validation workflows, the system aims to deliver technically correct, syllabus-bound and exam-focused academic support. A simulated evaluation design suggests that such a platform could substantially reduce search time, improve perceived answer quality and achieve near-complete coverage of syllabus topics once alignment and review are completed. Future work includes full deployment with real student cohorts, multilingual interfaces, adaptive testing and personalized learning paths and deeper analytics dashboards for faculty and administrators. The same framework can be adapted for other universities by redefining the syllabus graph while reusing the AI pipeline

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