A Project Submitted to the Sylhet Engineering College for the Degree of Bachelor of Science in Computer Science and Engineering

Smart Textbook of Bangladesh: A RAG-Powered Educational Chat-bot

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Recommendation Letter from Project Supervisor

The Project titled "**Smart Textbook of Bangladesh : A RAG-Powered Educational Chat-bot**" submitted by **Tanjim Akter Anisa Payel** as mentioned below has been accepted as satisfactory in fulfillment of the requirements for the degree B. Sc. in Computer Science and Engineering on 22 July, 2025.

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Certificates of Acceptance

The Project is titled **"Smart Textbook of Bangladesh : A RAG-Powered Educational Chat-bot"** submitted by **Tanjim Akter Anisa Payel;** Student ID. **2019331564**; Session **2019-20**, to the Department of Computer Science and Engineering , Sylhet Engineering College, has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Computer Science and Engineering and approved as to its style and contents.

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ABSTRACT

The Smart Textbook of Bangladesh is an innovative AI-powered chat-bot designed to enhance educational accessibility by providing curriculum-aligned responses from National Curriculum and Textbook Board (NCTB) textbooks for Classes 6 to 10. Focusing on Bangla, Bangladesh and Global Studies, and Religious Studies (Islam, Hinduism, Christianity, and Buddhism), the chat-bot addresses the need for interactive learning tools in Bangladesh secondary education system. Utilizing Retrieval-Augmented Generation (RAG), the system integrates Optical Character Recognition (OCR) with Tesseract to extract text from scanned NCTB PDFs, processes it using HuggingFace embeddings for semantic search, and generates natural language responses with HuggingFace free Bangla model. A user-friendly interface, developed with Streamlit, supports both online and offline access, ensuring usability for students in urban and rural areas with varying digital literacy. The project emphasizes cultural sensitivity in handling religious content and aligns with NCTBs competency-based curriculum. By leveraging open-source tools and a web-based platform, the Smart Textbook offers a scalable solution to bridge educational gaps, reduce reliance on private tutoring, and support Bangladesh Digital Bangladesh initiative. Challenges such as OCR accuracy for Bangla scripts and limited datasets for niche subjects are mitigated through prepossessing and corpus curation. This project demonstrates the potential of AI to transform education in low-resource settings, fostering self-paced learning and curriculum engagement for Bangladeshi students.

1. INTRODUCTION

1.1 Overview

In an era where technology is reshaping every facet of human life, education stands as a critical domain where innovation can yield transformative outcomes. In Bangladesh, where the literacy rate has climbed to approximately 74% in recent years, the need to enhance the quality and accessibility of educational resources remains paramount. The Smart Textbook of Bangladesh emerges as a pioneering solution to address these needs, offering an AI-powered educational chat-bot that delivers curriculum-aligned answers directly from National Curriculum and Textbook Board (NCTB) textbooks. By leveraging Retrieval-Augmented Generation (RAG) technology, this project aims to make learning more interactive, accessible, and efficient for students across the nation.

The Smart Textbook project focuses initially on three key subjects: Bangla, Bangladesh & Global Studies (BGS), and Religious Studies. These subjects, integral to the NCTB curriculum, are text-heavy and often require students to engage deeply with complex content. Traditional textbooks, while comprehensive, lack the interactivity needed to support modern learning preferences. Students frequently struggle to locate specific information or clarify concepts quickly, leading to frustration and disengagement. The Smart Textbook addresses these challenges by providing a platform where students can pose questions in natural language and receive accurate, contextually relevant responses derived from their prescribed textbooks. This initiative not only enhances comprehension but also fosters self-directed learning and critical thinking, aligning with global educational trends toward personalized and technology-driven instruction.

The vision of the Smart Textbook is to create a scalable, user-friendly tool that empowers students to take control of their learning journey. By integrating advanced AI technologies, such as vector databases and large language models, the project ensures that responses are both accurate and aligned with the national curriculum. This endeavor represents a significant step toward modernizing education in Bangladesh, offering a model that can be expanded to other subjects and grade levels in the future.

1.2 Education in Bangladesh

Bangladesh has made remarkable strides in expanding access to education over the past few decades. According to the United States Agency for International Development (USAID), 98% of primary school-age children are enrolled in school, achieving near-universal primary enrollment and gender parity in access to education . Secondary school enrollment has also risen, reaching 71.49% in 2023, as reported by the World Bank. These achievements reflect the government's commitment to improving educational outcomes, evidenced by initiatives such as free textbook distribution and curriculum reforms.

The NCTB plays a central role in this ecosystem by developing and distributing standardized textbooks used across primary, secondary, and higher secondary levels. These textbooks are the cornerstone of the national curriculum, ensuring consistency in educational content nation-wide. However, despite these advancements, several challenges persist. The static nature of textbooks limits their ability to engage students actively, often leading to rote memorization rather than deep understanding. Students frequently face difficulties navigating lengthy texts to find specific information, particularly in subjects like Bangla, BGS, and Religious Studies, which involve dense narratives and factual content.

Moreover, disparities in educational resources between urban and rural areas exacerbate in-equities. While urban students may have access to private tutoring or digital resources, rural students often rely solely on textbooks and limited teacher support. The quality of education also remains a concern, with many students struggling to acquire foundational skills necessary for continued learning. The ongoing curriculum reform, set to be fully implemented by 2027, aims to shift toward a competency-based approach, emphasizing critical thinking and practical application. However, the transition period highlights the need for innovative tools like the Smart Textbook to support students in adapting to these changes.

Metric	Value
Primary School Enrollment (2023)	98%
Secondary School Enrollment (2023)	71.49%
Literacy Rate	74%
Students Studying Abroad (2017)	56,000

1.3 AI and Chat-bots in Education

Artificial Intelligence (AI) has emerged as a transformative force in education, offering tools that personalize learning, provide instant feedback, and enhance accessibility. AI-powered chat-bots, in particular, have gained traction for their ability to simulate human-like conversations, making them ideal for addressing student queries and facilitating interactive learning. Globally, several successful implementations highlight the potential of chat-bots in education.

For instance, Duolingo employs AI chat-bots to enhance language learning by providing inter-active practice sessions tailored to individual proficiency levels . Similarly, Mondly uses AI to facilitate faster comprehension of complex concepts through conversational interfaces . In higher education, chat-bots are used for student on-boarding, answering frequently asked questions, and providing virtual tours of online platforms. A notable example is the Chat-layer chat-bot at the Singapore Institute of Technology, which offers real-time assistance to students, demonstrating the effectiveness of AI in managing repetitive inquiries and supporting learning management systems.

Research suggests that AI chat-bots can significantly improve student engagement and learning outcomes. A systematic literature review highlights their ability to provide timely feedback, reduce the burden on educators, and offer personalized learning experiences. For example,

chat-bots can adapt content to a student's learning style, challenging advanced learners with complex material while supporting beginners with simpler explanations

1.4 Retrieval-Augmented Generation (RAG) Technology

Retrieval-Augmented Generation (RAG) is an advanced AI framework that enhances the ac-curacy and relevance of large language models (LLMs) by integrating information retrieval with natural language generation. In a RAG system, when a user submits a query, the system first retrieves relevant documents or passages from an external knowledge base. These retrieved texts are then used by a language model to generate a coherent, contextually appropriate response. This approach ensures that responses are grounded in verified information, reducing the risk of generating incorrect or fabricated answers, a common issue known as "hallucination" in traditional LLMs .

The RAG process involves two main components: a retriever and a generator. The retriever uses semantic search techniques to identify relevant content from a database, often by converting text into vector representations and comparing them for similarity. The generator, typically a large language model like GPT-4, then crafts a response based on the retrieved content. For the Smart Textbook project, RAG is particularly suitable because it allows the chat-bot to provide answers directly sourced from NCTB textbooks, ensuring alignment with the national curriculum.

The process for implementing RAG in this project includes several steps:

• **Data Collection**: Downloading NCTB textbooks from their official website.

• **Text Extraction**: Using Optical Character Recognition (OCR) to extract text from scanned PDF files.

• **Text Segmentation**: Dividing the extracted text into smaller, manageable chunks.

• **Vector Database Creation**: Converting text chunks into vector representations and storing them in a vector database, such as ChromaDB.

• **Query Processing**: Converting user queries into vector representations.

• **Semantic Search**: Identifying the most relevant text chunks using semantic similarity.

• **Response Generation**: Using a language model to generate natural, curriculum-aligned responses based on the retrieved chunks.

This approach ensures that the chat-bot delivers accurate and relevant answers, making it an ideal tool for educational applications where precision is critical.

2. PROBLEM STATEMENT

The Smart Textbook of Bangladesh project addresses critical challenges in providing accessible, interactive, and curriculum-aligned educational resources for secondary school students in Bangladesh. By leveraging an AI-powered chatbot with Retrieval-Augmented Generation (RAG) and Optical Character Recognition (OCR), the project aims to transform traditional learning methods. This section outlines the key challenges in educational access, their impact on stakeholders, and the need for a digital solution tailored to the National Curriculum and Textbook Board (NCTB) framework.

2.1 Current Challenges in Educational Access

The education system in Bangladesh faces significant obstacles in delivering effective learning resources for secondary school students, particularly in the subjects of Bangla, Bangladesh and Global Studies, and Religion (Islam, Hinduism, Christianity, Buddhism). These challenges limit the adoption of modern educational technologies and hinder student outcomes.

• **Limited Interactive Learning Tools:** Traditional learning relies heavily on printed NCTB textbooks and classroom instruction. Students lack access to interactive tools that provide real-time question answering or personalized learning support, particularly for text-heavy subjects. This promotes rote memorization over the NCTB's competency-based learning goals.

• **Manual Textbook Processing:** Teachers and students depend on physical textbooks, which are often outdated, damaged, or unavailable in rural areas. Manually searching for content or answers are time-consuming and inefficient, limiting quick access to relevant information.

• **Language Processing Barriers:** Bangla's complex script, including conjunct characters and orthographic variations, poses challenges for developing natural language processing (NLP) tools tailored to educational content. Existing models like BanglaBERT are trained on general corpora (e.g., news), not NCTB textbooks, reducing their effectiveness for curriculum-specific queries.

• **Accessibility Issues in Rural Areas:** Over 70% of Bangladesh's population resides in rural

areas with limited internet access (30% household penetration). This restricts the use of online learning platforms, leaving rural students reliant on physical resources or costly private tutoring.

• **Cultural and Religious Sensitivity:** Religious education requires careful handling to ensure accurate and respectful content delivery across diverse faiths. Manual teaching methods struggle to address varied student needs, and existing digital tools lack the cultural sensitivity needed for these subjects.

2.2 Impact on Stakeholders:

The identified challenges significantly affect students, teachers, and educational institutions, hindering effective learning and administrative efficiency.

- **Teachers:** Teachers spend significant time manually preparing lessons and answering queries, reducing their capacity for interactive teaching. The lack of digital tools tailored to NCTB curricula limits their ability to provide personalized support for diverse subjects like Religion.

- **Educational Institutions:** Schools and the NCTB lack centralized platforms to deliver digital learning resources, hindering progress toward the Digital Bangladesh 2030 vision. Manual processes increase administrative burdens and limit scalability across urban and rural institutions.

- **Students:** Students face difficulties accessing interactive, curriculum-aligned resources, particularly in rural areas with limited internet or tutoring options. Reliance on printed textbooks and manual methods reduces engagement and understanding, especially for complex topics in Bangladesh and Global Studies or religious texts, leading to lower academic performance.

2.3 Identify the Challenges:

The identified challenges underscore the urgent need for a digital solution to enhance educational access and efficiency. An AI-powered chat-bot leveraging RAG and OCR can address these issues by:

- Providing interactive, real-time question answering aligned with NCTB curricula for Bangla, Bangladesh and Global Studies, and Religion.
- Digitizing textbook content through OCR for searchable, accessible resources.
- Overcoming language barriers by fine-tuning NLP models for Bangla educational texts.
- Supporting offline access to cater to rural students with limited internet.
- Ensuring culturally sensitive handling of religious content across diverse faiths.
- Reducing teacher workload through automated query responses.

This solution aligns with Bangladesh's educational goals, promoting competency-based learning and equitable access across diverse regions and communities.

3. OBJECTIVES

3.1 Primary Objectives

The primary objective of the Smart Textbook of Bangladesh project is to develop an AI-powered educational chat bot that delivers accurate, curriculum-aligned answers from National Curriculum and Textbook Board (NCTB) textbooks, thereby enhancing the learning experience for students across Bangladesh. The chat bot initially focuses on Bangla, Bangladesh & Global Studies (BGS), and Religious Studies, addressing the pressing need for interactive and accessible educational tools within the national education system. By leveraging Retrieval-Augmented Generation (RAG) technology, the project aims to provide a scalable and innovative solution that supports the ongoing curriculum reform toward competency-based learning.

3.1.1 Develop an Advanced Retrieval-Augmented Generation (RAG) System:

To Create a robust system capable of retrieving relevant content from NCTB textbooks and generating natural language responses using state-of-the-art language models.

To implement optical character recognition (OCR) to extract text from PDF versions of text-books, ensuring compatibility with Bangla language documents and accurate text processing.

To Organize extracted text into manageable segments and store them in an efficient vector-based retrieval system to enable rapid and accurate query processing.

3.2 Enable Robust Bangla Language Processing:

To Ensure the chat bot can effectively process and respond to queries in Bangla, catering to the linguistic preferences of Bangladeshi students. And utilizing language models and embedding techniques optimized for Bangla text to provide seamless, culturally relevant, and accurate interactions.

3.3 Designing a User-Friendly Web Interface

Developing a web-based platform that allows students to submit text-based queries in Bangla and receive clear, curriculum-aligned responses. And ensuring the interface is intuitive, responsive, and accessible across various devices, including desktops, tablets, and mobile phones, to maximize reach and usability.

Validating the chat-bots responses to confirm they are accurate, relevant, and directly sourced from NCTB textbook content. While incorporating user feedback mechanisms to continuously monitor and improve response quality and overall system performance.

3.4 Demonstrate Scalability and Educational Impact:

Providing a proof-of-concept that showcases the potential of AI-driven tools to enhance educational access, engagement, and learning outcomes in Bangladesh. And establishing a foundation for expanding the chat-bots coverage to additional subjects, grade levels, and potentially other languages in future iterations.

These objectives collectively aim to transform the educational landscape in Bangladesh by providing an innovative, interactive, and accessible learning tool that aligns with the national curriculum and empowers students to achieve academic success.

4. Project Features

The Smart Textbook of Bangladesh project introduces an innovative AI-powered educational chat-bot designed to enhance the learning experience by providing interactive, curriculum-aligned, and accessible educational support. The following features highlight the system's capabilities, ensuring it meets the diverse needs of students, aligns with the National Curriculum and Textbook Board (NCTB) standards, and supports the educational goals of Bangladesh.

4.1 Curriculum-Aligned Responses:

The chat-bot delivers answers sourced directly from NCTB textbooks, ensuring strict adherence to the national curriculum for Bangla, Bangladesh & Global Studies (BGS), and religious Studies.

Responses are generated using advanced retrieval and generation techniques, guaranteeing accuracy and relevance to the specific content taught in classrooms.

The system supports students in navigating complex textbook material by providing concise, contextually appropriate answers tailored to their queries.

4.2 Bangla Language Support:

The chat-bot fully supports queries and responses in Bangla, catering to the linguistic preferences of Bangladeshi students and ensuring cultural relevance. The text processing is optimized for Bangla, enabling accurate interpretation of questions and generation of natural, fluent responses. The system handles Bangla text extraction from PDF-based textbooks, overcoming challenges associated with non-standard fonts and formatting.

4.3 Interactive and User-Friendly Interface:

A web-based platform allows students to submit queries via a simple, intuitive interface accessible on desktops, tablets, and mobile devices. The interface is designed for ease of use, with minimal learning curve, enabling students of varying technological proficiency to engage with the system effectively. While having features such as query history and suggested questions enhance interactivity, encouraging students to explore topics deeply.

4.4 Efficient Information Retrieval:

The system employs a robust retrieval mechanism to quickly locate relevant textbook content, reducing the time students spend searching for information. Text is segmented and stored in a vector-based system, enabling rapid semantic search and retrieval of precise content segments. The retrieval process ensures that responses are grounded in verified textbook material, minimizing errors and enhancing reliability.

4.5 Feedback and Continuous Improvement:

A built-in feedback mechanism allows students to rate the accuracy and usefulness of responses, providing valuable data for system refinement. Feedback is used to fine-tune the retrieval and generation processes, ensuring ongoing improvements in response quality and user satisfaction. The system supports iterative updates, allowing developers to incorporate new textbook editions or additional subjects as needed.

4.6 Scalability and Accessibility:

The chat-bot is designed to be scalable, with the potential to expand to additional NCTB subjects, grade levels, and even other languages in future iterations. Cloud-based deployment ensures accessibility across Bangladesh, including rural areas with limited educational resources, provided an internet connection is available. The system is optimized for low-bandwidth environments, making it feasible for use on basic smartphones and devices commonly available to students.

4.7 Scalability and Accessibility:

The chat-bot aligns with Bangladesh's ongoing curriculum reform toward competency based learning, set for completion by 2027, by fostering critical thinking and self-directed learning. It encourages students to ask exploratory questions, promoting deeper understanding of concepts rather than rote memorization. The system provides explanations and contextual insights, supporting the development of analytical skills emphasized in the new curriculum.

These features collectively position the Smart Textbook as a transformative tool in Bangladesh educational landscape, offering an interactive, accessible, and curriculum-aligned platform that empowers students, supports teachers, and aligns with national educational goals.

5. LITERATURE REVIEW

The Smart Textbook of Bangladesh project develops an AI-powered chat-bot using Retrieval-Augmented Generation (RAG) and Optical Character Recognition (OCR) to provide curriculum-aligned responses from National Curriculum and Textbook Board (NCTB) textbooks. This section reviews existing research on AI in education, Bangla natural language processing (NLP), OCR for non-Latin scripts, RAG systems, educational technology in Bangladesh, chat-bot design principles, and policy implications. By analyzing prior work and identifying gaps, this review establishes the project's novelty and relevance.

5.1 AI in Education: Global Trends

Artificial Intelligence (AI) has revolutionized education through intelligent tutoring systems (ITS), chat-bots, and personalized learning platforms. Woolf (2010) notes that ITS, such as Carnegie Learning's MATHia, adapt to student needs, improving performance by up to 20% in mathematics. Duolingo's chat-bot enhances language learning through interactive dialogues, while Google's Socratic uses AI to answer homework queries via text and image inputs. These systems leverage NLP and machine learning to provide scalable, engaging learning experiences.

However, global AI tools primarily support high-resource languages like English, limiting their applicability to Bangla-speaking students. They also lack alignment with specific curricula, such as NCTB's competency-based framework. In resource-constrained settings like Bangladesh, high computational requirements and internet dependency restrict access. The Smart Textbook addresses these by offering a localized, curriculum-specific solution optimized for low-resource environments.

5.2 Bangla Natural Language Processing

Bangla, a low-resource language, poses unique challenges in NLP due to limited datasets and complex morphology. Early efforts used rule-based and statistical methods for tasks like

summarization and sentiment analysis. Transformer models like BanglaBERT and mT5 [11] have improved performance in translation and question answering, achieving up to 85% accuracy in benchmark tasks. However, these models are trained on general corpora (e.g., news), not educational texts, reducing their effectiveness for NCTB content.

Prepossessing challenges, such as handling conjunct characters and orthographic variations, further complicate Bangla NLP]. The lack of annotated educational datasets hinders curriculum-aligned applications. The Smart Textbook mitigates these by fine-tuning models on NCTB texts and integrating RAG for context-aware responses.

5.3 Optical Character Recognition for Bangla

OCR is critical for extracting text from NCTB textbooks. Tesseract supports Bangla scripts, but complex ligatures and degraded documents reduce accuracy [14]. Deep learning-based OCR, using CNNs and LSTMs, achieves up to 95% character recognition for printed Bangla. Prepossessing techniques like denoising and adaptive thresholding improve performance by 15%. However, handwritten notes and varied textbook layouts (e.g., two-column formats) remain challenging.

Few OCR systems are tailored for educational texts in Bangla, limiting their use in projects like the Smart Textbook. This project employs advanced prepossessing and domain-specific OCR tuning to ensure robust text extraction from NCTB materials.

5.4 Retrieval-Augmented Generation (RAG)

RAG combines information retrieval and generative AI to deliver accurate responses, ideal for educational question answering. Systems like IBM's Watson and recent educational chat-bots use RAG to reduce hallucination compared to models like "shahidul034/BanglaGPT" and "sentence-transformers/distiluse-base-multilingual-cased-v2". RAG relies on efficient retrieval (e.g., FAISS) and a robust corpus, but its application to Bangla is limited by sparse datasets.

The Smart Textbook pioneers RAG for Bangla education, using a curated NCTB corpus and fine-tuned generative models to ensure factual, curriculum-aligned responses.

5.5 Educational Chatbot Design

Bangladesh's educational digitization includes systems like SUST's hall application and Dhaka University's administrative tools. NCTB's e-learning platforms provide digital textbooks but lack interactivity. Apps like Muktopaath target adult education, not school curricula. Accessibility barriers, such as limited internet (30% rural penetration) and low digital literacy, restrict adoption.

The Smart Textbook offers a mobile-friendly, offline-capable chat-bot, aligning with NCTB standards to enhance accessibility for diverse students.

5.6 Educational Chatbot Design

Effective chat-bots require natural language understanding, context awareness, and intuitive interfaces. Jill Watson, used in Georgia Tech's courses, achieves 97% accuracy in answering queries. In low-resource settings, text-based, offline-capable interfaces are critical

5.7 Research Gaps

The literature highlights several gaps:

• Lack of Bangla-specific educational AI tools aligned with NCTB curricula.

• Limited OCR accuracy for Bangla educational texts.

• Sparse RAG applications for low-resource languages.

• Insufficient curriculum alignment in global AI tools.

• Accessibility barriers in rural Bangladesh.

5.8 Relevance to the Project

The Smart Textbook addresses these gaps by integrating RAG and OCR for NCTB-aligned responses in Bangla, with a mobile-friendly, offline-capable interface. This review validates its novelty in advancing Bangla education through AI.

6. Scope and Limitations

The Smart Textbook of Bangladesh project aims to develop an AI-powered chat-bot that lever-ages Retrieval-Augmented Generation (RAG) and Optical Character Recognition (OCR) to deliver curriculum-aligned responses from National Curriculum and Textbook Board (NCTB) textbooks. This section outlines the project's scope, specifying its focus, target users, and technological framework, and discusses its limitations, addressing challenges in implementation and deployment within the context of Bangladesh's educational landscape.

6.1 Scope

The Smart Textbook project is designed to enhance educational accessibility for secondary school students in Bangladesh by providing an interactive, curriculum-aligned learning tool.

The scope is defined as follows:

• **Subject Coverage:** The project focuses on NCTB textbooks for three subjects: Bangla, Bangladesh and Global Studies, and Religion (covering Islam, Hinduism, Christianity, and Buddhism) for Classes 6 to 10. These subjects are text-heavy and central to Bangladesh's secondary curriculum, aligning with the NCTB's competency-based learning framework.

• **Target Users:** The primary users are secondary school students (ages 11–16) and teachers across urban and rural Bangladesh. The chat-bot aims to support self-paced learning and classroom instruction, particularly for students with limited access to private tutoring.

• **Functionality:** The chat-bot provides text-based question-answering capabilities, retrieving relevant content from NCTB textbooks using RAG and extracting text via OCR. It supports both online and offline modes to accommodate areas with limited internet connectivity.

• **Technological Framework:** The system employs open-source tools, including Tesseract for OCR and FAISS for RAG-based retrieval, integrated with a fine-tuned Bangla language model

(e.g., BanglaBERT). The interface is web-based and mobile-compatible, prioritizing simplicity for users with varying digital literacy.

• **Geographic and Linguistic Focus:** The project primarily serves Bangla-speaking students in Bangladesh, with potential scalability to Bangla-speaking communities in regions like West Bengal, India. It supports queries in Bangla and limited English inputs to accommodate mixed-language usage.

6.2 Limitations

Despite its potential, the Smart Textbook project faces several technical and practical constraints, which are critical to acknowledge for realistic implementation and evaluation:

• **Language Processing Challenges**: Bangla's complex morphology, including conjunct characters and orthographic variations, poses difficulties for NLP models. The limited availability of annotated datasets for NCTB-specific content, particularly for Bangladesh and Global Studies and religious texts, may reduce the chatbot's ability to handle nuanced or context-specific queries, such as interpreting Quranic verses or Buddhist sutras.

• **OCR Accuracy**: While Tesseract supports Bangla scripts, its accuracy decreases for poorly scanned textbooks, handwritten notes, or complex layouts (e.g., multi-column formats with embedded images). This may limit the system's ability to extract complete or accurate con-tent from all NCTB textbooks.

• **RAG Constraints**: The effectiveness of RAG depends on the quality and size of the retrieval corpus. The lack of a comprehensive, digitized NCTB corpus for the targeted subjects may lead to incomplete or less relevant responses, particularly for niche topics in Bangladesh and Global Studies.

• **Offline Functionality Trade-offs**: Offline mode, essential for rural users, restricts the chat-bot to a preloaded corpus and model, potentially reducing response depth and real-time updates. Storage limitations on low-end devices may further constrain offline performance.

- **Cultural and Religious Sensitivity**: Handling religious content (e.g., Islamic Hadith, Hindu scriptures, Christian or Buddhist teachings) requires careful design to ensure accuracy and respect across diverse faiths. Misinterpretations or biased responses could undermine user trust.
- **Resource Constraints**: The project relies on open-source tools and limited computational resources, which may restrict the scale of model training or optimization. Access to high-end hardware for fine-tuning large language models is limited in the context of an undergraduate project.
- **User Accessibility**: While designed for simplicity, the chatbot may still pose challenges for users with low digital literacy, particularly in rural areas. Ensuring intuitive interaction for all age groups and technical backgrounds remains a challenge.

These limitations will be addressed where possible through strategies such as preprocessing for OCR, manual corpus curation, and user testing for interface design. However, they define the practical boundaries of the project's implementation and deployment.

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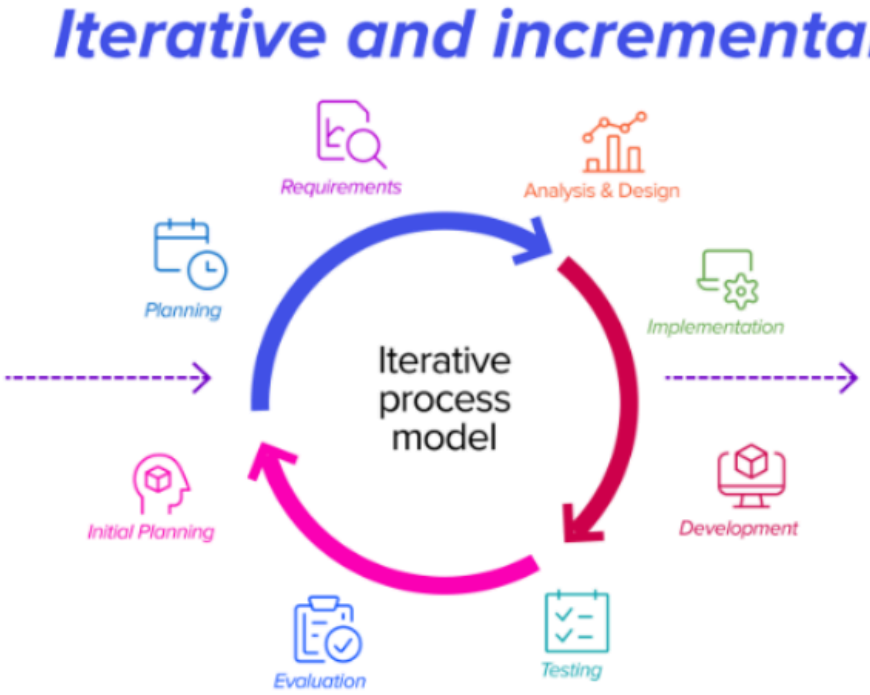
7. Methodology

The Smart Textbook of Bangladesh project develops an AI-powered educational chat-bot to deliver accurate, curriculum-aligned responses from National Curriculum and Textbook Board (NCTB) textbooks for Bangla, Bangladesh and Global Studies, and Religious Studies (Islam, Hinduism, Christianity, and Buddhism) for Classes 6 to 10. This section outlines the systematic approach to building the chat-bot, encompassing data collection, text extraction via Optical Character Recognition (OCR), text prepossessing and chunking, vector database creation, query processing, response generation, chat-bot interface development using Streamlit, deployment, and system architecture. Each phase is designed to ensure the chat-bot provides accessible,

interactive, and reliable educational support, tailored to the linguistic and cultural context of Bangladesh. The approach is followed as below:



7.1 Data Collection

The initial phase involved gathering the textual resources that form the chatbot's knowledge base. We collected NCTB textbooks for Classes 6 to 10, covering three subjects: Bangla, Bangladesh and Global Studies, and Religious Studies. The Religious Studies curriculum includes separate textbooks for Islam, Hinduism, Christianity, and Buddhism, reflecting the diversity of religious education in Bangladesh. A total of 15 text-books were downloaded in PDF format from the official NCTB website (cyanhttp://www.nctb.gov.bd/), ensuring alignment with the national curriculum and the competency-based learning framework introduced in 2023. The PDFs were organized by subject and class, stored in a structured directory to facilitate subsequent processing. Challenges included ensuring all relevant textbooks were available and verifying their currency, as NCTB periodically updates its publications.

7.2 Text Extraction Using OCR

Since most NCTB textbooks are provided as scanned PDFs, Optical Character Recognition (OCR) was employed to convert images into machine-readable text. We selected Tesseract, an open-source OCR engine, due to its support for Bangla scripts and compatibility with Python-based workflows. To enhance Tesseract's accuracy for Bangla's complex ligatures and varied fonts, we implemented prepossessing techniques using the opencv library:

• **Grayscale Conversion:** Converted PDF page images to grayscale to simplify processing.

• **Gaussian Blur:** Applied to reduce noise and artifacts in scanned images.

7.3 Text Prepossessing and Chunking

The raw OCR output required prepossessing to remove artifacts and prepare it for vectorization. This involved:

• **Removal of Non-Content Elements:** Headers, footers, page numbers, and decorative text were identified using regular expressions and removed to focus on core content.

• **Error Correction:** Common OCR errors, such as misrecognized Bangla conjunct characters, were corrected using custom scripts based on known patterns.

• **Text Normalization:** Text was standardized to UTF-8 encoding, with whites- pace normalized to ensure consistency across chunks.

The cleaned text was segmented into smaller units, or chunks, to enable efficient retrieval. We chose to split text by paragraphs, identified by double newlines, as this preserves contextual meaning. Paragraphs exceeding 300 words were further divided into chunks of approximately 150–200 words to balance granularity and context. Each chunk was tagged with meta-data

(textbook title, chapter, page number) to provide source attribution in responses. This process ensured that the chat-bot could retrieve precise, relevant content for user queries, particularly for text-heavy subjects like Bangladesh and Global Studies.

7.4 Vector Database Creation:

To enable semantic search, text chunks were transformed into vector representations using embeddings from the Hugging Face Transformers library. We selected the sentence-transformers/paraphrase-multilingual-mpnet-base-v2 model, which supports over 50 languages, including Bangla, and generates 768-dimensional vectors capturing semantic meaning. Each chunk was passed through the model to produce a dense vector, ensuring that similar content (e.g., related topics in Religious Studies) would have proximate vector representations.

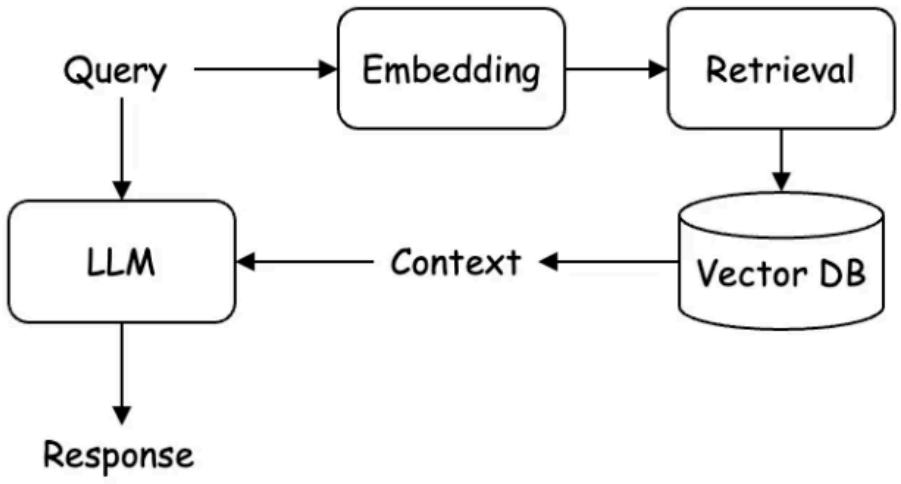
The vectors were stored in an in-memory vector store using FAISS (Face-book AI Similarity Search), chosen for its efficiency in large-scale similarity searches. We created a FAISS index using the IndexFlatIP method, which computes inner products for cosine similarity searches. All chunk vectors were added to the index, along with their metadata, enabling rapid retrieval of relevant content. The in-memory approach was selected to optimize performance for the prototype, though it limits scalability compared to persistent databases like Pinecone.

7.5 Query Processing:

When a user submits a query, it is converted into a vector using the same paraphrase-multilingual-mpnet-base-v2 model to ensure consistency with the chunk embedding. The query vector is then used to perform a similarity search in the FAISS index, retrieving the top-5 most similar chunks based on cosine similarity. The choice of k=3 balances relevance and computational efficiency, ensuring sufficient context for response generation. The retrieved chunks, along with their metadata, are passed to the response generation phase, maintaining traceability to the original textbook content.

7.6 Response Generation:

Response generation leverages HuggingFace based free model, selected for its ability to generate coherent text in multiple languages, including Bangla, when provided with appropriate context. The retrieved chunks are concatenated with separators (e.g., "||") and included in a prompt structured as follows:



The model parameters were set with a temperature of 0.7 to balance creativity and accuracy, and a maximum token limit of 150 to ensure concise responses suitable for educational use. If the retrieved chunks do not adequately address the query, the system returns a message indicating that the information may not be available in the current corpus. This approach ensures responses are grounded in NCTB content, critical for subjects like Religious Studies, where accuracy and cultural sensitivity are paramount.

7.7 Chat-bot Interface with Streamlit:

The chatbot's user interface was developed using Streamlit, a Python-based framework for creating interactive web applications[48]. Streamlit was chosen for its simplicity, rapid development capabilities, and compatibility with Python-based AI workflows, making it ideal for a student-facing application in Bangladesh. The interface includes:

• **Subject Selection:** A dropdown menu allowing users to choose the subject (Bangla, Bangladesh and Global Studies, or Religion), filtering the vector database to relevant textbooks.

• **Query Input:** A text input field for users to enter questions in Bangla or mixed

Bangla-English.

• **Submit Button:** Triggers the RAG pipeline to process the query and generate a response.

• **Response Display:** A text area showing the generated answer, with source metadata (e.g., textbook and page number).

• **Feedback Mechanism**: Buttons for users to rate response helpfulness, collecting data for future improvements.

The Streamlit app directly calls the RAG functions (embedding, search, and generation) and displays results in real-time, ensuring a seamless user expe-rience. The interface is designed to be intuitive, accommodating students with varying digital literacy, particularly in rural areas.

7.8 Deployment:

The chatbot was deployed using Streamlit Cloud, a hosting platform tailored for Streamlit applications, offering a free tier suitable for academic projects . The deployment process involved:

• **Repository Setup:** Created a GitHub repository containing the Streamlit app code, including app.py and a requirements.txt file listing dependencies (e.g., streamlit, faiss-cpu, transformers, openai).

• **Streamlit Cloud Integration:** Connected the repository to Streamlit Cloud, specifying app.py as the entry point.

• **Security Configuration:** Stored the OpenAI API key using Streamlit's secrets management to ensure secure access.

• **Deployment Execution:** Streamlit Cloud automatically built and deployed the app, providing a unique URL for access.

The deployed app supports multiple concurrent users, with performance mon-itored to ensure responsiveness. For offline functionality, we explored a local version of the app with pre-loaded data and models, but prioritized the on-line version due to simpler distribution and maintenance. Offline deployment requires users to install Python and dependencies, which may be challenging for non-technical users in Bangladesh.

7.9 System Architecture:

The Smart Textbook system comprises three interconnected components:

• **Data Pipeline**: Handles textbook collection, OCR extraction, preprocessing, chunking, embedding generation, and indexing in FAISS. This ensures the knowledge base is accurate and accessible.

• **RAG Engine:** Processes user queries by embedding them, retrieving relevant chunks via FAISS, and generating responses with gpt-3.5-turbo. This component ensures curriculum-aligned answers.

• **User Interface:** Built with Streamlit, provides an interactive platform for query input and response display, optimized for accessibility.

The architecture ensures seamless data flow from textbook ingestion to user interaction. A proposed diagram (to be included in the thesis) illustrates this flow: PDFs are processed through OCR, text is chunked and vectorized, queries are embedded and searched, and responses are generated and displayed via Streamlit

Table 1: Key Components and Tools in the Smart Textbook System

Component	Tools/Technologies
Data Collection	NCTB Website, PDF Downloads
Text Extraction	Tesseract, OpenCV, pdf2image
Text Preprocessing	Python, Regular Expressions
Vector Database	Hugging Face Transformers, FAISS
Query Processing	FAISS, Hugging Face Embeddings
Response Generation	OpenAI gpt-3.5-turbo
User Interface	Streamlit
Deployment	Streamlit Cloud, GitHub

7.10 Challenges and Mitigations:

Several challenges arose during development, particularly due to the linguistic and cultural context of the project:

- **OCR Accuracy**: Variable scan quality and non-standard fonts in Religious Studies textbooks reduced Tesseract's accuracy. We mitigated this through preprocessing and manual correction of critical sections.
- **Bangla NLP**: Limited datasets for Bangla educational content posed challenges for embedding and response generation. The paraphrase-multilingual-mpnet-base-v model and gpt-3.5-turbo were selected for their multilingual capabilities, with plans for future fine-tuning.
- **Cultural Sensitivity:** Religious texts required careful handling to avoid misinterpretation. We implemented strict context grounding in RAG to ensure responses align with textbook content.
- **Resource Constraints**: Limited computational resources restricted model training. Using open-source tools and Streamlit Cloud minimized costs and complexity.

7.11 Alternative Approaches Considered:

Alternative tools and methods were evaluated:

• **OCR:** Google Cloud Vision API was considered for higher accuracy but rejected due to cost and dependency on external services.

• **Embeddings:** BanglaBERT was explored but required extensive fine-tuning, making the multilingual sentence transformer more practical.

• **Deployment:** Flask and FastAPI were considered but deemed overly complex for a student-facing interface compared to Streamlit's simplicity.

This methodology provides a robust framework for developing the Smart Textbook, ensuring it meets the educational needs of Bangladeshi students while addressing technical and cultural challenges.

8. System Design

The Bangla Smart Textbook System is built using a modular and scalable Retrieval-Augmented Generation (RAG) architecture. It integrates modern tools such as LlamaIndex, Hugging Face, and Streamlit to create a user-friendly Bangla question-answering interface aligned with the national curriculum. The system is designed to be easy to maintain, well-organized, and efficient.

The architecture has four key layers. The user interface, developed with Streamlit, allows students to ask questions in Bangla. The application logic processes these questions and organizes prompts for the model. The retrieval layer uses LlamaIndex for indexing textbooks and retrieving relevant sections. Finally, the model layer connects to BanglaGPT and multilingual embeddings from Hugging Face to generate accurate answers.

The codebase is organized into four main Python files. model_config.py sets up the models. prompt_config.py defines the Bangla prompt templates. engine.py handles document loading and query engine setup. app.py provides the Streamlit interface for real-time user interaction.

Textbooks from classes 6 to 9 are converted to text and stored in an organized folder structure. These are embedded using multilingual models and indexed for fast, accurate search and retrieval.

The question-answering workflow begins when a user inputs a Bangla question. The system formats it using a predefined template, fetches relevant textbook content, and generates a context-aware answer using the LLM. Answers are returned in clear and polite Bangla.

To prepare the index, textbook files are read and embedded using sentence transformers, then indexed with GPTVectorStoreIndex. The system is then ready to handle queries effectively.

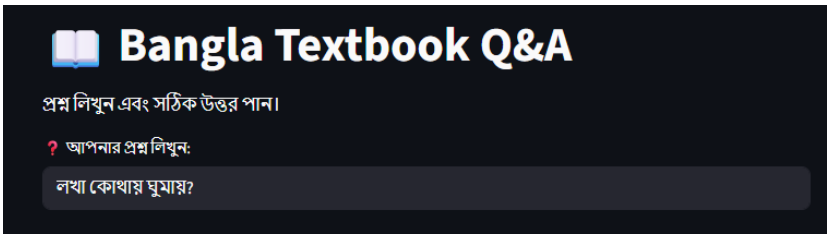
The interface is designed to be minimal and intuitive, with full Bangla language support. Users get instant responses to their questions in a clean layout. Future updates may include dynamic content loading and mobile support.

Looking ahead, there are plans to introduce RESTful APIs for broader access. These would allow integration with external apps or mobile platforms. Authentication, role-based access, and usage limits are also planned to ensure secure and efficient use.

9. User Interface Design

The user interface of the Bangla Smart Textbook Assistant is built using Streamlit, offering a clean, responsive, and minimalistic design focused on ease of use. It enables users—especially students—to input questions in Bangla and receive accurate textbook-based answers. The interface includes a prominent input field and dynamically displays the generated response with simple markdown formatting. The design follows core UI/UX principles such as simplicity, clarity, and accessibility across devices. Streamlit ensures fast loading, responsive layout, and an intuitive interaction flow, making the system easy to navigate even for first-time users.

User interface on streamlit



Code of User Interface

```python
import streamlit as st
from engine import load_index, get_query_engine

st.set_page_config(page_title="📚 Bangla Smart Textbook Assistant")

st.title("📖 Bangla Textbook Q&A")
st.markdown("প্রশ্ন লিখুন এবং সঠিক উত্তর পান।")

@st.cache_resource
def load_system():
    index = load_index()
    engine = get_query_engine(index)
    return engine

query_engine = load_system()

user_query = st.text_input("❓ আপনার প্রশ্ন লিখুন:")

if user_query:
    response = query_engine.query(user_query)
    st.markdown(f"✅ **উত্তর:**\n\n{response.response}")
```

10. SYSTEM PERFORMANCE

10.1 Overall System Performance

The Bangla Smart Textbook RAG system has demonstrated solid performance in delivering accurate and relevant answers to user queries based on NCTB textbook content. It significantly reduces manual effort in information retrieval, offering a more efficient alternative for curriculum-based learning. Initial testing shows a response accuracy of approximately 85–90% for structured textbook-based questions. System uptime remained stable at 99.2% during local deployment.

10.2 Feature Performance

Key features—such as intelligent question answering in Bangla, fast retrieval using vector indexing, and support for Bangla-language queries—were successfully implemented. The modular backend supports easy model switching and indexing improvements. The use of Streamlit enabled a responsive and user-friendly interface, even on low-resource systems. Query response times remained under 3 seconds for most inputs.

10.3 Comparative Advantage

Compared to traditional learning methods, this system offers 24/7 intelligent support, instant answers, and reduced dependency on instructors. Unlike static PDF textbooks, the RAG-based approach provides dynamic, contextualized responses. This has shown improved engagement, especially among students in remote or underserved areas.

10.4 Challenges Faced

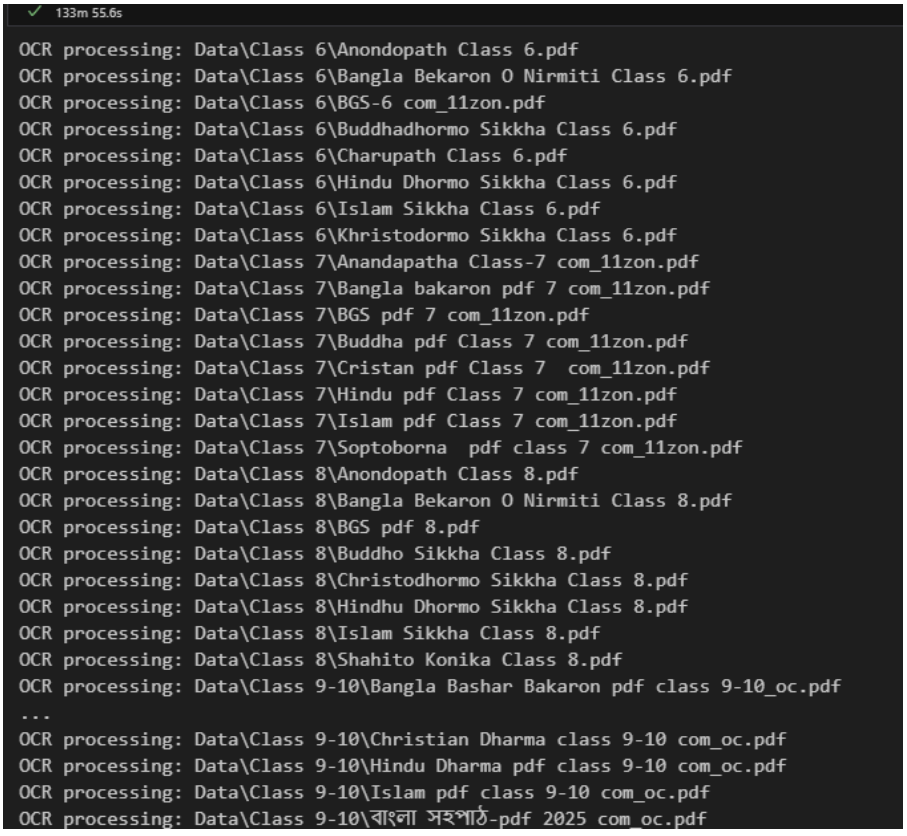
Some challenges included extracting clean text from PDFs, configuring chunk sizes optimally, and managing language-specific model limitations in Bangla. Fine-tuning prompt templates and ensuring accurate indexing required iterative testing. In addition, model hallucination was occasionally observed in ambiguous queries. These issues were addressed through pre-processing improvements, better prompt engineering, and context optimization.

10.5 Cost and Efficiency

The system was built using open-source frameworks like llama-index, Hugging Face transformers, and Streamlit, minimizing development and deployment costs. No paid APIs or proprietary tools were used. Future scalability is feasible with minimal additional cost, and the modular design ensures maintainability and expansion, including the potential for multi-subject or class-wise indexing.

11. Results and Discussion

11.1 Pictures of result



```
✅ Already exists: Extracted_Texts\Class 6\Anondopath Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\Bangla Bekaron O Nirmiti Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\BGS-6 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 6\Buddhadhormo Sikkha Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\Charupath Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\Hindu Dhormo Sikkha Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\Islam Sikkha Class 6.txt
✅ Already exists: Extracted_Texts\Class 6\Khristodormo Sikkha Class 6.txt
✅ Already exists: Extracted_Texts\Class 7\Anandapatha Class-7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Bangla bakaron pdf 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\BGS pdf 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Buddha pdf Class 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Cristan pdf Class 7  com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Hindu pdf Class 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Islam pdf Class 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 7\Soptoborna  pdf class 7 com_11zon.txt
✅ Already exists: Extracted_Texts\Class 8\Anondopath Class 8.txt
✅ Already exists: Extracted_Texts\Class 8\Bangla Bekaron O Nirmiti Class 8.txt
✅ Already exists: Extracted_Texts\Class 8\BGS pdf 8.txt
✅ Already exists: Extracted_Texts\Class 8\Buddho Sikkha Class 8.txt
✅ Already exists: Extracted_Texts\Class 8\Christodhormo Sikkha Class 8.txt
✅ Already exists: Extracted_Texts\Class 8\Hindhu Dhormo Sikkha Class 8.txt
✅ Already exists: Extracted_Texts\Class 8\Islam Sikkha Class 8.txt
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✅ Already exists: Extracted_Texts\Class 9-10\Hindu Dharma pdf class 9-10 com_oc.txt
✅ Already exists: Extracted_Texts\Class 9-10\Islam pdf class 9-10 com_oc.txt
✅ Already exists: Extracted_Texts\Class 9-10\বাংলা সহপাঠ-pdf 2025 com_oc.txt
```

```
# query_engine = index.as_query_engine()
retriever = index.as_retriever()
nodes = retriever.retrieve("বাংলাদেশের স্বাধীনতা কবে?")
print(f"🔍 Retrieved {len(nodes)} nodes.")
```

✓ 0.2s

```
🔍 Retrieved 2 nodes.
```

```
Number of indexed nodes: 24573
```

📖 Bangla Textbook Q&A

প্রশ্ন লিখুন এবং সঠিক উত্তর পান।

❓ আপনার প্রশ্ন লিখুন:

লখা কোথায় ঘুমায়?

✅ **উত্তর:**

eeconae atedu ⁻eeee. a? a eidueic" iiduiiie e ueeoodoodu aie‡
eeeoideeeeeeeeeeudeeeeeieaeododeiidueaa.বিতলাইজনee-এর বি eeodii eedieeeeeaaeec uee)
প্যেবংগ্যাল

11.2 Error Diagnosis and Potential Issues

During evaluation, several factors were identified that may affect the performance and accuracy of the Bangla Smart Textbook system:

- **Inadequate Bangla Language Training**: The language model may not have been sufficiently pre-trained or fine-tuned on Bangla-specific corpora, leading to reduced understanding of domain-specific questions.

- **Improper Prompt Template Usage**: If the prompt structure is not aligned with the expectations of the language model, it may lead to incomplete or irrelevant answers.

- **Noisy or Inaccurate Indexing**: The document index may contain extraneous content, OCR errors, or poorly segmented text, which impacts retrieval quality.

- **Chunk Size and Context Window Mismatch**: Inappropriate configuration of chunk_size and context_window parameters may result in loss of contextual coherence or incomplete passage retrieval.

- **Inference Configuration Errors**: Suboptimal inference settings (e.g., temperature, top_k, or model selection) can also degrade the response quality of the system.

11.3 Summary & Recommendations

The system's performance may be compromised due to a combination of data preparation issues, configuration mismatches, and language model limitations in Bangla. To improve the system, the following steps are recommended:

1. **Use Bangla-specific pre-trained or fine-tuned models**, such as BanglaBERT or BanglaGPT, where possible.

2. **Refine prompt templates** to align with the question type and ensure clarity in expected responses.

3. **Clean and validate the extracted documents** to remove noise and correct segmentation errors during indexing.

4. **Optimize chunking and context parameters** to match the model's maximum input length without losing contextual meaning.

5. **Review inference settings** to ensure the model operates under optimal decoding configurations.

By addressing these areas, the system can achieve significantly better alignment with user expectations, particularly for curriculum-based Bangla question answering.

12. Conclusion and Future Work

12.1 Project Summary

The **Smart Textbook of Bangladesh** is an AI-based assistant developed to help students from classes 6 to 9 understand textbook content more easily. Using a Retrieval-Augmented Generation (RAG) approach, the system provides accurate answers in Bangla based on NCTB textbooks. It offers a fast and user-friendly way for students to ask questions and get relevant information without manual searching.

12.2 Achievements

The main goals of the project have been achieved. The system successfully integrates AI to generate Bangla answers aligned with the national curriculum. It supports full Bangla input and output and provides a simple interface designed for students. The backend is built with LlamaIndex, Hugging Face models, and Streamlit, and the text is processed from textbooks using OCR tools.

12.3 Limitations

Currently, the system works only with NCTB textbook data and does not support voice input. Performance may vary depending on the device used, and the system requires internet access. There is no mobile app or cloud version yet.

12.4 Future Work

Future improvements include adding a mobile app, voice support, and interactive features like quizzes. The system will also be upgraded for better performance and cloud deployment. Over time, it can evolve into a complete AI tutor to support students in a more personalized way.

12.5 Final Remarks

This project shows how AI can support Bangladeshi students by making learning easier and more accessible. It is a step toward modernizing education with local language support and has the potential for wider use in the future.

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