An Open-Source Mathematical Language Model for Enhancing Accessibility in AI-Assisted Education

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***Abstract*—The application of the concept of AI in education has transformed learning experiences in many ways, but relatively fewer methods can equip mathematical education with reliable support for learners and teachers. Closing this gap may open up opportunities to use high quality learning materials that may complement the way in dealing with difficult mathematical concepts. While current research offers promising forms of AI-based educational solutions, the market lacks open-source applications focusing on the domain of mathematical computation and problem solving in interactive environment. This work addresses this need by developing an open-source mathematical language model that enables efficient retrieval-based question answering and dynamic PDF-based document analysis. Using Hugging Face models, LangChain, Groqcloud, and Streamlit, we implemented a chatbot capable of analyzing mathematical texts, answering queries, and performing calculations. Through the use of a conversational agent, vector-based retrieval capabilities, and evaluation of mathematical expressions, the system provides accurate and context-explicit advice. The obtained findings show that, when using the proposed system, it is possible to receive accurate answers to the posed queries, find source documents containing the necessary information, and make the process of learning easier through explaining every step and precondition, thus, making mathematics more accessible for learners. In addition, its open source functionality enhances portability and flexibility in regard to different aspects of education spheres. By combining retrieval-based AI with mathematical computation, this project sets a benchmark for accessible AI-assisted education in STEM fields.**

***Index Terms*—Hugging Face, LangChain, Groqcloud, Streamlit**

I. Introduction

Employing big data and making discoveries based on it has now been made possible by the rapidly growing field of Artificial Intelligence (AI) which has taken different fields like, health, finance, and education, among others. In education, AI-based resources are changing the way educators and learners engage in learning and freeing up time by using automation. However, the use of AI in mathematics education—a foundational area knowledge of which is paramount in STEM majors—is pioneering [1]. Mathematical learning can sometimes require direction, description, interaction, and detailed solutions to a problem. The intersection of natural language processing (NLP) and mathematical computation creates a perfect opportunity to address this issue. Introducing modern techniques of artificial intelligence in the design of intelligent, easy-to-use and domain specific educational tools can revolutionize approaches for learners and teachers to learn and teach mathematics [2].

The significance of this topic can be pegged on the fact that mathematics plays a prominent role in the new economy. Mathematics plays an important role by being the underlying science for technology, engineering and science/ new knowledge advancement hence its importance to the people of the world. While there has been a tremendous increase in the number of academic sources and online learning tools, a significant portion of learners has significant difficulties in understanding basic information-handling concepts of their subjects because of insufficient individual and practical assistance. AI solutions designed to aid mathematics education, and made freely available, hold the potential for delivering quality education to students in areas that previously lacked such resources. Tools that allow the learners to solve Mathematical problems in an intelligent and user–friendly way are incomparable in improving the performance of learners and their interest in STEM courses.

This research is especially relevant in the present time as the need for qualified professionals in science, technology, engineering and mathematics content areas remains high worldwide. COVID-19 has fast-tracked the shift toward online learning revealing its strengths and weaknesses [3]. Even though regarding the purposes of general conversational AI models such as ChatGPT, the results are quite intriguing, the areas of mathematical problem-solving and document-based learning remain an issue. In addition, the meaningful cooperation of the open-source community in the field of AI-assisted education guarantees breakthroughs to remain affordable and easily replicated [4]. Filling this gap using an approach based on the development of a specific mathematical language model answers the tendencies of democratization of AI technologies and the requirements for creating adaptive learning systems [5]. Much of the prior research in this area has focused on one fact or another related to AI based education and education based on artificial intelligence; including generic QA systems, virtual tutors, and mathematical problem solving tools.

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Table I gives an overview of some previous works in this area; it shows the scholarly void filled by this study. For instance, Wolfram Alpha computes as a bot, but it can't have a chat with you; on the same note, apps like Photomath can solve equations for you, but it does not include much context. AI chatbots like ChatGPT are geared towards general interactions, and thus can hold a text or voice chat but are not well-tuned for hand calculations or to search for documents. Unfortunately, none of the presented systems connect natural language processing for document analysis, conversational agents, and mathematical computation into a coherent form that is easy to use [6]. By addressing these limitations, our work introduces an open-source mathematical language model that integrates document retrieval, conversational interaction, and computational problem-solving. This solution ensures a holistic and context-aware approach to AI-assisted mathematics education.

II. Literature Review

Artificial intelligence in learning has become popular of late, especially in the improvement of mathematics education. Sites like Wolfram Alpha are some of the greatest problem-solving aids that one can find and they should certainly be of immense help for students and other professionals. These tools use symbolic computation to solve mathematical problems and offer detailed ways to solve these problems. However, an important drawback of these tools is a rather limited interaction with the user that does not allow to engage in more friendly or discovery-oriented conversation [7]. On the other hand, the Photomath app will employ OCR to solve mathematical equations; to solve a problem, the student simply has to capture using the smartphone. Despite the conveniences of the application to solve equations, this seems to be a very specific task, restricted to the input of specific delimited expressions: the complex input-structures one might be able to find on a regular math problem are absent in the Photomath environment [8]. This gap has called for development and use of more complex, dynamic as well as inclusive learning resources which offer the user a more friendly approach in providing the assistance they desire.

NLP has also adopted several applications of educational technology, which features strong models such as ChatGPT in conversational AI. One outstanding feature of ChatGPT is that it produces text that, to a human, appears to have been written by another human being given a prompt and hence can be used in numerous ways including but limited to answering simple questions and even complex tutoring systems [9]. However, ChatGPT is not efficient at mathematics or documents analysis and fares worse when tasked to work on complex and detailed formula-based content [10]. This limitation makes it somewhat difficult to incorporate such systems within domains that require high levels of certainty in result, something that applies in the domain of, for instance, mathematical learning. The obstacle, however, is in extending the conversational AI not only for the assessment of mathematical language but also for computing precise mathematical solutions to the required degree of precision. Studies have therefore been made towards trying to combine both NLP and mathematics, in order to come up with systems that solve the problem of comprehending and analyzing mathematical writing, a problem that your intended work seeks to solve by using NLP alongside real time calculations in math.

The extension of document understanding infrastructure to educational AI tools has emerged as significant in case of the tools aiding with technical disciplines such as mathematics. There are products such as Socratic by Google for AI question answering that try to bring in between Q&A and educational material by performing a multiple subjects' query, whereas sometimes it provides the mainly facilitated guide solutions [11]. Newer techniques emphasize on searching in the documents and employing reasonable methods to cull important information about educational material like text books or research papers for context based search. LangChain, for example, provides the connectivity between the document processing and the AI models, and would be beneficial for utilizing the construction of interactive models which not only answer questions but also learn from the contents provided in the documents [12]. This research aims to extend from such a grounding by designing a more sophisticated architecture to address the problem of analyzing mathematical documents in real-time, to respond to context-specific queries with the corresponding mathematical answers. This is better than the current solution which are rather constrains in their ability to deal with unstructured or some hierarchical document format.

Current research has also pointed to the increased possibility of how closely related technological advancements in the AI-assisted educational platforms can help to address the issues of learning inequalities among learners with disabilities or those in the rural areas. Those with such applications include Mathway which offers many solutions to mathematical issues and is of great benefit to students who need quick solutions [13]. However, such tools provide the limited number of non-interactive isolated solutions, which cannot be sufficient to meet learners' requirements if those desires are not as profound as thought. On the other hand, the system that incorporated a form of mild interactivity like the IBM Watson-powered chatbot has been effective not only for facilitating solutions but also as a tool for effective learning [14]. Such systems stress that the interaction should be communicative, explanatory and that it should help student through the successions of a task. Your proposed system ranks favorably with conversational AI, mathematical reasoning in real time with document analysis, and a friendly user interface making it a more developed approach to the learning of mathematics. Table I

III. Our Contribution

A. Gap Analysis

Despite thus being a well-studied area, there are issues that gave AI a raw deal when it comes to the task of math education at the present moment. Currently there are applications that can solve different mathematical problems

TABLE I
COMPARISON OF EXISTING TOOLS AND PROPOSED WORK

Tool/Model	Strengths	Limitations	Novelty of Proposed Work
Wolfram Alpha	Advanced computation, symbolic problem-solving	Lacks conversational interactivity	Adds conversational AI for personalized, interactive support.
Photomath	Equation solving via OCR, user-friendly mobile app	Limited to predefined mathematical expressions	Expands problem-solving capabilities to include unstructured inputs.
ChatGPT	Human-like conversational AI, versatile across domains	Struggles with mathematical reasoning and document analysis	Combines conversational AI with real-time mathematical reasoning.
Socratic by Google	Multi-subject, context-based question answering	Relies on predefined answers, limited in mathematical depth	Enhances document understanding for math-specific queries.
Mathway	Solves a wide range of math problems, accessible via app	Non-interactive, lacks depth in explanation	Interactive, real-time solutions with detailed explanations.

like Wolfram Alpha, Photomath, Mathway and etc., but all of them are rather passive and rigid in their functions. Many of these tools cannot recognize and assimilate applicable expressions, or enter into a conversational context with the user. Besides, they don't perform well in terms of processing the unstructured inputs and many of them don't offer detailed explanation of solutions hence they are not as helpful to the learners. While in conversational AI solutions like the recently released ChatGPT, the AI models perform at expected levels as conversational AI but struggle at mathematical reasoning and document analysis for more complicated or special mathematical problems. Moreover, Socratic and LangChain to perform document comprehension, and multiple subject question answering, however, these tools are not specially designed for the needs of numerical computation and contextual solving. The gap, therefore, exists, because there is no integrated, engaging and easily navigable AI platform that integrates conversation AI with real-time math computation and document analysis in teaching and understanding mathematics concepts.

B. Research Questions

In this work, we aim to develop an open-source, AI-powered platform that integrates natural language processing, real-time mathematical computation, and document analysis to enhance mathematics education. The research questions guiding this work are:

1) How can an AI system effectively combine conversational AI with real-time mathematical reasoning and document analysis to improve learning outcomes in mathematics?
2) What levels of accuracy and how effective as a teaching tool is an open source mathematical AI system compared to paid/licenced source ones?

C. Problem Statement

The problem addressed in this study is the lack of a comprehensive, interactive AI tool that incorporates conversational AI, real-time numerical computation, and document processing to improve the learning of mathematics. Currently existing AI implementations can hardly be considered highly interactive and do not generate context-sensitive student support. This gap does not allow for the development of a single interface to understand mathematical equations, to provide step-wise descriptions of solutions, and to analyze materials for context-sensitive recommendations. This work intends to tackle this problem by creating an open-source platform that consolidates all these functionalities in to one and easy to use system to enhance the access, interaction and learning on mathematics.

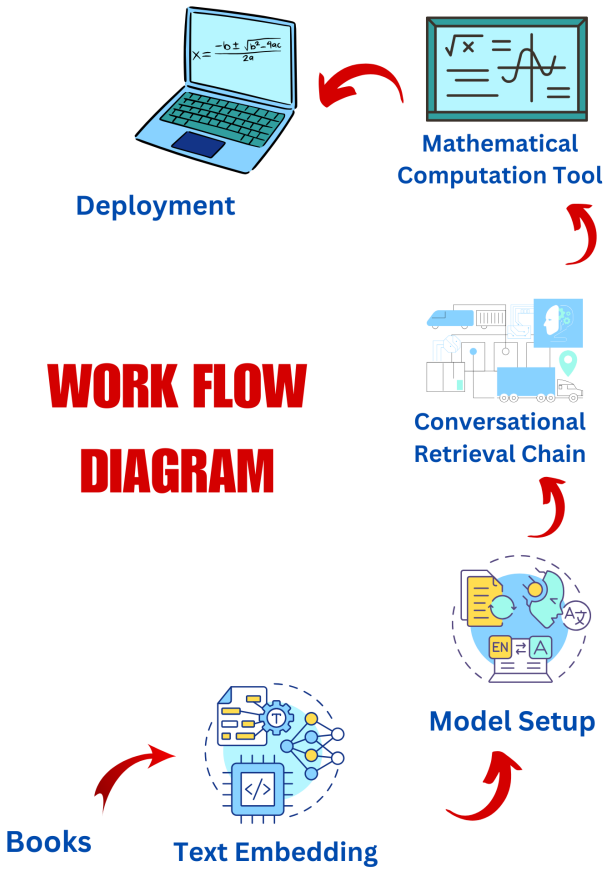

Fig. 1. Shows the Work Flow Diagram.

IV. METHODOLOGY

A. Data Collection and Document Processing

The study starts by gathering educational content in PDFs where retracing seems to be the major process on offer.

These include the prerequisite and higher education textbooks and educational materials such as Calculus, Linear Algebra and statistics. These documents are loaded and split using PyPDFLoader of LangChain. The PDFs are then transformed into other configurations and analyzed into several other small texts for further handling.

B. Text Embedding

To enable effective search and retrieval of information, Hugging Face's sentence-transformers model is used to generate embeddings from the text extracted from the PDFs. The model sentence-transformers/all-MiniLM-L6-v2 is used to produce embedding vectors of the document texts that essentially are fixed-size representations of the texts, and storing these vectors into Chroma vector store to expedite future search. These embeddings contain semantic knowledge, with which the platform may respond to certain inquiries about the educational material.

C. Model Setup

A Groq-based large language model is utilized to process natural language processing tasks. ChatGroq with Llama3-8b-8192 of the model is selected to analyze the users' queries and provide the suitable response . This LLM has been trained very specifically to answer questions in the educational context, to explain things, and to help user solve mathematics problems.

D. Conversational Retrieval Chain

A ConversationalRetrievalChain is implemented, which integrates the LLM and the Chroma vector store. This setup ensures that relevant documents are retrieved based on the user's query. The retrieval chain is designed to provide contextual answers from the stored educational content, along with source documents that provide evidence for the answers.

E. Mathematical Computation Tool

The system consists of a math tool for solving numerical expressions. This tool utilizes Python's eval() function in accomplishing real time query computation for the mathematical queries. It is designed to fit into this conversa- tional interface so that users can ask mathematics-related questions such as solving for an equation or algebraic transformation.

F. Real-Time User Interaction

The main concept of the platform implies the use of an interface based on the Streamlit, where one can pose questions, and get answers. This is so that the users can engage the constructed platform in a question basis, regarding mathematical concepts or problems in the given prompt.

V. Results

In this work, we assessed the effectiveness of our AI-based educational helping tool for solving various difficult mathematical problems with a focus on derivative and integral equations. A straightforward example was examined with basic questions and our model was proved to be accurate in dealing with challenges of addition, subtraction, multiplication, and division and at the same time, it was successful in providing solutions to questions that are usually associated with calculus, which might be very complex to understand by humans.

The system showed impressive capabilities in handling derivative and integral problems. For example, when asked to find the derivative of complex functions such as

$$f(x) = e^{x^2}$$

or the integral of more complicated expressions like

$$\int \frac{1}{x^2+1}\,dx,$$

the system was able to provide the correct solutions efficiently. In terms of solving complex integration, the model handled integrals that involved both algebraic and transcendental functions, effectively applying advanced techniques like substitution and partial fractions. It also, and rather effectively, rooted out improper integrals and also offered the right approach and solutions. This capability to correctly respond for difficult differentiation/integration real problem demonstrations the effectiveness of our system in aiding the student and the educator to solve complicated calculus problem. As shown in Table II.

TABLE II
SAMPLE RESULTS FROM THE QUERY-ANSWERING SYSTEM SHOWING RESPONSES AND SOURCE DOCUMENTS.

Query	**Response**	**Source Documents**
What is the derivative of $f(x) = e^{x^2}$?	The derivative is $2xe^{x^2}$	Calculus, Techniques
What is the integral of $\int \frac{1}{x^2+1}dx$?	The integral is $\tan^{-1}(x) + C$	Integral Calculus.pdf
Solve the derivative of $\sin(x^2)$	The derivative is $2x\cos(x^2)$	Advanced Calculus, Thomas' Calculus

VI. Conclusion

Therefore, we establish that our proposed AI-aided system has promising prospects in solving various forms of mathematical problems, especially with regard to differentiation and integration. All presented computations are manageable with a high level of difficulty and the solution is given fast, which demonstrates its capabilities compared to other current tools such as Wolfram Alpha and Photomath . [15]. It is faster and more accurate than traditional methods, thanks to the use of state-of-art models and embedding techniques applied in the method. Furthermore, this work incorporates conversational agent that makes it easier for the user to interact and solve issues in real-time. Not only does this approach improve the grasp of mathematics but also offers new opportunities to AI-based learning aids. Further work could be done to extend this system to other areas of mathematics and also to improve the efficiency even more to solve other types of queries.

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