AI-Facilitated Cross-Cultural Problem-Solving in Calculus

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Artificial Intelligence agents are used by undergraduates to support their doing of mathematics (D'Mello et al., 2023; Isgandarli, 2022; Khazanchi et al., 2023). For example, ChatGPT is increasingly used by undergraduates and their professors (Davies et al. 2021; Li et al., 2023). How can this reality be leveraged to improve the mathematical learning experiences of students in the U.S. and globally? (Almoubayyed et al., 2023).

The authors report preliminary findings of a research project that explored Large Language Models (LLM) as tools for facilitating cross-cultural discussions about the "big ideas" of calculus. The following question guided the study: (Q1) *What impact do LLMs have on the collaboration and mathematical problem-solving of calculus and precalculus students in an international context?*

In the study, two precalculus students from a state university in the United States (SFSU) and two calculus students from a state university in China (SCUPI) worked collaboratively to solve rich mathematics tasks. Four students participated, two from each university. Across three 90 minute sessions, the students met online (via ZOOM) and engaged in three types of collaborative mathematics tasks---namely, (1) a computational task, (2) an applied problem, and (3) a conceptually-oriented question. At the end of each session, students completed a short exit survey consisting of Likert-style and open-ended prompts that asked about the nature and quality of their interactions with each other and AI as well as their mathematical learning. An AI assistant facilitated the meetings in a student breakout room, with human instructors available as needed (in the main ZOOM room). The online meetings were recorded for further analysis.

In addition to the students' written work on tasks, responses on exit surveys, and ZOOM recordings, the authors report participant responses on a recruitment survey. These four data sources comprise all of the data sources for the study. The research team at SCUPI followed the ethical guidelines and standards established by SFSU.

Data analysis is ongoing at the time of this writing and will include thematic coding of student activities during the meetings, and a discussion analysis using Techno-Mathematical Discourse (TMD) framework, focusing on the AI assistant's role in facilitating discussions including the nature and depth of the mathematical and cultural conversations. The authors compare and contrast interactions of students with each other and AI both within and across cultures as they consider the research question (Q1).

The poster will include illustrations of the AI assistant-in-use, further details of the research protocol, and QR code for accessing the research study AI agent directly. Poster-side conversation will focus on the design of the study, lessons learned about cross-cultural aspects from the first use of the protocol, and advice for revising the protocol.

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PROJECT OVERVIEW

We engaged in a **case study** with four undergraduates--two from San Francisco State University (USA) and two from Sichuan University (China) who worked (via ZOOM) on collaborative calculus tasks assisted by an AI agent embedded into the sessions. The study explored the impact that the **AI-based agent** had on students' understanding of **foundational ideas of calculus**.

THE TASK

In particular, three types of collaborative mathematics tasks were explored in the sessions: (1) a computational task, (2) an applied problem, and (3) a conceptually-oriented question. At the end of each session, students completed a short exit survey about their interactions and their mathematical learning.

THE AGENT

The Agent has a focus on mathematical guidance and cultural insight. It has three functions: (1) leads math discussions, (2) engages in discussions embodying historical mathematicians, and (3) helps create examples. The adaptive and inclusive approach aims to provide a friendly learning experience.

The agent is programmed using **prompt engineering** techniques such as algorithm of thoughts (AoT) (Bilgehan et al., 2023), program simulation (Scalamogna), and chain-of-thought (CoT).
The result is a single prompt that starts the agent when entered to a large language model (LLM) to initiate the assistant. *Note: An LLM is a mathematical construct employing transformer-based neural networks to model probability distributions over sequences of words.*

DATA COLLECTED

Zoom recordings, Students' work on tasks, Conversation with AI assistant, Responses on surveys

AI has potential as a supportive educational tool. Students used the AI agent to assist in understanding and solving calculus problems.

Open tasks provide better contexts for AI learning agents to assists students.

"We ask the AI to help us understand and see ways to solve open problems"

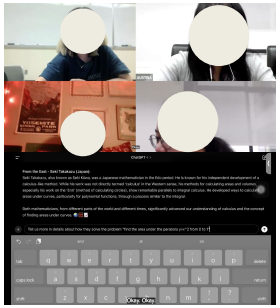
Scan the code to access the agent through GPT-4

MEETING SUMMARIES

First meeting: Meeting each other
The focus was to meet each other, explain the objectives of the study, and provide context on technology setup. Students completed 2 ice-breaker tasks and explored the agent.

Second meeting: Derivative - Optimization
Students explored the notion of derivative and collaboratively solved the Fenced Vegetable Garden task (Find dimensions would maximize the area of the vegetable garden). We used knowledge gained in this session to inform the revision of our AI-based agent for our final meeting.

Third meeting: Integral - Area
Students engaged mathematically and culturally through a study of Eastern and Western contributions to calculus. Students calculated areas under curves, comparing methods used by 16-17th century mathematicians. Students constructed an example "where the value of the area under the graph of a function may not be found" and explain why.



FINDINGS

The Agent Matters: Sometimes the AI leaves out important steps in the calculations. For example, the agent described how Isaac Newton would have calculated the area under f(x) not explaining the evaluation of the anti-derivative at the limits of integration. "if we think, his approach is not very clear. Shall we ask the agent to explain more about that?"

IMPACT

The combination of the AI-agent and tasks designed to engage students' vocational aspirations strengthened student understanding of calculus and culture in ways not always possible with more traditional methods. This highlights the relevance of culturally responsive teaching.

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