2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION
Paper ID #51092

Effective Use of Generative AI for Reducing Knowledge Gap

John Yoo, Bradley University

Dr. John Yoo is a Professor in the Department of Industrial & Manufacturing Engineering & Technology at Bradley University, Peoria, IL, USA. He earned his Ph.D. in Industrial Engineering from The Pennsylvania State University, State College, PA. His research interests include Artificial Intelligence (AI) planning theory and applications, healthcare system optimization, trading agent technology for supply chain management, and data science and analytics applications. His recent publications focus on engineering education, particularly AI-planning-based personalized curriculum design. He is a senior member of the Institute of Industrial and Systems Engineers (IISE) and a member of the Association for Supply Chain Management (ASCM).

Dr. Se Jeong Yang, Bradley University

WIP: Effective Use of Generative AI for Reducing Knowledge Gap

Abstract

This study investigates the effectiveness of Generative AI, specifically ChatGPT's Study Mode, in supporting engineering students without prior Linear Algebra coursework as they learn Linear Programming (LP) modeling in a supply chain modeling course. LP formulation is a fundamental skill in optimization, yet many students enter the course with uneven mathematical backgrounds, creating knowledge gaps that may hinder students' achievement of learning outcomes. To address this challenge, the research evaluates whether ChatGPT can help bridge the knowledge gap by providing personalized guidance and explanations in addition to traditional classroom instruction. The methodology involves collecting student background data on Linear Algebra competency prior to taking the course and comparing performance on LP-related homework and exams between two groups after having AI assistance: students with a Linear Algebra background and those without. Anticipated findings show whether the integration of ChatGPT helps to narrow existing performance gaps between the two groups and seek to determine the degree to which the tool contributes to reducing these disparities. By quantifying differences between the two groups in an exam and homework grades before and after introducing the use of ChatGPT's Study Mode, the study aims to assess ChatGPT's role as an effective learning support tool for those who lack mathematical backgrounds in engineering courses. The results are expected to inform educators on the potential of Generative AI to supplement traditional instruction, particularly in identifying and filling foundational knowledge gaps.

Introduction

The rapid emergence of large language models (LLMs) such as ChatGPT has reshaped how students engage with mathematics learning in higher education. Recent empirical studies have begun to evaluate whether these tools genuinely support mathematical understanding, skill development, and academic performance. A growing body of empirical research demonstrates that artificial intelligence (AI) has the potential to meaningfully enhance mathematics learning [1, 2]. Similarly, studies in higher education settings have found that AI-assisted learning can increase students' engagement, motivation, and conceptual understanding, such as in differential equations courses where students used ChatGPT to explore real-world modeling through numerical methods [3-7]. Despite these promising results, the effectiveness of AI is not uniform and depends heavily on how learners interact with it.

OpenAI introduced Study Mode in 2025 to shift ChatGPT from answer-giving toward guided learning, using Socratic questioning, scaffolded explanations, knowledge checks, and metacognitive prompts designed with input from educators and learning scientists. Study Mode aims to help students work through problems step-by-step and retain concepts rather than "finish tasks" quickly. The study aims to assess ChatGPT's role as an effective learning support tool for those who lack mathematical backgrounds in engineering courses by observing student performance and perception before and after using ChatGPT Study Mode.

Theoretical Framework

This study is grounded in Sadler's (1989) formative assessment model [8], which conceptualizes feedback as a mechanism for reducing the gap between a learner's current performance and a desired standard. According to Sadler, feedback improves learning only when three essential conditions are met: (1) learners possess a clear understanding of the performance standard, (2) learners are able to compare their current performance with that standard, and (3) learners can take action to close the identified gap. Feedback, therefore, is not merely corrective commentary but a process that builds learners' evaluative judgment and self-regulatory capacity.
Applying Sadler's framework to AI-mediated feedback provides a strong theoretical rationale for examining AI as a learning support tool. Generative AI systems have the potential to operationalize all three of Sadler's conditions in structured and scalable ways.

Literature Review

Several empirical and review studies investigate how ChatGPT and similar large language models (LLMs) function as educational tools in math learning contexts [3, 4, 6, 9].

AI Tutoring and Mathematical Engagement

Broader research on AI-based tutors provides relevant context. Intelligent tutoring systems have been shown to produce modest gains in math achievement and can scaffold learner understanding when integrated carefully with instructional design. These systems share pedagogical goals with ChatGPT Study Mode, such as providing feedback, tracking learner knowledge, and encouraging active problem solving [6].

Although not specific to ChatGPT Study Mode, studies of AI-augmented learning environments show general benefits for learner engagement and confidence, which are important precursors to long-term skill development. Research on adaptive systems suggests that dialogic interaction, immediate feedback, and cognitive scaffolding help students persist through mathematical challenges and build habits conducive to lifelong learning [4].

There are some studies that showed AI's impact on college students' math learning. For example, Guida-Zarrad and Gunn (2024) showed that students using ChatGPT in calculus classes reported positive shifts in engagement and attitudes toward mathematics. While some responses were imperfect, many students perceived ChatGPT as playing a supportive role in reinforcing learning and clarifying concepts, which is consistent with studies on student perceptions of AI tools in mathematics education. Zhuang (2025) also explored college students' use of AI for Math learning [10]. The study investigates how undergraduate students use ChatGPT to support their learning of calculus and, importantly, how student perceptions of ChatGPT influence their actual usage behavior. The study found a direct relationship between how students perceive ChatGPT and how they actually use it to learn calculus. Students with more positive perceptions toward AI use AI more often and more tolerant with AI errors and showed greater satisfaction with AI as a learning tool for their math learning.

Large language models (LLMs) are rapidly reshaping how students learn especially in mathematics. Research indicates that ChatGPT exhibits high accuracy in solving many mathematical problems, particularly at lower difficulty levels, and may support student reasoning and understanding in introductory mathematics contexts. However, reliability issues persist, especially for more complex problem types, suggesting that guiding mechanisms such as Study Mode could be critical for effective use in learning settings.

Methodology

This study, approved by the Bradley University Institutional Review Board (IRB I-2025-035), adopts a convergent mixed-methods research design to examine the effectiveness of generative AI, specifically ChatGPT Study Mode, in supporting student learning in IME 486/586 Logistics & Supply Chain Systems, a cross-listed undergraduate/graduate course at Bradley University. The study was conducted in Fall 2025. A total of twelve students were enrolled in the course, of whom two declined to participate in the study. Qualitative and quantitative data are collected concurrently and integrated to provide a comprehensive assessment of generative AI's impact, particularly for students lacking fundamental knowledge in industrial and manufacturing engineering.

The qualitative component investigates students' perceptions, experiences, and attitudes toward generative AI as a learning aid. Data sources include students' reflections, semi-structured interviews with a sample of students representing varying levels of prior knowledge, classroom observations, and open-ended survey responses. These data are used to explore how students engage with generative AI, how they perceive AI, and how generative AI supports conceptual understanding. Qualitative data were analyzed using content analysis, a systematic approach used to identify, organize, and interpret patterns of meaning within textual data. Content analysis is particularly well-suited for studies examining learners' perceptions because it enables the researcher to move beyond surface-level descriptions and generate coherent thematic representations of participants' experiences.

The quantitative component evaluates the effect of generative AI on student performance by comparing assessment outcomes before and after AI intervention. Measures include scores from Quiz 1 administered prior to generative AI use, an assignment completed after AI introduction, and Quiz 2 administered following AI integration. Performance comparisons are conducted between students with and without fundamental knowledge, specifically, Linear Algebra, to assess whether generative AI use reduces knowledge gaps. No control or experimental groups are employed. To support qualitative analysis, classroom sessions are video recorded using electronic devices. These recordings capture instructor-student interactions, student engagement, and real-time use of generative AI tools, enabling analysis of participation patterns and contextualized AI usage.

Preliminary Results

Quantitative Analysis

As described in Methodology, Quiz 1 was administered before AI intervention to assess the performance of students before they learn how to use ChatGPT to formulate set covering problems in Linear Programming. After demonstrating how to use ChatGPT in a class, an assignment was given to reinforce the use of ChatGPT by themselves for their learning. The grades of the assignment were released before Quiz 2. Finally, Quiz 2 was administered to assess the performance of students after learning how to use ChatGPT. Based on their mathematical background, students were divided into two groups for analysis: Group A - Students with Linear Algebra and Group B - Students without Linear Algebra. The difference in problems between Quiz 1 and Quiz 2 is the degree of complexity in set covering problem. Quiz 1 requires only coverage constraints, while Quiz 2 requires both coverage and capacity constraints.

Table 1 presents a comparison of two student groups in terms of average scores on Quiz 1, the assignment, and Quiz 2: Group A (students with Linear Algebra) and Group B (students without Linear Algebra). The maximum score for each quiz and the assignment was 40. A Mann–Whitney U test was conducted to compare Group A and Group B, and the difference was not statistically significant ($U = 11.5$, $p = 0.50$). Although the results show no statistically significant differences, the average gap between the two groups was reduced. Before the AI intervention, the performance gap was 2.42, which decreased to 2.17 after the intervention. Interestingly, students in Group B, who did not have the Linear Algebra prerequisite, outperformed Group A by 2.00 points on the assignment. In terms of the overall performance of the class, average scores across both groups increased from 35.70 in Quiz 1 (before AI intervention) to 36.80 in Quiz 2 (after AI intervention), with scores in Group B improving slightly more than those in Group A.

Table 1. Comparison of Two Student Groups

Group \ Average Scores	Quiz 1	Assignment	Quiz 2
Group A	36.67	33.00	37.67
Group B	34.25	35.00	35.50
Group A & B	35.70	33.80	36.80
Difference (A - B)	2.42	-2.00	2.17

Qualitative Analysis

Qualitative Findings: Student Perceptions of Math Learning Using ChatGPT Study Mode
Qualitative analysis of student reflections data revealed three distinct perceptions regarding the use of ChatGPT Study Mode in math learning: (1) AI as highly beneficial for learning, (2) AI as a supportive but non-substitutive tool, and (3) AI as minimally helpful. These perceptions could reflect differences in students' learning preferences, prior experiences with mathematics, and expectations of instructional support but may also be due to other factors specific to this study.

Finding 1: ChatGPT as Highly Beneficial for Math Learning

One group of students perceived ChatGPT Study Mode as extremely helpful for understanding mathematical concepts. These students emphasized the tool's ability to provide step-by-step explanations, immediate feedback, and multiple ways of explaining the same concept.

Students in this group valued the non-judgmental nature of AI, noting that they felt comfortable asking repeated questions without embarrassment. Several participants highlighted that ChatGPT allowed them to control the pace of learning, revisit explanations, and explore alternative problem-solving strategies, which they felt was not always possible in a traditional classroom setting. Overall, these students viewed ChatGPT Study Mode as an effective learning companion that enhanced conceptual understanding and promoted self-directed learning.

Finding 2: ChatGPT as Useful but Not a Replacement for Human Instruction

A second group regarded ChatGPT Study Mode as useful but limited, emphasizing its value as an auxiliary support tool rather than a standalone learning solution. These students appreciated ChatGPT for practice, clarification, and checking understanding but they noted that the responses required human verification, as the system occasionally produced errors. These students framed ChatGPT as a supplementary tool, helpful for reinforcing learning but insufficient as a standalone instructional resource.

Finding 3: ChatGPT as Not Very Helpful for Math Learning

A third group of students reported that ChatGPT Study Mode was not particularly helpful for their math learning. Students in this group reported that ChatGPT largely reiterated information they already knew and did not meaningfully contribute to new learning. They noted that the AI tended to restate familiar procedures rather than propose insights, explanations, or instructional approaches that supported deeper understanding. As a result, participants perceived limited instructional value in using ChatGPT for mathematics learning.

Discussion

The quantitative results show that the gap between Group A (students with Linear Algebra) and Group B (students without Linear Algebra) was reduced. In addition, student performance improved from Quiz 1 to Quiz 2. Quiz 1 focused on a basic set covering problem that considered only coverage, whereas Quiz 2 addressed a more advanced set covering problem that incorporated both coverage and capacity considerations. Quiz 2 required students to define an additional set of decision variables with two subscripts, in addition to the single-subscript variables used in the basic set covering problem, and to formulate capacity constraints alongside coverage constraints. Therefore, the performance improvement stems not from repeated problem-solving practice, but from a deeper understanding of the problem and the associated mathematical formulation.

The qualitative results reveal a wide range of perceptions regarding the benefits of ChatGPT Study Mode. While using it in class, students experienced both positive and negative interactions. For instance, when students input the exact same problems into ChatGPT, the answers which they received varied significantly. Some of these outputs contained obvious errors, which students themselves identified and reported. These instances underscored an important takeaway for both students and the instructor: effective use of ChatGPT Study Mode requires well-developed verification and critical evaluation skills. This finding aligns with

previous research indicating that students perceive both advantages and limitations in their use of AI tools [3, 4, 6, 9]. Moreover, participants in the present study demonstrated varied perceptions of ChatGPT, consistent with Zhuang's (2025) findings that students' perceptions differ and are closely linked to their patterns of use and levels of satisfaction. Together, these results reinforce earlier conclusions that, while AI holds considerable potential for learning, its effectiveness depends on appropriate guidance and ongoing verification.

Conclusion

The preliminary results show positive contributions of generative AI to reduce knowledge gap. Unlike human assistants such as instructors and teaching assistants, AI learning assistant tools such as ChatGPT Study Mode can provide continuous support without time constraints or relational barriers. Overall, these findings suggest that AI can serve as a helpful learning tool when used with appropriate caution. Given the small sample size in the current study, a larger cohort would help provide a clearer and more comprehensive understanding of how AI is used, along with its benefits and limitations.

Acknowledgment

This research was partially supported by a Caterpillar Research Fellowship through Bradley University.

References

[1] D. Serhan and N. Welcome, "Integrating ChatGPT in the Calculus Classroom: Student Perceptions," *International Journal of Technology in Education and Science,* vol. 8, no. 2, pp. 325-335, 2024.
[2] R. Thakur and R. C. Poonia, "Mathematical Capabilities of LLMs," presented at the International Conference on Computational, Communication and Information Technology (ICCCIT), Indore, India, 2025.
[3] R. Gouia-Zarrad and C. Gunn, "Enhancing Students' Learning Experience in Mathematics Class through ChatGPT," *International Electronic Journal of Mathematics Education,* vol. 19, no. 3, 2024.
[4] J. Liu, T. Keane, D. Sun, Y. Yang, and Y. Yang, "Design and evaluation of ChatGPT-MWPS: an AI-enhanced learning system for improving primary students' mathematical word problem solving," *Smart Learning Environments,* vol. 12, no. 1, p. 68, 2025.
[5] D. Sommerhoff and S. Ufer, "Acceptance criteria for validating mathematical proofs used by school students, university students, and mathematicians in the context of teaching," *Zdm,* vol. 51, no. 5, pp. 717-730, 2019.
[6] L. Yi, D. Liu, T. Jiang, and Y. Xian, "The effectiveness of AI on K-12 students' mathematics learning: A systematic review and meta-analysis," *International Journal of Science and Mathematics Education,* vol. 23, no. 4, pp. 1105-1126, 2025.
[7] W. Yunianto, Z. Lavicza, O. Kastner-Hauler, and T. Houghton, "Investigating the use of ChatGPT to solve a GeoGebra based mathematics+ computational thinking task in a geometry topic," *Journal on Mathematics Education,* 2024.

[8] D. R. Sadler, "Formative assessment and the design of instructional systems," *Instructional science,* vol. 18, no. 2, pp. 119-144, 1989.
[9] Y. Wardat, M. A. Tashtoush, R. AlAli, and A. M. Jarrah, "ChatGPT: A revolutionary tool for teaching and learning mathematics," *Eurasia Journal of Mathematics, Science and Technology Education,* vol. 19, no. 7, p. em2286, 2023.
[10] Y. Zhuang, "Lessons from Using ChatGPT in Calculus: Insights from Two Contrasting Cases," *Journal of Formative Design in Learning,* pp. 1-11, 2025.