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## Experimentation and Potential for Generative AI Tools in Gateway Mathematics

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### Article Info

### Abstract

#### Article History

Received:  
3 September 2025

Revised:  
11 January 2026

Accepted:  
30 January 2026

Published:  
13 March 2026

#### Keywords

Gateway mathematics  
Generative AI tools  
ChatGPT in mathematics  
High Impact practices

With the aid of tools like computer algebra systems, routine mathematical calculations and symbolic manipulations can be quickly and accurately performed. In the advent of rapid growth of Generative AI tools, we examine how ChatGPT performs in solving a variety of mathematical problem-types and methods of representations in gateway mathematics courses. Our survey on the current use of ChatGPT among learners and experimentation with this generative AI tool in a learning environment, compels us as educators to examine how ChatGPT incorporated in teaching and learning, can be used to enhance acquisition of factual, procedural and conceptual knowledge in gateway mathematics. Applying ChatGPT in mathematical discourse elicits some potential issues with both discipline-specific and general instructional practices while enhancing benefits associated with elements of High Impact Practices (HIPs). We focus on discipline-specific instructional practices that are characterized by problem-solving, problem-posing, open-ended questions with multiple solutions, modeling project activities, and technology integration. When applied to a class learning environment, the question of the quality of the ChatGPT output and what can be offloaded to ChatGPT becomes important to both learners and educators. Our analysis of the students' survey and the experimentation with ChatGPT shows that using mathematical problem-based tasks, with instructor-curated content and learners equipped with refined prompts enriches the quality of gateway mathematics education in AI environments.

**Citation:** Kamau, B. & Shukla, N. (2026). Experimentation and potential for generative AI tools in gateway mathematics. *International Journal of Technology in Education and Science (IJTES)*, 10(2), 191-218. <https://doi.org/10.46328/ijtes.5581>



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## Introduction

Artificial Intelligence (AI) is a product of technological advances in Machine Learning and evolution of Natural Language Programs, that simulate human intelligence, behaviors, and processes. “AI is everywhere” is a phrase used to express the extensive applications that AI has had in everyday life. AI technologies have found invaluable applications across various industries including finance, healthcare, marketing, digital spaces, navigation, automation, entertainment, and many more (Shakarian et al., 2023). More so are generative AI tools that exploded to public domain with extensive capabilities producing content and knowledge. Generative AI tools not only mimic human intelligence but also draw on existing large data to create new content. The rapid growth and breakthrough in achieving complex deep-learning models for natural language understanding and generation has been fueled by the development of Generative Pre-trained Transformers (GPT) (Yenduri, 2023). The release of ChatGPT, an AI-powered Generative Pretrained Transformer trained on vast amounts of data in 2022 created a buzz across all sectors due to its ability to offer human-like responses and its potential applications. ChatGPT provides a more natural and effective text and image input communication using deep learning techniques in generating creative output (Zhang et al., 2023), at a level far superior to any other AI model (Wen & Wang, 2023). The rapid emergence of ChatGPT models, with their unprecedented accuracy and fluency, has raised the stakes and potential to transform many industries, including education.

Advances and growth in capabilities and potential impact of AI tools in many professional fields and areas of our lives have ignited debates about ethical implications due to inherent bias, appropriateness of use and issues of academic integrity. Prior to 2022, the use and awareness of AI in higher education particularly for instruction and student learning remained low (Hutson et al., 2022). Although increasing demand for adaptive learning reinforces the need for research on Artificial Intelligence (AI) in education, there have been few approaches that engage learners in meaningful interactions (Lee & Yeo, 2022). Studies have shown positive outcomes that AI has had on higher education including improved learning outcomes, retention and time to completion (Klutka et al., 2018). In the same period, towards instruction and student learning, the benefits of AI in higher education have been shown to include personalized learning, automated grading systems, conversational AI chatbots, and AI teaching assistants (Shakarian et al., 2023). With the advent of GPTs in 2022, the questions are, will same benefits of AI tools of yester years carry into the world of GPTs for example ChatGPT that generate new content, pretrained on massive data and with unparalleled accessibility and ease of use through natural language and image inputs. The ethical implications of GPT models, like any other rapidly developing technology, need to be taken into account. Like many technologies, the AI-Powered GPTs have taken business and digital spaces by storm, and it is bound to disrupt higher education and open possibilities that carry risks, challenges and promises. In higher education, the GPT will influence students' learning, how teachers work, and the structure of the education system. The potential disruption in higher education calls for educators to embrace and employ AI-Powered GPT as transformative elements to better prepare students as well as adapt to their drawbacks (Tili et al., 2023).

In anticipation of AI disruptions in Higher Education, educators will need to carefully rethink planning, teaching and learning activities, course content and structure, and assessment types. Furthermore, in addition to the use of technology in teaching and learning, generative AI tools allow for new, previously inconceivable tasks. The AI

disruption encourages us to evaluate our approach to instruction and assessment, and ensure we are placing greater emphasis on process, authenticity, and depth. Overreliance solely on AI powered GPT tools as a source for immediate solutions without engaging in the learning process may hinder development of critical thinking skills, communication skills and skills necessary for solving complex problems. This potentially disruptive technological innovation calls for stakeholders in education, including instructors and students, to partner in addressing the emerging accessibility, ethical and pedagogical challenges of generative AI tools like ChatGPT. Though potential benefits and challenges of ChatGPT in education have been suggested; its performance has been shown to be varied across subject disciplines (Lo, 2023), and potential impact on foundational knowledge gap poses new instructional challenges (Sánchez-Ruiz et al., 2023). Suggesting a more comprehensive course level understanding of the impact of ChatGPT and other GTP tools on student learning, content, pedagogy, and best practices is needed. Positive attributes have been highlighted in the use of ChatGPT in STEM; including quality, accuracy and inclusion of higher-order problem solving associated with recent version ChatGPT 4 (Lewandowski et al., 2024). ChatGPT has been championed as a tool to think with; develop reflective and critical thinking, creativity, problem-solving skills, and concept comprehension in STEM education (Vasconcelos & dos Santos, 2023). ChatGPT, unlike mathematical software, provides ease of use and access in an environment where students can interact with mathematics without the need for computing skills or software. Studies conducted so far have focused on ChatGPT mathematical capabilities and performance (Frieder et al., 2023; Shakarian et al., 2023), which are found to be weaker than in other fields.

Historically, there have been evolving concerns in Mathematics teaching and learning towards hand-held calculator and computers; however today these technologies are an integral part of teaching and learning. Like digital technology, AI technologies are envisaged to continue to stimulate educational system and teachers to integrate AI-powered GPTs into classroom practices in order to provide students with more experiences to interact with technology as a powerful learning tool (Thurm et al., 2023). According to NCTM (2024) position on AI, the AI tools do not replace the need to teach or problem solving, rather the technologies need to create positive pressure to reimagine teaching and assessment. Additionally, teachers' roles in the digital era need to be aimed at developing crucial skills students need to cope with the demands of modern life (Wijaya, 2020).

Despite the significant impact the rise of AI tools has had on various fields of advanced mathematics, the impact of AI technology on the teaching and learning of mathematics has only registered some success in undergraduate level mathematics (Luzano, 2024). Diverse threats and opportunities have been identified for assessments in AI environment (Shakarian et al., 2023) and strong performance is limited to exam-solving abilities. Overemphasis on procedural knowledge, and neglect of conceptual knowledge and authentic problem-solving skills is a challenge associated with integration of AI in learning mathematics in the recent past; prior to recent proliferation of GPTs. There is need for a more comprehensive approach that can counteract these limitations by a) employing safeguards to mitigate these threats, b) providing compelling opportunities for teachers and learners partnering in the learning process c) harnessing the synergy between AI technologies and mathematics learning, and d) building connections and context in mathematical concepts.

This study investigates the role of ChatGPT in promoting students to develop conceptual and procedural

knowledge in gateway mathematics. In achieving that goal, the study will consider three questions in leveraging the potential of ChatGPT in advancing High Impact Practices in Teaching and Learning process:

- 1) How does ChatGPT perform in different mathematical representations in Mathematics gateway courses
- 2) How can ChatGPT be used to enhance teaching and learning of procedural and conceptual mathematics
- 3) What is the potential discipline-specific issues associated with applying ChatGPT in Mathematical discourse.

Standard educational technologies used in teaching and learning mathematics have shown promoted student engagement (Attard & Holmes, 2020), improved performance; providing opportunity for self-paced learning and immediate feedback (Bright et al., 2024). Educational technology has been shown to have a significant impact on student achievement, motivation, and attitudes (Qadir, 2022). The AI-powered GPTs in this context are poised to be effective tools for improving personalized instruction and adaptive learning (Carbonell, 2012), automating assessments and mechanisms for real-time feedback. According to Luzano (2024) and Higgins (2017), the personalized instruction, adaptive learning and timely feedback foster deeper conceptual understanding and mastery of mathematical concepts, leading to desired learning outcomes. The difficulties associated with integration of computers and Computer Algebra Systems (CAS) in the learning mathematics in the past have included a) compatibility with math content and symbols, b) lack of experience in using the CAS, c) limited appropriate teaching materials, d) acquisition of software licenses and e) unsystematic utilization among others. Potential utilization of AI-powered GPTs in mathematics has signaled a set of challenges different from those of the previous generation of technology and AI in education.

ChatGPT models have shown different performance levels in problem-solving in different advanced mathematics fields (Udias, 2024). The flexibility and ability of ChatGPT to search for mathematical objects, given information about them, is shown to be suitable for gateway mathematics courses (Susnjak, 2022). However, the extent to which the potential benefits can be traced to “what the student is learning” in a specific course content with ChatGPT models outside of problem-solving components is not clear at this point.

### **Rationale for the Study**

Studies on the performance of ChatGPT on mathematics learning has largely been focused to its computational capabilities in select mathematics word-problems (MWP) (Shakarian et al., 2023), and the correctness of solutions and accuracy of mathematical facts across various tasks that test mathematical skills (Frieder et al., 2023). In this study, we combine the elements of students’ perspectives, analysis of ChatGPT capabilities, and performance on specific types of math questions drawn from course content and assessments. The study pursues aspects of correctness, appropriateness of level, clarity, and mathematical representation across domains in learning scenarios. Studies have shed light on the considerable potential for ChatGPT to impact pedagogical practices (Sandu, 2024). Most observed aspect of AI in mathematics education is its effectiveness in teaching and learning process (Mohamed, 2022). An essential component of effective mathematics instruction requires thoughtful use of High Impact Practices (HIPs). This study further examines the impacts of integration of ChatGPT and similar AI tools into elements of High Impact Practices (HIPs) towards creating engaging learning environments.

## Methods

### Student Survey

Educational technologies, Learning Management Systems (LMS) and technology-mediated learning environments have been utilized differently depending on instructor preference. Despite the current unsystematic utilization of AI tools by instructors and students, given the versatility of the GPT tools; AI will certainly be integrated into the future of the workforce students are getting into. Towards cultivating positive awareness, leveraging AI's potential and creating opportunity to integrate AI tools into our classroom consistently; we set out to conduct this study on sections of gateway mathematics courses, considered foundational and prerequisites to upper division mathematics courses. We frame the study into three themes, firstly, to gain insights into students' perception, use, and impact of freely available generative AI tools, in particular ChatGPT 3. To accomplish this task, we used two surveys from students conducted concurrently. The first was an institutional survey applied to the general student population at Columbus State University in spring semester 2024. The second survey was administered to three sections of gateway mathematics during spring semester 2024. These surveys were aimed in part at determining whether or not the students were already using AI-powered GPTs in their courses, and to what extent the learning climate has been disrupted by in particular ChatGPT-the most readily available AI powered GPT so far.

### Experimenting with ChatGPT on Assessment of Instructional Material

Secondly, we applied ChatGPT to specific mathematics content concepts, problems from assigned homework, and select questions from three Problem Sets assigned in the spring 2024 semester. These tasks were aimed at profiling the interaction of ChatGPT with the gateway mathematics content, instructional materials, and assessment tools in our context. Even with the improvement of mathematical performance of ChatGPT across GPT-3.5 and GPT-4 versions, the mathematical quality of AI generated outputs is still under exploration.

The application of ChatGPT on the concepts was geared towards a) correctness and improvements of the ChatGPT responses with changes in user prompts and, b) experimentation with different input prompts that utilized restrictions specified to the concepts. From the homework and Problems Sets, we considered Word-problems, directly formulated problems and problems involving graphs. We evaluated the mathematical forms and representations of the ChatGPT responses on a variety of problems for consistency, appropriateness of the depth, clarity, and precision. On True/False questions in our homework and Problem Sets, we delved to generate counterexamples using ChatGPT and studied them for appropriateness of level and relevance. The nature of prompts has been shown to influence the problem-solving capabilities of AI-powered GPTs; particularly in straight forward computational tasks (Mohamed, 2022); however, influence of the GPTs on the development and acquisition of expected procedural and conceptual skills for students remains under explored.

### Incorporating ChatGPT for HIPs

Thirdly, as attested to by the Request for Information (RFI) (Gates Foundation, 2024), AI has the potential to

transform mathematics learning and instruction for all students particularly minorities, underrepresented, and underprepared. The effect and implications of the potential transformations on existing best practices, and emerging best practices as a result of using ChatGPT and other AI tools needs educators' attention. In this work, we explore the potential impact of ChatGPT on effective mathematics teaching practices that include:

- connections among mathematical representations to deepen understanding of mathematics concepts and procedures (NCTM, 2014).
- building procedural fluency and conceptual understanding (NCTM, 2014) to create mathematical proficiency necessary for success in mathematics learning.
- improved formative assessments through enabling enhanced question types (Cardona et al., 2023); that allow students to demonstrate and apply their knowledge in ways that emphasize process rather than products derived directly from the ChatGPT and other generative AI tools.

The study also points out the need for new teaching best practices and competencies to cater to the incorporation of current and future advancement of generative AI tools in teaching and learning of gateway mathematics. We study potential discipline specific issues associated with applying ChatGPT in Mathematical discourse, including High Impact Practices (HIPs).

## Results

### Analysis of Student Survey Data

The student survey conducted in three sections of gateway mathematics courses comprised seven mixed type questions that generated both quantitative and qualitative data. The survey garnered 81 respondents, with some questions eliciting less than the total number of respondents. The qualitative data of student responses was further organized around significant themes to establish the climate of students' current usage and perception to ChatGPT amid its public pervasiveness and stunning fluidity. This mathematics student survey data is studied in tandem with the institutional data conducted during the same period, spring semester 2024. The institutional student survey collected responses from 366 respondents.

To determine whether or not students are engaging in use of the AI-powered GPT already, we considered responses to our first survey question, "Have you ever used an AI tool in a course?". 60% of the respondents indicated "Yes", using AI tools in a course. This is significant given the current self-selection nature of the use of AI tools in classrooms by students. Thirty-six percent of the respondents indicated "No", not having used AI tools in a course, while 4% were unsure, responding to "Maybe". To have responded "Maybe", in our opinion, indicates students' lack of clarity on what use or no-use of AI tools in a course constituted.

From the institutional data, 38% of the students responded to the affirmative on using generative AI tools, while 62% indicated "No" to using any AI tools. The reversal of the usage data indicates unsystematic utilization of AI tools across disciplines within the institution, with the highest percentage of use cases being in STEM fields (Zhang & Aslan, 2021). The "Technology" and "Engineering" in STEM are directly influenced by emerging technologies, while "Science" and "Mathematics" are the foundational knowledge of AI emerging technologies

(Chiu & Li, 2023). This provides compelling justification to pursue the study on the impact of AI-powered GPTs, particularly ChatGPT, on gateway mathematics courses.

### *AI Tools Familiar to Students*

With the proliferation and rapid emergence of generative AI tools, we next needed to establish what tools were available to students so far. A non-exhaustive list of 18 generative AI tools currently available in the market was presented, and respondents were asked to name AI tools they have used or are familiar with so far. The results of AI tools familiar to students are shown in Table 1.

Table 1. AI Tools Familiar to Students

Generative AI tool	Have used or familiar with
ChatGPT	59%
Grammarly	30%
Mathway	19%
PhotoMath	14%
Other tools	23%
None	11%

Students had the option of multiple selections, and hence the percentages overlap, adding to more than 100%. The trend of AI tools choice resonates with institutional data. Independently when student responded to the question, “Have any of your teachers discussed the use of the following AI tools?” 52% polled ChatGPT while 28% polled Grammarly. The comparison of ChatGPT and Grammarly is not surprising since ChatGPT is content-oriented while Grammarly is predominantly language-based. ChatGPT has similarly been viewed favorably by 83% of students with a nationwide sample of students in Grades 10 through 12 (Schiel et al., 2023). The overall use of AI tools is set to increase as these cohorts of students get to college. Data on AI tools used by students is shown in Figure 1.

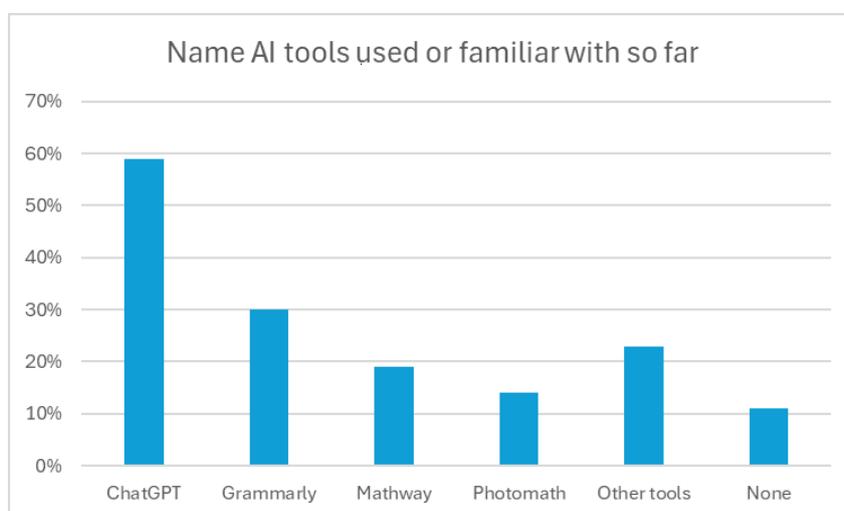


Figure 1. AI Tools Used by Students

ChatGPT is a choice for this study owing to its popularity in public domain in past years as well as its free accessibility (model 3.5 sufficient for this study) and ease of use. ChatGPT is accessible to hand-held devices such as android phones, iPad, and iPhone with an app download. The advantages include no sophisticated software or computer programs required to access this AI tool.

#### *For What Purpose Students Utilized AI Tools?*

In evaluating AI tools students are utilizing, it was essential to determine what the tools do in the context of class activities embedded in the three sections under our study. Our survey Question two, “Which of the following activities did you use AI tool for?” sought to establish for what learning activities the AI tools were utilized among “Problem Solving”, “Answer short answer questions on homework or Problem Set”, Answer Written Response Question on homework or Problem Set”, “Check solutions or get feedback on a mathematical problem,” and “All of the above”. Utilizing AI tools in “Checking solutions or getting feedback on a mathematical problem”, scored highest at 66%. The significantly low scores in utilization of AI tools in problem solving (8%) or answering specific types of questions in assignments indicate low uses of AI tools in completing complex tasks. Use of AI tools at the front end of learning, exploration, brainstorming, and problem-solving skills is suggested. This indicates that students apply AI tools with minimal or lack of guidance on usability or feasibility. The data on activities in which students used AI tools are shown in Figure 2.

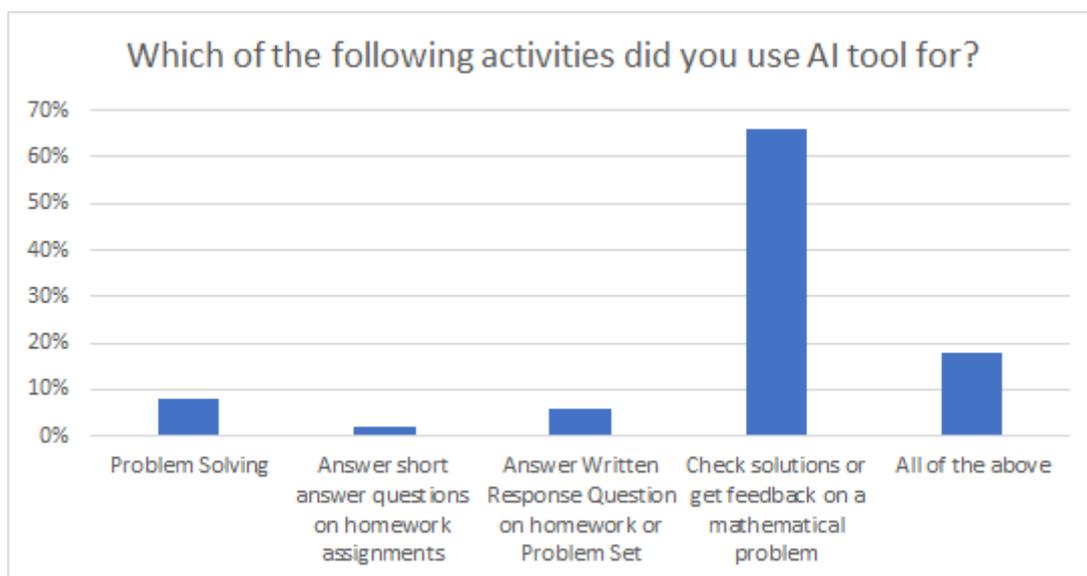


Figure 2. Activities Students Used AI Tools

#### *Students' Awareness or Usage of Some Specific AI Tools*

The survey also sought to identify students' awareness or usage of some specific AI tools applicable in their disciplines. The students responded to the question; “Have you used or heard about any of the following AI tools? Explain briefly”. The AI tools included ChatGPT, Grammarly, WolframAlpha, Mathway, Photomath and Chegg Study. Of the respondents, 90% indicated they have “heard” or “used” from the selection of six AI tools; of that

group 52% have used one of these AI tools. Only 10% indicated they have not used or heard of these AI tools. This highlights a positive awareness in the AI tools applicable to their discipline.

The awareness of specific AI tools at discipline level outpaces the institutional one, where data shows 66% of respondents indicating “heard from faculty or peers” or “read from media outlets or sources outside of the institution”. In responding to the part of the question that asked respondents to explain briefly on the AI tools they have used or heard about, checking of answers and getting a better understanding of the steps in solving a problem dominated the responses as mirrored in Figure 2.

#### *How Helpful Were the AI Tools Used to Achieve Learning Goals?*

Students identified a variety of ways in which AI tools are helpful. Of those who used AI tools, 90% indicated the tools were very useful, and 10% indicated that they did not find AI tools very useful. Checking their work, which included double checking their answers, was prevalent among the students as areas where AI tools were useful. Providing step-by-step explanations and providing similar examples were identified as help derived from AI towards solving problems.

This underscores the importance of AI tools in providing feedback and reflection which is considered a means of self-assessment and a tool for which students attach meaning to their work (Landers & Reinholz, 2015). Students indicated that ChatGPT provides examples for concepts that the textbooks or LMS do not provide; thus, ChatGPT's generative nature bridges the concept gaps and students' experience. In this context, the generative AI tools provide flexibility and adaptivity that accord personalized instruction and offer effective tutoring. Other perceived helpfulness of AI tools highlighted by students included, providing starting points whenever they are stuck, learn from different perspectives, identify misconception, create confidence and assurance, provide details, and help identify background information the user needs to pay attention to, e.g. methods or techniques to be used. Traditionally, mathematics learning starts with conceptual understanding to promote procedural fluency; however, with the use of ChatGPT, procedural tools may be used to develop conceptual skills. Even with the step-by-step explanation of problems and availability of answers, the students pointed out that there is a need to “...practice to understand the process and become better.”

#### *On How AI Might Hinder Learning*

Students identified that overreliance on AI tools may hinder their critical thinking skills and ability to actually understand an assignment. This implies that the use of AI tools without understanding the underlying concepts results in gaps in foundational knowledge and the inability to transfer the skills gained. The students pointed out the possibility of AI tools providing wrong answers, misleading content resulting in frustration and demotivation among students. While some of these limitations are being addressed with improvements such as from ChatGPT-3.5 to ChatGPT-4.0, in some areas, their ability to for deep and accurate representation of mathematics concepts is not readily available (von Hippel, 2024). Better prompting strategies have been proposed to improve the outcome of the AI responses. For mathematics, besides the loss of critical thinking and masking of problem-

solving skills acquired through human computations, the students also identified that a false sense of progress for students may result from unguided use of AI tools.

Students observed that uncharted use of AI tools will bypass authentic feedback for the instructor about the class's progress due to potential cheating, plagiarism, and extraneous information abounding in AI tools. From “It might make you complacent and it also takes a strong sense of morality to not cheat.”, “I mean it can take away from actually learning”, and “People can become dependent on it, and they can use it to cheat instead of actually grow their mind.”, underscores the potential decline in students exerting themselves towards their learning goals as a result of overreliance on AI tools (González-Calero et al., 2014). Towards assessments, students observed that while AI tools might be helpful in providing steps-by-step explanations and answers; “test are outdated and make no real world sense anymore when we have so much information at are finger tips” This highlights the fact that as AI tools evolve, their potential to revolutionize teaching and learning becomes increasingly apparent to students as well.

#### *Potential Impact of AI Tools on Your Education*

The general student perception of the potential impact of AI on their education was surveyed, with 54% indicating they envision a positive impact on their education. 22% projected negative impact while those neutral and unknown polled 14% and 8% respectively. Compared to similar but a different question in an institutional survey on the impact of AI tools to careers, and future prospects, there seems to be a reversal where only 25% indicated positive impact. The nature of step-by-step examples to learn mathematics and which is efficiently supported by AI-powered GPT tools are desirable to many students as qualitatively attested to by students' responses. This may in part have influenced the higher positive ratings of 54% for potential impact of AI on their education in the mathematics students survey. The student continued to observe; “While I think AI can hinder learning, it's really helpful when I need more instant explanations and revisions of my work without letting it do the work for me.” Here, the student emphasizes the need to work with AI tools rather than letting the AI do the work for them. “Important to be able to have a product that can assist me in understanding and completing a problem by going step by step and reverse engineering it.”

While there is more to learning mathematics than explanations and examples, the students observe the potential for AI tools to place example generation into the hands of students (Watson & Mason, 2002). Additionally, GPT provide powerful tools to complete computational tasks and potentially enhancing interactive learning (Ouaazki et al., 2023), thus “it's much more efficient to ask AI to break down a problem into digestible pieces rather than needing to refer back to a 1hr lecture, sort through class notes, schedule a tutoring session, or refer to Google/YouTube and hope to find a solution that way” student observed. This highlights the importance of tidbits derived from ChatGPT in learning mathematics. Another consideration is students' feelings towards AI-powered GPTs and their potential impact on their education. On this, the institutional survey indicated Excitement or Curiosity at 43%, Anxious or Concerned at 31% and 24% indicated neutral. The last two states of feelings indicate a potential for significant disruption by AI in teaching and learning if there are no systematic utilization or immediate interventions.

## Experimentation with ChatGPT

The ability for ChatGPT to simulate human-like interactions, break down complex concepts into tidbits, and provide real-time feedback makes it a viable tool for teaching and learning mathematics. With the rapid evolution of AI tools, and widespread use, it is imperative to rethink course content, teaching and learning activities and assignments. In this study, we apply the current course content taking into account the capabilities afforded by ChatGPT-3.5, reflect on its functionality, and consider applications to teaching in a gateway mathematics context.

### Computation

We applied ChatGPT on questions sampled from Problem Sets and homework assigned for spring semester 2024. The homework comprised of True/False, Multiple Choice, Short Answer, and Written Response-type questions. On the other hand, the Problem Sets comprised primarily of Short Answer and Written Response- type questions. The Problem Set questions included standard word problems, numerical-equation problems, and graphical problems. We applied ChatGPT to provide solutions to diverse types of questions in the assignments for semesters and analyzed the ChatGPT output. We started off by typing in ChatGPT, a general mathematical statement “Design a rectangular box of minimum surface area with volume 24” that missed some details like dimensions and units. The ChatGPT solution output is shown in Figure 3.

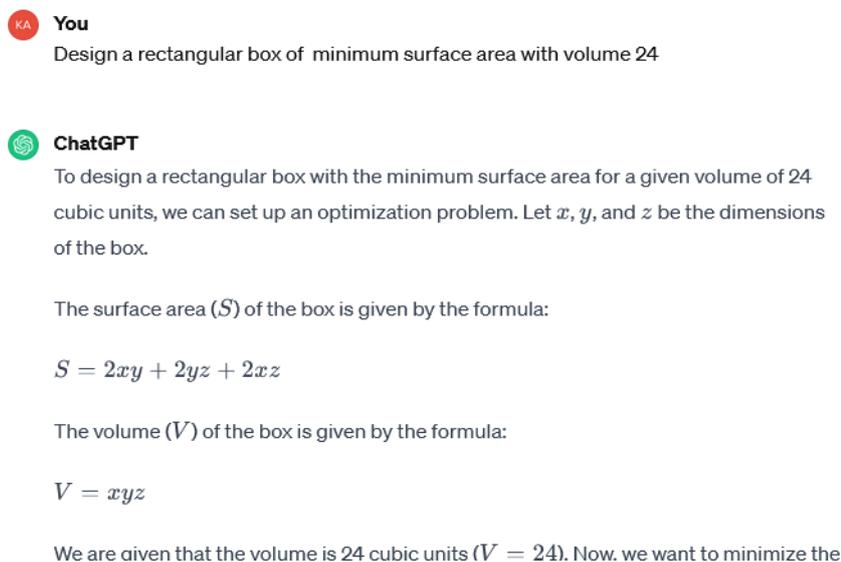


Figure 3. ChatGPT Response to the Prompt

In this output (Figure 3), it was observed that GPT paraphrased and provided a preamble to the classification of an “optimization problem” and ordered solution steps accordingly. The summary of steps and mathematical facts provided in an interactive dialogue style are envisioned to teach students how to organize key ideas into logical patterns, reflect on their work, and clarify their mathematics reasoning (Smit et al., 2023). In this case, where there are no specifications on the nature of the rectangular box, i.e. open or closed, ChatGPT defaults to a closed rectangular box. This highlights the essence of inputting refined prompts for appropriate ChatGPT response.

Multiple representation among the four domains of mathematics, verbal, graphic, algebraic and numeric, enhances teaching and learning of mathematics, promoting understanding (Mainali, 2021), and sensemaking. In Figure 4, ChatGPT could not provide a graph of the piecewise-defined function but described it instead. While the description is correct, the absence of the expected domain of representation, i.e., a graph, is a classic case of a picture worth a thousand words. This limitation observed in ChatGPT-3.5 has been remedied by newer versions of ChatGPT.

 **Anonymous**  

$$\text{graph } x^2 \& \text{\textit{if}} x < 0 \text{\textit{}} \\ 2x \& \text{\textit{if}} x \geq 0 \\ \text{\textit{end}{cases}} \text{\textit{}}$$
 The left-hand limit of  $f(x)$  as  $x$  approaches 0 from the left (denoted as  $\lim_{x \rightarrow 0^-} f(x)$ ) would be the limit of  $x^2$  as  $x$  approaches 0, which is 0.

 **ChatGPT**  
 I can describe the graph of the given piecewise function  $f(x)$  in two parts:

1. For  $x < 0$ , the function is defined as  $f(x) = x^2$ .
2. For  $x \geq 0$ , the function is defined as  $f(x) = 2x$ .

Let's describe each part separately:

1. For  $x < 0$ :
  - The graph is a parabola opening upwards since  $x^2$  is a quadratic function.
  - The vertex of the parabola is at the origin  $(0, 0)$ , and the curve extends towards negative values of  $x$ .
  - As  $x$  approaches 0 from the left ( $x \rightarrow 0^-$ ), the values of  $f(x) = x^2$  approach 0.
2. For  $x \geq 0$ :
  - The graph is a straight line with a slope of 2, passing through the origin  $(0, 0)$ .
  - As  $x$  increases from 0, the values of  $f(x) = 2x$  increase linearly.

To summarize, the graph is a combination of a parabola and a line. The left-hand limit of  $f(x)$  as  $x$  approaches 0 from the left ( $\lim_{x \rightarrow 0^-} f(x)$ ) is indeed 0, as the values of the parabola approach 0 as  $x$  approaches 0 from the left.

Figure 4. ChatGPT Response to a Piecewise-Defined Function

ChatGPT may provide more advanced solutions beyond student level. While this has the potential benefit of providing advance organizer, challenging exercises, and further readings for the students, the capability to refine the prompts and improve the quality and level-appropriateness of the responses rests on the user's mathematical skills. At some point, additional information may not be necessary for incremental learning of mathematics concepts. In Figure 5, a direct prompt to “provide a diagram” of a given polynomial function elicited first the acknowledgement from ChatGPT that “I'm sorry for the inconvenience, but as a text-based AI model, I'm unable to generate diagrams directly”. ChatGPT then proceeded to guide on how to sketch graph of the function through standard steps that involved obtaining first and second derivatives to determine intercepts, critical points, intervals of increase and decrease, and inflection points.

Provide a diagram for  $f(x)=x^3-2x^2+5$

I'm sorry for the inconvenience, but as a text-based AI model, I'm unable to generate diagrams directly. However, I can guide you on how to sketch the graph of the function  $f(x) = x^3 - 2x^2 + 5$ .

To sketch the graph of  $f(x) = x^3 - 2x^2 + 5$ , you can follow these steps:

1. **Find the y-intercept:** Substitute  $x = 0$  into the equation to find the y-intercept. In this case,  $f(0) = 0^3 - 2(0)^2 + 5 = 5$ , so the y-intercept is  $(0, 5)$ .
2. **Find the critical points:** Calculate the derivative of the function,  $f'(x)$ , and solve for  $f'(x) = 0$  to find critical points. In this case,  $f'(x) = 3x^2 - 4x$ . Set  $f'(x) = 0$  and solve for  $x$  to find critical points.

$$3x^2 - 4x = 0$$

$$x(3x - 4) = 0$$

$$x = 0, \frac{4}{3}$$

So, the critical points are  $x = 0$  and  $x = \frac{4}{3}$ .

3. **Determine the intervals of increase and decrease:** Test the intervals between critical points and beyond to see where the function is increasing or decreasing. You can use the first derivative test for this.
4. **Find the inflection points:** Calculate the second derivative  $f''(x)$  and solve for  $f''(x) = 0$  to find inflection points.

$$f''(x) = 6x - 4$$

$$6x - 4 = 0$$

$$x = \frac{2}{3}$$

So, the inflection point is  $x = \frac{2}{3}$ .

5. **Sketch the graph:** Based on the information gathered from the steps above, you can now sketch the graph of the function, making sure to incorporate the y-intercept, critical points, intervals of increase and decrease, and inflection point. You may also want to consider the end behavior of the function as  $x$  approaches positive and negative infinity.

Remember, the graph of  $f(x) = x^3 - 2x^2 + 5$  is a cubic function, so it will have a characteristic shape with certain key points.

Figure 5. Prompt Yields Standard Results Beyond Learners' Level

The multi-step word problem in Figure 6 has additional parts asking the students to rate their confidence in ability to solve the word problem and rate the importance of knowledge to solve it efficiently. As shown in Figure 6, ChatGPT provided a 10/10 confidence level in this question without restrictions. When the restrictions “Without using derivatives and using only your prior knowledge” were added, the confidence level reduced to 7/10. It is noteworthy that, even with the restrictions in place, ChatGPT used derivatives at the end of the output. ChatGPT’s confidence level on the “importance of knowing how to solve such a problem efficiently” being an 8/10, provided a helpful aspect in consideration of this question in future assessments.

**You**

A rectangular container with an open top is required to have a volume of 24 cubic meters. In addition, one side of the rectangular base is required to be 4 meters long. If material for the base costs \$8 per square meter, and material for the sides cost \$2 per square meter, find the dimensions of the container so that the cost of material to make it will be a minimum.

**Part 1**

On a scale of 1 to 10 (1 being the least and 10 the highest) how confident are you that you can solve the problem using only your prior knowledge?

**Part 2**

On a scale of 1 to 10 (1 being the least and 10 the highest) how do you rate the importance of knowing how to solve such a problem efficiently.

**Part 3**

Use only your prior knowledge to solve the problem.

- Solutions obtained from the internet or other sources will not be accepted.
- Clearly explain your steps and reasoning, you may use words, diagrams, graphs, formulas, or tables to describe your solution

**ChatGPT****Part 1: Confidence Level**

On a scale of 1 to 10, I would rate my confidence at a 10. I am confident in my ability to solve optimization problems using calculus, which is a standard method for solving problems of this nature.

**Part 2: Importance Rating**

On a scale of 1 to 10, I would rate the importance of knowing how to solve such a problem efficiently at 8. Optimization problems arise in various fields, and the ability to find optimal solutions is crucial in areas such as engineering, economics, and physics.

**Part 3: Solution**

Let's denote the dimensions of the rectangular base as  $x$  and  $y$ , where  $x$  is the length of the side given to be 4 meters. The height of the container will be  $h$ .

The volume of the container is given by the product of its dimensions:

$$V = x \cdot y \cdot h$$

We also have the constraint that the volume is 24 cubic meters:

$$xyh = 24$$

Now, we want to minimize the cost function,  $C$ , which is the sum of the cost of the base and the cost of the sides:

$$C = 8xy + 2(x + y)h$$

We can use the constraint to eliminate one of the variables. Solve the constraint equation for  $h$ :



Figure 6. ChatGPT Output for Multi-Step Word Problem

For the following conceptual question, ChatGPT failed to provide a coherent mathematical argument to support the solution provided, highlighting the fact that GPTs may provide misleading information.

**You**

At 10:17 a.m., you pass a police car at 55 mph that is stopped on the freeway. You pass a second police car at 55 mph at 10:53 a.m., which is located 39 mi from the first police car. If the speed limit is 60 mph, can the police cite you for speeding? Use concepts in calculus to explain Why or why not.

**ChatGPT**

To determine whether you can be cited for speeding, we need to analyze the information given and use calculus concepts to understand your speed at different points in time.

Let  $d(t)$  represent your distance from the first police car at time  $t$ . Since you're moving at a constant speed of 55 mph, the position function is  $d(t) = 55t$ , where  $t$  is the time in hours.

The second police car is located 39 miles from the first one, so when you pass the second police car, the distance function is  $d_2(t) = 55t - 39$ .

Now, we can find the time at which you pass the second police car. Set  $d(t) = d_2(t)$  and solve for  $t$ :

$$55t = 55t - 39$$

The  $t$  values will cancel out, indicating that there is no solution. This means that you never pass the second police car because the two functions are parallel, and the distance between them remains constant. 

Figure 7. ChatGPT Generated Conceptually Misleading Information

For question in Figure 7, the use of Intermediate Value Theorem or otherwise, is recommended and the average speed is 65 mph. While it is not clear why ChatGPT failed to solve a standard word problem; this type of output provides an opportunity for feedback and learning moment for students to reflect on, and critic AI generated solutions. Another feature of ChatGPT we applied towards the teaching and learning environment is its ability to generate examples of a mathematical concept as shown in Figure 8.

ChatGPT capability to generate relevant examples provides both instructors and students with additional examples of specified concepts. The limitation here was that standard representations and notations were not used; instead, text descriptions were provided. Additional work is required to transcript the responses into standard mathematical formulation and symbols. This has the potential to dissuade or discourage inexperienced learners from utilizing ChatGPT for this purpose.

To explore the performance of ChatGPT on external content, e.g. graphs generated by some online graphing calculators, we copied and pasted graph questions into the ChatGPT. ChatGPT responded "It looks like you have embedded a Desmos graph. How can I assist you with this graph?" When the prompt "find the limit as  $x$  approaches 4" was input, ChatGPT responded "I don't have the ability to view external content including embedded Desmos graphs..." ChatGPT output proceeded to provided interactive suggestions for possible inputs to allow progress in solving the problem. Future improvements on the functionality of the graph interface features

will help students towards fluency in numerical, graphical, and algebraic representations, which is a critical interplay in the learning of mathematics.

 **Anonymous**  
Write examples of limits of  $f(x)$  from the left

 **ChatGPT**  
Sure, here are some examples of limits from the left (left-hand limits) for various functions:

1. **Piecewise Function:**  
Consider the function  $f(x)$  defined as follows:  

$$x^2 \text{ if } x < 0$$

$$2x \text{ if } x \geq 0$$

$$\end{cases}$$
 The left-hand limit of  $f(x)$  as  $x$  approaches 0 from the left (denoted as  $\lim_{x \rightarrow 0^-} f(x)$ ) would be the limit of  $x^2$  as  $x$  approaches 0, which is 0.

2. **Step Function:**  
Let  $g(x)$  be a step function defined as:  

$$1 \text{ if } x < 2$$

$$3 \text{ if } x \geq 2$$

$$\end{cases}$$
 The left-hand limit of  $g(x)$  as  $x$  approaches 2 from the left (denoted as  $\lim_{x \rightarrow 2^-} g(x)$ ) would be 1.

3. **Rational Function:**  
Consider the rational function  $h(x)$  given by:  

$$h(x) = \frac{2x-1}{x}$$

Figure 8. ChatGPT Capability to Generate Relevant Examples

The student survey outcome and the experimentation with ChatGPT on actual instructional and assessment materials suggest that further explorations will be needed to fully understand the scope and challenges of application of ChatGPT to mathematics content and its representation both to the student and the instructor.

### HIPs Considerations

The impact of AI on established HIPs has not received much attention owing to the rapid advancements in AI tools. Comprehensive study on how the elements of HIPs integrated in teaching and learning materials are impacted or supported by generative AI tools is limited. Faculty and their students should engage in teaching and learning activities that promote HIPs in generative AI environments.

In reviewing the current elements of High Impact Practices (HIPS), and analysis of the ChatGPT outputs, we established that:

- a) To place expectations at an appropriately high level, generative AI tools provide great potential for exploring high level material with the appropriateness guided by well-designed prompts and/or guidance by instructors.
- b) Significant investment of time and effort by students can be achieved through students pursuing complex

tasks in contextualized projects. In such projects, students apply ChatGPT to explore questions and related complexities of the project.

- c) Frequent, timely, and constructive feedback is achieved through the adaptive and interactive nature of ChatGPT. The interactions and feedback have the potential to allow students to learn, to monitor, and adjust their approaches to learning.
- e) Periodic structured opportunities to reflect and integrate learning through Lab activities guided by feedback from ChatGPT.

give step by step instruction for geogebra to construct a slop of secant line



To construct the slope of a secant line using GeoGebra, follow these steps:

1. **Open GeoGebra:**  
Launch GeoGebra and select the Geometry workspace.
2. **Create a Function:**  
Input a function into the input bar at the bottom. For example, type `f(x) = x^2` and press Enter.
3. **Create Two Points on the Function:**  
Use the "Point" tool (the dot icon in the toolbar) to place two points on the function. Click on the function graph twice to create points A and B.
4. **Draw the Secant Line:**  
Select the "Line through Two Points" tool (the icon with two points connected by a line). Click on points A and B to draw the secant line between them.
5. **Calculate the Slope:**
  - Use the input bar to calculate the slope of the secant line. Type `slope = (y(B) - y(A)) / (x(B) - x(A))` and press Enter.
  - This creates a new variable `slope` which GeoGebra will display.
6. **Display the Slope:**
  - To display the value of the slope on the canvas, type `Text["slope: " + slope, (x(A)+x(B))/2, (y(A)+y(B))/2]` in the input bar and press Enter. This places a text box with the slope value between points A and B.

Figure 9. ChatGPT Instructions for Students' Interaction with Other Software

This study applied ChatGPT to a pre-project designed to engage students, leading to a milestone course project. The assignment's initial steps ask respondents to rate their confidence in solving the subsequent parts of an optimization problem. Analysis of the ChatGPT output was conducted and the results used to revise the course project that incorporates use of ChatGPT. In the two sections of the courses, GeoGebra and Desmos were used

for exploratory learning in the mathematics labs. On lab activities, we applied ChatGPT to provide instructions, responses and feedback to allow students interaction with the exploratory software as shown in Figure 9.

The step-by-step interaction between the student, ChatGPT, and the software helps the student develop a deeper understanding of the mathematics concepts and provides opportunities to explore applications of mathematics in class environments. Student achievement has been shown to be higher with learning supported by explorations as compared to problem solving (Sokolowski et al., 2015). The labs are integral to active learning sessions and provide students with a reflective and contextualized environment supported by ChatGPT.

## **Challenges of ChatGPT in Teaching and Learning of Mathematics**

### **Ethical Challenges**

The accuracy and reliability of the information generated by earlier versions of ChatGPT and AI tools in general have been brought to question. Besides the errors abound in use of AI tools, there are concerns towards potential of generative AI tools propagating biases across historical inequalities, cultural differences, user backgrounds (Hrastinski, 2019), (Akgun & Greenhow, 2022) and entry behavior. Coupled by the user privacy and data security concerns, there are unintended consequences that may stem from generative AI adoption and dependency in education, that include loss of human decision-making capabilities, laziness (Ahmad et al., 2023), loss of autonomy and academic integrity. Despite the potential benefits attributed to AI tools, students do not have equitable access to the technology needed to benefit from generative AI tools. The unique feature of text-based conversational responses from ChatGPT provides a level of access beneficial to the majority of users. The caveat here is that the quality of responses primarily depends on the quality of the prompts input (Gao et al., 2023). This may exacerbate gaps among students in readiness and foundational knowledge. Students with limited ability to create targeted ChatGPT prompts when overwhelmed with extraneous or incorrect information and beyond their level of preparedness may find less utility in the generative AI tools and be demotivated to learn. Responsible and effective generative AI usage requires planning, learning, and frequent assessment informed by comprehensive guidelines and policies at the course and institutional levels.

### **Technical Challenges**

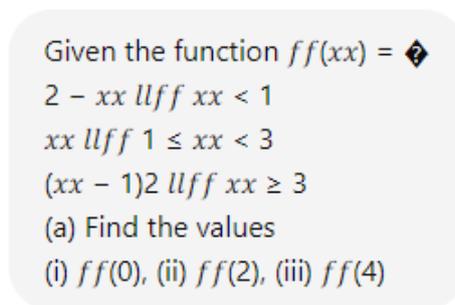
Representation from one mathematical form to another is crucial in learning and teaching of gateway mathematics. The ability of ChatGPT to represent different mathematical forms has been shown to be a limitation for particularly the ChatGPT-3.5 version. For example, expressing responses in graphical form or inputting graphical information is not readily done in this version of ChatGPT. While descriptions are provided in ChatGPT responses, it may require a student to interpret that response into a visual graph. Figure 4. above shows an instance where ChatGPT responses are not in closed form, as students are accustomed to seeing. Such a situation necessitates the learner to possess the ability to interpret that response into closed-form mathematical equations and expressions. In problem-solving, the natural tendency for the learner will be to input closed-form mathematical equations and expressions in ChatGPT as presented in textbooks or assignments; however, it is not intuitive how the student can achieve this. One of the alternatives we considered was to copy and paste into

ChatGPT. And while ChatGPT provides responses when copy-and-paste is utilized, the input is transformed into a form different from what was copied. For example, copying and pasting into ChatGPT the prompt in figure 10, yielded the output in Figure 11.

$$\text{Given the function } f(x) = \begin{cases} 2 - x & \text{if } x < 1 \\ x & \text{if } 1 \leq x < 3 \\ (x - 1)^2 & \text{if } x \geq 3 \end{cases}$$

(a) Find the values  
 (i)  $f(0)$ ,      (ii)  $f(2)$ ,      (iii)  $f(4)$

Figure 10. Piecewise Defined Function Prompts



Given the function  $ff(xx) =$   
 $2 - xx \ llff \ xx < 1$   
 $xx \ llff \ 1 \leq xx < 3$   
 $(xx - 1)2 \ llff \ xx \geq 3$   
 (a) Find the values  
 (i)  $ff(0)$ , (ii)  $ff(2)$ , (iii)  $ff(4)$

Figure 11. Output of ChatGPT to the Prompt in Figure 10

The difference between the input question form and the ChatGPT output form and syntax presents a disconnect and confusion for a learner reviewing the material. If a student cannot write symbolically, can they write verbally and vice versa? Even equipped with the fluency between verbal and symbolic representations, the introduction of mathematical symbols noise as depicted in figure 11. above is likely to alarm the most experienced users. Another aspect that raises a challenge is the ability for a student to write in mathematics, language, and symbolism. Without the ability on the learner's part to communicate with or discern from ChatGPT, correct mathematics terminology, order of operations, symbols or forms; an unnecessary level of complexity is introduced, and errors are propagated.

### Pedagogical Challenges

While leveraging the power of generative AI tools in the realm of teaching and learning, the educators will need to ensure that the essential activities that constitute learning remain with the student. Essential learning activities including critical thinking, analysis and synthesis, problem-solving, reflection, collaboration, and demonstration are impacted by generative AI in different ways. Though problem-solving, critical thinking or other skills may be gained, gaps in foundational knowledge are exacerbated due to overdependence on generative AI tools. Overreliance on ChatGPT, like any other emerging technologies, may hinder learning affecting student's decision-making, critical thinking, and analytical reasoning (Zhai, et al., 2024). Considering this challenge, it is important for instructors to work in partnership with students to determine what learning activities are to be offloaded to AI. The instructor has the fundamental task to ensure that the activities remain intentional, meaningful, and useful in the learning environment supported by generative AI tools. To engage students in learning activities that are likely

to result in achieving the learning outcomes in the generative AI environment, instructors will need to be equipped to respond and determine, what changes and when new information come with minimal disruption to students and the learning activities.

Integrate 1/x over [0, 1]

The integral of  $\frac{1}{x}$  from 0 to 1 is improper because  $\frac{1}{x}$  approaches infinity as  $x$  approaches 0. To evaluate this integral, we can express it as a limit:

$$\int_0^1 \frac{1}{x} dx = \lim_{a \rightarrow 0^+} \int_a^1 \frac{1}{x} dx.$$

Now, we can compute the integral:

$$\int \frac{1}{x} dx = \ln|x| + C.$$

Thus, we have:

$$\int_a^1 \frac{1}{x} dx = [\ln|x|]_a^1 = \ln(1) - \ln(a) = 0 - \ln(a) = -\ln(a).$$

Now taking the limit as  $a$  approaches  $0^+$ :

$$\lim_{a \rightarrow 0^+} -\ln(a).$$

As  $a$  approaches  $0^+$ ,  $\ln(a)$  approaches  $-\infty$ , so  $-\ln(a)$  approaches  $+\infty$ . Therefore,

$$\int_0^1 \frac{1}{x} dx = +\infty.$$

In conclusion, the integral diverges:



Figure 12. ChatGPT Response

### Question

Integrate 1/x over [0, 1]

### Gauth AI Solution

#### Answer

$$\ln|x| + C$$

#### Explanation

$$\int \frac{1}{x} dx$$

↓ Evaluate the integral using  $\int \frac{1}{x} dx = \ln(|x|)$

$$\ln|x|$$

↓ Add the constant of integration  $C \in \mathbf{R}$

$$\ln|x| + C$$

Figure 13. Gauth App Output

Extraneous information and sometimes beyond the appropriate level of the learner results from prompts that are not well refined. Poorly refined prompts often produce irrelevant or overly complex content and context. Creating effective prompts requires more practice and interaction with the body of knowledge that matches the learners' cognitive level. Instructor support to build these skills and guidance is required, allowing adequate time for task completion, encouraging exploration and recognition of learning acquired in the process of experimenting with different prompts. The limitation, even with well-refined and targeted prompts, may be to focus more on prompts and less on content and problem solving. Additionally, even across the AI tools, the accuracy and quality of the information generated can vary for the same input, which negatively impacts learning outcomes (Hasanein & Sobaih, 2023). For example, we compared ChatGPT response in Figure 12, to that generated by Gauth App, an AI calculator first launched in 2019 and touted as "the best homework helper" and downloadable in smartphones. In Figure 13, Gauth App generated an algorithmic solution lacking the underlying mathematical concepts and resulting in a faulty incomplete solution. Potentially, this phenomenon leads to an inability to adapt to non-standard problems or problems requiring creative solutions.

Adaptability of the AI tools like ChatGPT prompted by feedback and user interaction to refine its responses overtime (Frieder et al., 2023), requires the ability to determine what are the students learning in generative AI environments. With the capabilities associated with ChatGPT and other generative AI tools predicated on problem solving in gateway mathematics, it is not clear how these tools affect the acquisition of procedural and/or conceptual knowledge. While it has been demonstrated that conceptual knowledge for the expert impacts problem-solving; contrasting with problem solving largely being independent of concepts for the learner (Gerace, 2001), over relying on problem-solving aspects of ChatGPT and other generative AI tools presents a pedagogical challenge to acquisition of conceptual and procedural knowledge. A student's prior mathematical knowledge that is robust, accurate, and activated at the appropriate time provides a strong foundation for building new mathematical knowledge. To provide opportunities and environments that support authentic learning, educators will need pedagogical approaches that emphasis systematic utilization of generative AI tools to aid students to acquire, organize, align, and apply that knowledge.

## Discussion

This study combines the elements of students' perspectives of AI tools, ChatGPT capabilities on problem-solving different types of mathematics problems, and high impact practices in a contextualized learning scenario. The anticipated widespread use of generative AI tools invites instructors to design courses and assessments that take into account capabilities afforded by these AI tools, while preserving the integrity of the learning taking place. This necessitates looking at in context, our pedagogy, integrity of course content and assessment, and accessibility issues. As demonstrated by students' survey in this study, only a section of the students is aware of or using AI tools despite the influx of new and updated generative AI technologies, not to mention the broad public debate it has ignited. Educators on the other hand have mixed responses towards use of AI tools and by large still lag behind in reimagining teaching and assessments approaches that are beneficial to students in generative AI environment. Given the potential power and the rapid advances in AI tools, the ensuing underutilization of the tools and the cloud of uncertainty among educators, there is evidence of need for creating positive awareness around use of AI

tools in teaching and learning. ChatGPT has so far shown the highest utilization among students compared to other tools applicable in mathematics, primarily due to its accessibility, flexibility, and ease-of-use. The survey shows that students' use of ChatGPT and other generative AI tools is tentative, with the majority using it to check their work. The responsible use of AI is also hampered by lack of guidelines and policy, particularly academic integrity. Some students expressed concerns that AI tools can take away from actual learning through extraneous information, inaccurate information, or overreliance on it at the expense of learning with it. This points to the question "What are the students learning?" Which underscores the need for promoting AI tools exploration by integrating use of generative AI tools into curricula, wherein instructors and students partner to evaluate tools like ChatGPT and their output critically. The disparity in the usage of the generative AI tools among the students coupled with their attitudes and perception will affect their ability to utilize the tools for effective learning outcomes. An implementation plan needs to be in place to ensure generative AI tools usage aligns with educational goals, in such a way that essential activities that constitute learning remain with the student. Determining what can be offloaded to generative AI to ensure student success, with minimal disruption, is a natural step towards leveraging ChatGPT capabilities.

In applying ChatGPT to our Problem Sets questions, it is evident that the task of computation and simplification can be delegated to the AI tool. The scenario suggests the need to formulate questions that go beyond computation and connect concepts to procedures in meaningful ways. Additionally, providing questions as advance organizers for example; What knowledge do you need to solve this problem? What applications do you see for this concept? elicits interactions with ChatGPT that has potential to develop deeper conceptual understanding. The interactive nature of ChatGPT responses to procedural questions provides opportunity for multiple avenues to build conceptual understanding, depending on the quality of the prompts. The feedback from ChatGPT responses is key to helping students organize and apply knowledge in other contexts, as attested to in our student survey. Our study findings indicate that effective integration of AI tools at the classroom level requires educators to critically re-evaluate course objectives, class activities, assessment practices, question formulation, and the alignment of assignment objectives to ensure meaningful and ethical learning outcomes.

The ability of ChatGPT to create multiple examples or counterexamples on a concept while explaining solution process has been lauded by students and carries the promise of personalized instruction. As noted in NCTM's position on procedural fluency in Mathematics (NCTM, 2024), the interplay of conceptual understanding and procedural fluency requires at the disposal of the student, a repertoire of strategies. Beyond problem-solving, ChatGPT and other generative AI tools provide the opportunity to develop the ability to effectively identify and dissect problems, exploring their boundaries and creatively redefining them to create solution spaces (Acar, 2024).

ChatGPT is positively identified by students as providing such strategies and aiding in transfer of skills to solve similar problems. This capability is also demonstrated in the experimentation with ChatGPT on the Problem Sets we assigned in the sections. ChatGPT application to isolated problems provides responses that are with limited context and may not align with learner's level or meet learning goals. ChatGPT responses in mathematics while interactive have tended to be in standard structure and limited in human touch afforded by human tutors. In essence to realize the intended impact of ChatGPT at the instructional level, educators will need to design courses,

assignments, teaching and learning activities that consider capabilities afforded by ChatGPT, while anchored in sound pedagogy. The role of HIPs in learning mathematics (Shukla et al., 2024), coupled with the potential for ChatGPT to promote student learning, requires developing a framework that considers the student's needs and learning outcomes in generative AI environments such as ChatGPT.

This study has identified challenges associated with specific types of mathematics problems in ChatGPT environments, disparity in use of AI tools among students, limited coherence of what can productively be offloaded to ChatGPT and to achieve the desirable learning outcomes. As ChatGPT among other AI generative tools emerge as a revolutionary tool reshaping teaching and learning interactions, with information and content knowledge, there is need for an expert eye and intervention to examine its role and confronting the challenges that arise in an academic learning environment, where such tools are applied. Upon implementing the use of ChatGPT in class environments, the future direction of this work will be on leveraging the approach of flipped classroom (Shukla & McInnis, 2021), with the power of ChatGPT to improve student learning outcomes. There is potential to overcome some of the initial hurdles in mathematical capabilities of ChatGPT including word problems, graphs and sense-making with new iterations of ChatGPT including MathGPT. The extent to which the newer iterations of ChatGPT will impact learning outcomes remains out of the time scope of this study.

## Conclusion

This study highlights the significant potential, capabilities, and scope of usage of ChatGPT in teaching and learning environments. The disparity in usage, unsystematic utilization and implementation challenges of ChatGPT among students and faculty provides classroom-level considerations in leveraging the power of current generation of generative AI tools like ChatGPT. Besides the ethical, technical and pedagogical challenges to be addressed for ChatGPT's effective use in classroom environment, there is a need for content curation with High Impact Practices as guardrails to better incorporate ChatGPT in teaching and learning of foundational mathematics. To minimize the disruption in the implementation of ChatGPT and other generative AI, partnering with students allows for better alignment with their learning needs and outcomes. As the results of this study show, many students, faculty and institutions are yet to engage meaningfully with ChatGPT for structured education purposes. Incrementally embedding components of individualized learning and assessment strategies into the courses promotes students' engagement with ChatGPT for their learning.

This study provides a foundation for further work on implementation strategies of ChatGPT in classroom environment, and its integration into active teaching and learning activities, authentic assessments and scalable personalized learning. The onus on the educators is to determine how can the capabilities of ChatGPT in teaching and learning integrate and scale up to the level of teaching and learning activities, course content and structure, assessment and curriculum while maintaining integrity and ensuring ease of use and access of these generative AI-technology. Further, the responsibility of educators extends to non-superficial addressing of limitations associated with AI tools to include overreliance, taking away from foundational knowledge, reliability of ChatGPT outputs and generating of problem-solving tasks that require deeper cognitive engagement.

## Recommendations

Our recommendations point to mitigating steps taken in creating an environment where ChatGPT is applicable as a teaching and learning tool in meaningful ways. Creating positive awareness by introducing ChatGPT in supportive ways that allow students to learn with ChatGPT and not learn from it. Students' responses associated learning from AI tools with complacency, comfortable safety net, overreliance, and bypassing authentic feedback about one's progress. The awareness is also enhanced by allowing students to experiment with ChatGPT in low-stakes or no-stakes tasks before expecting them to use it for graded assignments and learning activities. The learning process requires the faculty and student to learn from each other, clarify and determine what can be off-loaded to ChatGPT through instructor guidance and experimentation while ensuring that essential activities that constitute learning, for example problem-solving, critical analysis, and reflection remain with the student. To encourage exploration beyond the classroom, and students investing significant amounts of time and effort over extended periods of time; we recommend giving students guided opportunity to complete contextualized course projects using ChatGPT. These explorations allow students to control their own learning journey by asking deeper questions and generating and testing ideas in collaborative assignments and projects.

Central to the implementation and the leveraging of ChatGPT in learning environments is the need for educators to curate and contextualize content to motivate students to apply ChatGPT outputs to local and real-world problems so that learning is relevant and meaningful. Organizing and making connections between pieces of knowledge generated through ChatGPT to a coherent body of knowledge that students are better able to retrieve and apply effectively are skills that need to be developed. As evidenced, refined and precise prompts help ChatGPT generate better and useful output, thus practicing precise prompting is essential to teach students how to write clear learning questions as prompts and engage creatively. Appropriate use of AI tools holds immense potential and promise in education considering the tools' generative capabilities and ability to enhance teaching and learning.

In harnessing the potential and realizing the promise in the AI environments, educators must rethink and reshape the ways in which teaching and learning is designed and experienced. The pervasive influence of artificial intelligence will require educators to contend with the fact that teaching and learning can no longer be confined to the transmission of established knowledge; rather, it must foster adaptability, critical and ethical reasoning, creativity, and the capacity for lifelong learning. The challenges of designing learning environments suited to uncertain and rapidly evolving futures of generative AI tools, positions the educators to reconceptualize learning activities and assessments not as static processes but as dynamic ones that prepare students to learn alongside intelligent systems while navigating the complexities of their academic journey.

## Statements and Declarations

**Conflict of Interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## References

- Acar, O. (2024). *With generative AI we can reimagine education — and the sky is the limit*. World Economic Forum. <https://www.weforum.org/stories/2024/02/with-generative-ai-we-can-reimagine-education-and-the-sky-is-the-limit/>
- Ahmad, S. F., Han, H., Alam, M. M., Rehmat, M. K., Irshad, M., Arraño-Muñoz, M., & Ariza-Montes, A. (2023). Impact of artificial intelligence on human loss in decision making, laziness and safety in education. *Humanities & Social Sciences Communications*, 10(1), 311. <https://doi.org/10.1057/s41599-023-01787-8>
- Akgun, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K–12 settings. *AI and Ethics*, 2, 431–440. <https://doi.org/10.1007/s43681-021-00096-7>
- Attard, C., & Holmes, K. (2020). “It gives you that sense of hope”: An exploration of technology use to mediate student engagement with mathematics. *Heliyon*, 6(1). <https://doi.org/10.1016/j.heliyon.2019.e02945>
- Bright, A., Welcome, N. B., & Arthur, Y. D. (2024). The effect of using technology in teaching and learning mathematics on students’ mathematics performance: The mediation effect of students’ mathematics interest. *Journal of Mathematics and Science Teacher*, 4(2). <https://doi.org/10.29333/mathsciteacher/14309>
- Carbonell, M. R. E., Saà-Seoane, J., & Pons, J. V. (2012). Innovative self-assessment and teaching/learning techniques for calculus within the RIMA Project (UPC-ICE). *Procedia – Social and Behavioral Sciences*, 46, 686–691. <https://doi.org/10.1016/j.sbspro.2012.05.182>
- Cardona, M., Rodriguez, R., & Ishmael, K. (2023). *Artificial intelligence and the future of teaching and learning: Insights and recommendations*. Office of Educational Technology, U.S. Department of Education. <https://www.ed.gov/sites/ed/files/documents/ai-report/ai-report.pdf>
- Chiu, T., & Li, Y. (2023). How can emerging technologies impact STEM education? *Journal for STEM Education Research*, 6, 375–384. <https://doi.org/10.1007/s41979-023-00113-w>
- Frieder, S., Pinchett, L., Chevalier, A., Griffiths, R., Salvatori, T., Lukasiewicz, T., Petersen, P., & Berner, J. (2023). Mathematical capabilities of ChatGPT. *arXiv:2301.13867v2* [cs.LG]. <https://arxiv.org/abs/2301.13867>
- Gao, J., Zhao, H., Yu, C., & Xu, R. (2023). Exploring the feasibility of ChatGPT for event extraction. *arXiv:2303.03836v2* [cs.CL]. <https://doi.org/10.48550/arXiv.2303.03836>
- Gates Foundation U.S. Program. (2024). *AI-powered innovations in mathematics teaching & learning* (Request for Information). <https://usprogram.gatesfoundation.org/news-and-insights/articles/ai-powered-innovations-in-mathematics-teaching-and-learning-rfi>
- Gerace, W. (2001). *Problem solving and conceptual understanding*. Scientific Reasoning Research Institute, University of Massachusetts. <https://www.srri.umass.edu/sites/srri/files/gerace-2001psc/index.pdf>
- González-Calero, J., Arnau, D., Puig, L., & Arevalillo-Herráez, M. (2014). Intensive scaffolding in an intelligent tutoring system for the learning of algebraic word problem solving. *British Journal of Educational Technology*, 46(6), 1189–1200. <https://doi.org/10.1111/bjet.12183>
- Hasanein, A., & Sobaih, A. E. (2023). Drivers and consequences of ChatGPT use in higher education: Key stakeholder perspectives. *European Journal of Investigation in Health, Psychology and Education*,

- 13(11), 2599–2614. <https://doi.org/10.3390/ejihpe13110181>
- Higgins, K., Huscroft-D'Angelo, J., & Crawford, L. (2019). Effects of technology in mathematics on achievement, motivation, and attitude: A meta-analysis. *Journal of Educational Computing Research*, 57(2), 283–319. <https://doi.org/10.1177/0735633117748416>
- Hrastinski, S., Olofsson, A. D., Arkenback, C., Ekström, S., Ericsson, E., Fransson, G., Jaldemark, J., Ryberg, T., Öberg, L., Fuentes, A., Gustafsson, U., Humble, N., Mozelius, P., Sundgren, M., & Utterberg, M. (2019). Critical imaginaries and reflections on artificial intelligence and robots in postdigital K–12 education. *Postdigital Science and Education*, 1, 427–445. <https://doi.org/10.1007/s42438-019-00046-x>
- Hutson, J., Jeevanjee, T., Graaf, V., Lively, J., Weber, J., Weir, G., Arnone, K., Carnes, G., Vosevich, K., Plate, D., Leary, M., & Edele, S. (2022). Artificial intelligence and the disruption of higher education: Strategies for integration across disciplines. *Creative Education*, 13(12), 3953–3980. <https://doi.org/10.4236/ce.2022.1312253>
- Klutka, J., Ackerly, N., & Magda, A. J. (2018). *Artificial intelligence in higher education: Current uses and future applications*. Learning House.
- Landers, M., & Reinholz, D. (2015). Students' reflections on mathematics homework feedback. *Journal of Developmental Education*, 38(3), 22–36. <http://www.jstor.org/stable/24614022>
- Lee, D., & Yeo, S. (2022). Developing an AI-based chatbot for practicing responsive teaching in mathematics. *Computers & Education*, 191, 104646. <https://doi.org/10.1016/j.compedu.2022.104646>
- Lewandowski, M., Łukowicz, P., Świetlik, D., & Barańska-Rybak, W. (2024). ChatGPT-3.5 and ChatGPT-4 dermatological knowledge level based on the specialty certificate examination in dermatology. *Clinical and Experimental Dermatology*, 47(7), 686–691. <https://doi.org/10.1093/ced/llad255>
- Lo, C. K. (2023). What is the impact of ChatGPT on education? A rapid review of the literature. *Education Sciences*, 13(4). <https://doi.org/10.3390/educsci13040410>
- Luzano, J. (2024). Assessment in mathematics education in the sphere of artificial intelligence: A systematic review on its threats and opportunities. *International Journal of Academic Multidisciplinary Research*, 8(2), 100–104. <https://dx.doi.org/10.2139/ssrn.5221121>
- Mainali, B. (2021). Representation in teaching and learning mathematics. *International Journal of Education in Mathematics, Science, and Technology*, 9(1), 1–21. <https://doi.org/10.46328/ijemst.1111>
- Mohamed, M. Z., Hidayat, R., Suhaizi, N. N., Sabri, N. M., Mahmud, M. K. H., & Baharuddin, S. N. (2022). Artificial intelligence in mathematics education: A systematic literature review. *International Electronic Journal of Mathematics Education*, 17(3). <https://doi.org/10.29333/iejme/12132>
- National Council of Teachers of Mathematics (NCTM). (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA.
- National Council of Teachers of Mathematics. (2023). *Procedural fluency in mathematics* (Position statement). <https://www.nctm.org/Standards-and-Positions/Position-Statements/Procedural-Fluency-in-Mathematics/>
- National Council of Teachers of Mathematics. (2024). *Artificial intelligence and mathematics teaching* (Position statement). <https://www.nctm.org/standards-and-positions/Position-Statements/Artificial-Intelligence-and-Mathematics-Teaching/>
- Ouaazki, A., Bergam, K., & Holzer, A. (2023). Leveraging ChatGPT to enhance computational thinking learning

- experiences. *IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, 1–7. <https://doi.org/10.1109/TALE56641.2023.10398358>
- Qadir, J. (2022). Engineering education in the era of ChatGPT: Promise and pitfalls of generative AI for education. *TechRxiv*. <https://doi.org/10.36227/techrxiv.21789434.v1>
- Sánchez-Ruiz, L. M., Moll-Lopez, S., Nunez-Perez, A., Morano-Fernandez, J. A., & Vega-Fleitas, E. (2023). ChatGPT challenges blended learning methodologies in engineering education: A case study in mathematics. *Applied Sciences*, *13*(10). <https://doi.org/10.3390/app13106039>
- Sandu, R., Gide, E., & Elkhodr, M. (2024). The role and impact of ChatGPT in educational practices: Insights from an Australian higher education case study. *Discover Education*, *3*, 71. <https://doi.org/10.1007/s44217-024-00126-6>
- Schiel, J., Bobeck, B., & Schnieders, J. (2023). *High school students' use and impressions of AI tools*. ACT Research. <https://www.luminafoundation.org/wp-content/uploads/2024/01/High-School-Students-Use-and-Impressions-of-AI-Tools.pdf>
- Shakarian, P., Koyyalamudi, A., Ngu, N., & Mareedu, L. (2023). An independent evaluation of ChatGPT on mathematical word problems. *arXiv:2302.13814v2* [cs.CL]. <https://doi.org/10.48550/arXiv.2302.13814>
- Shukla, N. J., & McInnis, E. (2021). Flipped classroom: Success with first-year mathematics students. *International Journal on Social and Education Sciences*, *3*(1), 32–47. <https://doi.org/10.46328/ijonses.56>
- Shukla, N. J., Lilly, K., & Kamau, B. (2024). Evaluation of intertwined project-based learning in introductory mathematics and statistics courses. *International Journal of Education in Mathematics, Science, and Technology*, *12*(2), 552–574. <https://doi.org/10.46328/ijemst.3339>
- Smit, R., Hess, K., Taras, A., Bachmann, P., & Dober, H. (2023). The role of interactive dialogue in students' learning of mathematical reasoning. *Learning and Instruction*, *86*. <https://doi.org/10.1016/j.learninstruc.2023.101777>
- Sokolowski, A., Li, Y., & Willson, V. (2015). The effects of using exploratory computerized environments in grades 1 to 8 mathematics: A meta-analysis. *International Journal of STEM Education*, *2*, 8. <https://doi.org/10.1186/s40594-015-0022-z>
- Susnjak, T. (2022). ChatGPT: The end of online exam integrity? *arXiv:2212.09292v1* [cs.AI]. <https://arxiv.org/abs/2212.09292>
- Thurm, D., Ebers, P., & Barzel, B. (2022). Professional development for teaching mathematics with technology: Fostering teacher and facilitator noticing. In A. Clark-Wilson, O. Robutti, & N. Sinclair (Eds.), *The mathematics teacher in the digital era* (Vol. 16, pp. 1–29). Springer. [https://doi.org/10.1007/978-3-031-05254-5\\_1](https://doi.org/10.1007/978-3-031-05254-5_1)
- Tlili, A., Shehata, B., Adarkwah, M. A., Bozkurt, A., Hickey, D. T., Huang, R., & Agyemang, B. (2023). What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education. *Smart Learning Environments*, *10*, 15. <https://doi.org/10.1186/s40561-023-00237-x>
- Udias, A., Alonso-Ayuso, A., Alfaro, C., Algar, M. J., Cuesta, M., Fernández-Isabel, A., Gómez, J., Lancho, C., Cano, E. L., Martín de Diego, I., & Ortega, F. (2024). ChatGPT's performance in university admissions tests in mathematics. *International Electronic Journal of Mathematics Education*, *19*(4). <https://doi.org/10.29333/iejme/15517>
- Vasconcelos, M. A. R., & dos Santos, R. P. (2023). Enhancing STEM learning with ChatGPT and Bing Chat as

- objects to think with: A case study. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(7). <https://doi.org/10.29333/ejmste/13313>
- von Hippel, P. (2024). GPT-4 is still not ready to teach geometry. *Education Next*. <https://www.educationnext.org/chat-gpt-4-is-still-not-ready-to-teach-geometry/>
- Watson, A., & Mason, J. (2002). Student-generated examples in the learning of mathematics. *Canadian Journal of Math, Science & Technology Education*, 2(2), 237–249. <http://dx.doi.org/10.1080/14926150209556516>
- Wen, J., & Wang, W. (2023). The future of ChatGPT in academic research and publishing. *Clinical and Translational Medicine*, 13(3). <https://doi.org/10.1002/ctm2.1207>
- Wijaya, A. (2020). The role of mathematics teacher in the digital era. *Journal of Physics: Conference Series*, 1581(1). <https://doi.org/10.1088/1742-6596/1581/1/012069>
- Yenduri, G., Ramalingam, M., Selvi, C. G., Supriya, Y., Srivastava, G., Maddikunta, P. K., Raj, D. G., Jhaveri, R. H., Prabadevi, B., Wang, W., Vasilakos, A. V., & Gadekallu, T. R. (2023). GPT (Generative Pre-trained Transformer): A comprehensive review. *arXiv:2305.10435v2* [cs.CL]. <https://arxiv.org/abs/2305.10435>
- Zhai, C., Wibowo, S., & Li, L. D. (2024). The effects of over-reliance on AI dialogue systems on students' cognitive abilities: A systematic review. *Smart Learning Environments*, 11, 28. <https://doi.org/10.1186/s40561-024-00316-7>
- Zhang, C., Zhang, C., Zheng, S., Qiao, Y., Li, C., Zhang, M., Dam, S. K., Thwal, C. M., Tun, Y. L., Huy, L. L., Kim, D., Bae, S., Lee, L., Yang, Y., Shen, H. T., Kweon, I. S., & Hong, C. S. (2023). A complete survey on generative AI (AIGC). *arXiv:2303.11717v1* [cs.AI]. <https://arxiv.org/abs/2303.11717>
- Zhang, K., & Aslan, A. B. (2021). AI technologies for education: Recent research & future directions. *Computers and Education: Artificial Intelligence*, 2. <https://doi.org/10.1016/j.caeai.2021.100025>