

Enhancing Quality Instruction and Learning Experiences in Higher Education through ChatGPT: An Exploratory Case Study

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Abstract

Despite trepidations about the use of generative artificial intelligence (AI) and chatbots like ChatGPT, there is significant potential to enhance instruction in Higher Education (HE). Scholars have explored this Generative AI's features, and the implications for teaching and learning in HE since the release in 2022. This has led to discussions on academic integrity which have raised questions about the authenticity of students' creative output, ethical practices regarding intellectual property, as well as arguments about the validity of traditional assessments. However, there has been limited practical discourse on the opportunities for Generative AI as a tool for innovative authentic assessments and for fostering students' active participation in collaborative learning and self-assessment. Using an exploratory approach, this case study examines an instructor's use of ChatGPT to teach mathematics at a tertiary-level institution, investigating the capabilities of AI in enhancing students' engagement, assessment types, and instruction in higher education. The study involved 70 students and one instructor exploring strategies for promoting collaboration and engagement in mathematics talk communities, as well as implementing authentic assessments. The study's findings indicate that ChatGPT can provide insightful feedback on students' work and improve their learning experience through error-analysis type assessments while providing support to instructors in crafting classroom practices that foster critical thinking and problem solving. This study potentially offers a structured framework for maximizing the effectiveness of using ChatGPT in preparing learners for the 5th Industrial Revolution.

Keywords: Generative artificial intelligence, ChatGPT, mathematics talk community, pedagogy enhancement, authentic assessment, collaborative learning

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Introduction

“You are either ready for change or you are a dinosaur”¹

Since the significant advancement of generative artificial intelligence (AI) and chatbots like ChatGPT in 2022, Higher Education (HE) professionals have been raising concerns about their impact on teaching, learning, and academic integrity. Academic integrity involves adhering to ethical and professional principles, standards, practices, and a consistent system of values that guide decisions and actions in education, research, and scholarship (Tauginienė et al., quoted in Foltyněk et al., 2023). ChatGPT (Generative Pre-trained Transformer) is a language model that enables more natural and conversational interactions with computers, capable of generating human-like text, answering questions, and performing various natural language processing tasks (UNESCO, 2023). In response to concerns about its impact, some educational institutions have blocked access to OpenAI's website and issued statements warning against using ChatGPT for cheating (Heaven, 2023).

Despite these concerns, however, AI has the potential to enhance both academic and administrative HE operations. Reviews suggest that AI tools can provide insightful feedback on students' work and improve the overall quality of their learning experience (Ouyang et al., 2022). Scholars have explored ChatGPT's features and implications for teaching and learning in HE (Rudolph et al., 2023; Tlili et al., 2023), but varying opinions exist regarding academic integrity, including concerns with the authenticity of students' work and the effectiveness of traditional assessments, as well as ethical concerns about intellectual property (Perkins, 2023).

Literature Review

Quality Assurance and Artificial Intelligence in Education

Quality Assurance (QA) professionals have also weighed in, with organizations such as UNESCO, the UK Quality Assurance Agency (QAA), and the European Network for Academic Integrity (ENAI) issuing guidelines and recommendations on the use of AI in academia. Undoubtedly, Artificial Intelligence presents both challenges and opportunities for Higher Education Institutions (HEIs). For example, UNESCO-IESALC (2023) highlighted opportunities

¹ Quotation from a college leader in “Why Professors are Polarized on AI”. Susan D’Agostino (2023)

that ChatGPT could present in teaching, research, administration, and community engagement. Further, the QAA outlined two significant ways AI can enhance and improve HEIs: integrating it into curriculum and assessment to deepen learning and build AI-confident learners, as well as using it to speed up processes and drive efficiencies (QAA, 2023). However, concerns remain, including academic integrity, potential grade inflation, depersonalization of feedback, the digital divide, and variations in graduate skills (QAA, 2023).

Academic integrity is of paramount concern to HEIs, as it directly impacts an institution's reputation. The QAA (2023) emphasized that trustworthiness and value of qualifications rely on the confidence that a student's work is genuinely their own. However, AI tools may not always align seamlessly with these standards, and detecting AI-generated content is challenging. To address this, Baker-Gardner et al. (2022) stressed the importance of education and training in fostering academic integrity, suggesting that punitive approaches are not always effective. Foltynnek, et al (2023) focused on empowering stakeholders with skills and knowledge to ethically use AI tools, emphasizing the need for educational policies tailored to opportunities and challenges in AI Educational Development (AIED).

QAA (2023) in arguing for a re-evaluation of assessment strategies and the integration of AI tools in these strategies asked: should assessment test knowledge acquisition or be used as a learning tool? Despite this ongoing discourse, however, practical discussions about ChatGPT's potential applications as a tool for authentic assessments and student engagement are lacking. In the Caribbean, Accreditation Agencies have largely remained silent on this matter. However, in an attempt to address the issue, the University Council of Jamaica (UCJ) hosted the 7th Dennis Irvine Lecture in October 2023, focusing on the implications of AI for Quality Assurance. The invitation to participants emphasized the increasing recognition of AI's potential to transform educational practices (N. Murray, personal communication, September 29, 2023).

The University of the West Indies (UWI), the Caribbean region's leading higher education institution, has begun the discourse regarding ChatGPT, and issued a position statement aligning with UNESCO's guidelines. The UWI has also formed a committee to review policies on academic integrity, demonstrating a commitment to AI technology while upholding institutional principles (The UWI, 2023). The UWI's Core Values and Attributes of the Ideal UWI Graduate, including ethical values and IT skills, should guide how AI is used in education, research, and other areas of operation. This approach is meant to ensure that AI benefits the academy while maintaining integrity and excellence.

Concerns about AI Integration in Higher Education

Undoubtedly, artificial intelligence (AI) has been increasingly transforming instruction in recent years, with organizations and higher education institutions investing significantly in AI-based instructional and learning technologies. AI-driven instruction now focuses on personalization and adaptive learning, using algorithms to customize educational content to individual learning needs, styles, and self-efficacy, ultimately leading to more engaging and effective learning experiences and improved student performance (Ouyang et al., 2022).

AI has also revolutionized the creation of educational materials, with Natural Language Generation (NLG) tools and chatbots streamlining development processes and enhancing learning quality. Intelligent Tutoring Systems (ITS) now mimic human tutors by providing real-time, personalized feedback. Ouyang et al. (2022) observed that chatbots, which are increasingly utilized in education, provide instant support to students by answering questions, assisting with administrative tasks, and even serving as virtual tutors in classrooms. AI streamlines assessment and grading processes, delivering timely and consistent feedback (Baker & Smith, 2019). Educators also leverage AI-driven Learning Analytics (LA) to identify patterns in student behaviour and performance, enabling data-driven decisions that enhance the overall learning experience.

Despite these benefits, concerns and criticisms persist regarding AI integration in higher education. Critics argue that while AI's promises personalized learning, it risks depersonalization by potentially offering a one-size-fits-all education (Zawacki-Richter et al., 2023). Ethical concerns arise from AI systems perpetuating biases from training data, potentially resulting in unequal treatment and discrimination. Privacy issues also emerge from extensive student data collection, raising concerns about data protection and misuse (QAA, 2023). Educators fear job displacement due to AI reliance. However, Sims (2023) assures that “the key to successfully integrating AI into education lies in understanding that AI tools are not a replacement for human expertise, but rather they are tools that can augment and enhance it” (para. 9)). An additional concern of educators is the ability of AI tools to produce essays, hence raising questions about the validity and reliability of traditional assessments. Indeed, AI tools are providing a necessary opportunity for HE stakeholders to reimagine the role of education in the 21st Century and rethink traditional assessment (Sims, 2023).

The concerns that have been raised regarding biases can be addressed through rigorous oversight and continuous improvement in algorithm design to mitigate these biases. AI can be used to tailor educational experiences to diverse learning styles and abilities, enhancing engagement and comprehension (Chang et al., 2023). By removing educators from administrative tasks, AI can be utilized to enable more meaningful interactions with students. Long-term gains in efficiency and effectiveness can offset integration costs. According to Chang et al. (2023), AI provides instant feedback to students, allowing them to monitor progress and make timely improvements, thereby enhancing their learning experience. Advancements in technology can lead to the development of

AI tools that foster creativity and critical thinking. AI provides the opportunity to foster global collaboration and accessibility, thereby, reducing geographical barriers and making education more inclusive.

While challenges exist, effective AI integration can transform higher education by enhancing the quality of learning experiences. This paper explores the impact of AI on instruction at a tertiary institution in the Caribbean and presents a case study, using the reflexive praxis method. It examines the use of ChatGPT in teaching mathematics and offers a framework for preparing learners for the 5th Industrial Revolution.

Theoretical Framework

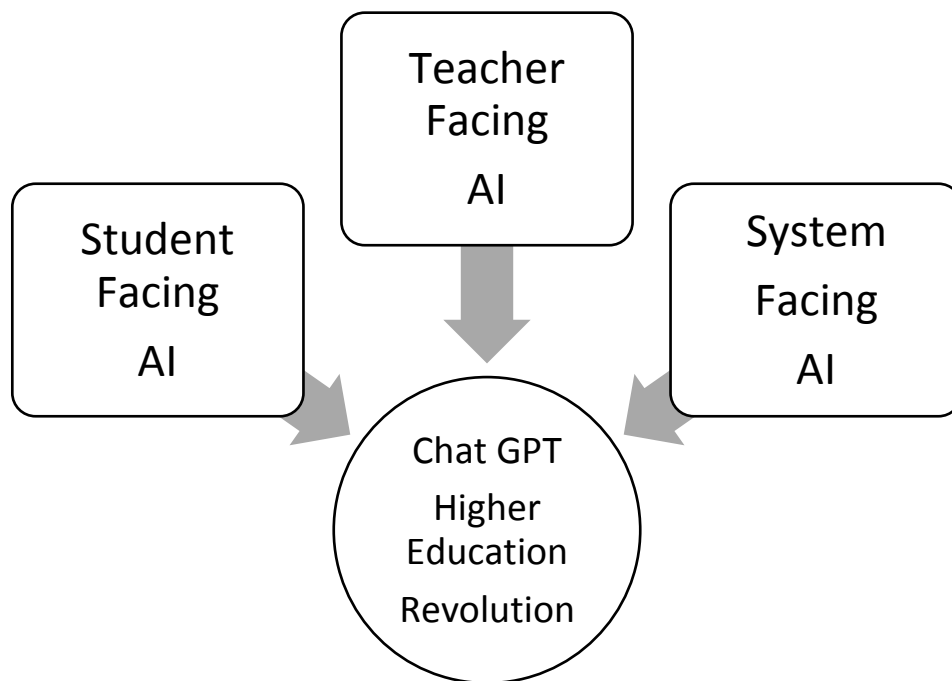
Artificial Intelligence in Education (AIEd) is nothing new, and has been evolving since the 1970s, with researchers exploring AI's potential to enhance learning technologies (du Boulay, 2016). However, recent advancements in AI, exemplified by ChatGPT, have transformed the field, offering sophisticated algorithms capable of learning, adapting, and improving independently (Tan, 2020). This technology has the capacity to revolutionize human interactions in education, leading to a paradigm shift in higher education instruction.

ChatGPT, powered by the GPT-3 architecture, represents a milestone in AI development with its 175 billion parameters, allowing for natural language conversations and contextually appropriate responses (Tan, 2020). It has revolutionized education by enabling AI-driven chatbots that provide instant support, answer questions, and assist with learning tasks, tailored to individual learning styles and improving student engagement and performance. Additionally, its language translation and accessibility features enhance inclusivity, benefiting non-native English speakers and students with disabilities. ChatGPT can also be used to streamline administrative tasks, facilitates content creation, and offers pedagogical guidance to educators, despite challenges related to bias, privacy, and equity.

To understand ChatGPT's potential impact on higher education, it's essential to contextualize it within frameworks like Baker and Smith's (2019) three dimensions: student-facing, teacher-facing, and system-facing AI (See Figure 1). Student-facing AI, such as Intelligent Tutoring Systems (ITS), personalizes learning experiences and provides tailored assistance in problem-solving, mimicking human tutors' support. ChatGPT's potential lies in enhancing personalized adaptive learning, particularly in subjects such as mathematics, supporting students' independent study.

Figure 1

Theoretical Framework: An Adaptation of Three Educational Context for AI (Baker & Smith, 2019)



Teacher-facing AI reduces teachers' workload by automating assessments, fostering innovative instruction, and providing feedback. AI-powered assessment applications, like Automated Essay Scoring (AES) systems, offer continuous feedback beyond traditional methods, enhancing students' writing skills across disciplines. ChatGPT can support educators in various disciplines, including mathematics, by enhancing students' writing skills through automated feedback.

System-facing AI in higher education monitors and evaluates students' performance, offering predictive models and real-time results. This integration of AI and Learning Analytics (LA) can enhance personalized, adaptive, and process-oriented instruction and learning, ultimately improving students' learning and performance. The synergy between AI and LA can provide quantitative performance metrics and qualitative feedback, fostering innovation and improving the quality of instruction in higher education.

A Case for Using ChatGPT

OpenAI, a leading AI research laboratory, aims to advance 'friendly AI' for the benefit of humanity, ultimately aspiring to achieve artificial general intelligence (AGI) (OpenAI, 2015). AGI, or 'strong AI,' represents machines' ability to perform intellectual tasks on par with humans (OpenAI, 2015; Grace et al., 2018). As indicated earlier, in a significant move, OpenAI launched a free preview of ChatGPT on November 30, 2022. ChatGPT, based on the GPT-3 family of large language models,

engages in human-like conversations, amassing one million users within five days of launch (Jin & Kruppa, 2023).

ChatGPT's strength lies in its robust language understanding, making it suitable for chatbots and ITS that support students' self-efficacy in independent study. Its flexibility allows fine-tuning for specific tasks, enhancing the accuracy of responses (Deng & Lin, 2022). ChatGPT's speed and cost-effectiveness make it ideal for real-time applications and as a 24/7 personal assistant (Guo et al., 2022). However, it has limitations, such as struggling with contextual nuances and lacking real-time access to up-to-date information (Azaria, 2022). Despite this, ChatGPT remains valuable for various applications in higher education, provided users understand its capabilities and constraints.

The Instructor's Perspective

The instructor's interest in artificial intelligence (AI) was sparked in November 2022 shortly after the development of ChatGPT. This interest led to a desire to explore its educational potential. Despite initial reservations, the instructor recognized ChatGPT's ability to enhance students' learning experiences, especially in mathematics since that was his area of focus. The institution initiated a peer tutoring programme in January 2021 to support students who were facing challenges with quantitative courses. Inspired by the programme's success, the instructor decided to investigate how AI's could further enhance this peer tutoring initiative in Mathematics Education. In preparation, the instructor participated in a 4-week international professional development workshop on integrating ChatGPT in education. The workshop focused on using ChatGPT to enhance student engagement, creative thinking, and teaching resources, with adaptable activities for any content area. Sessions were asynchronous, allowing educators to implement ideas in their teaching. Participants shared their impressions of ChatGPT before and after the workshop, highlighting its potential in education. The instructor's impressions before and after the workshop are discussed later in the findings.

Methods

Research Objective and Methodological Approach

The objective of this study is to explore the integration of ChatGPT in teaching mathematics at a Higher Education Institution (HEI) in the Caribbean. The study aims to investigate how AI-driven tools, particularly ChatGPT, could be used to enhance mathematical instruction, improve student engagement, and support learning outcomes in a pre-calculus course. The research also seeks to capture the reflections of both the instructor and students on the use of AI interventions in teaching and assessment.

The research team selected an exploratory case study to investigate the use of ChatGPT in mathematics instruction, which is a novel and evolving phenomenon. Given that the integration of AI tools in teaching is relatively new, the case study approach facilitated a detailed examination of the practical applications, challenges, and outcomes in a specific educational context. Moreover, the case study approach suited the research aims because it allowed the researcher to capture real-life experiences of both the instructor and students in the classroom setting. By focusing on qualitative data such as journal entries and student feedback, the exploratory case study provided rich insights into the use of AI tools and their impact on teaching practices. This approach was particularly useful when investigating new technologies and testing innovative teaching strategies.

Research Paradigm

The study employed the reflexive praxis research paradigm to examine the integration of ChatGPT in mathematics instruction. The reflexive praxis research paradigm is a qualitative research approach that emphasizes self-reflection and continuous critical evaluation throughout the research process. This paradigm involves the researcher actively engaging in reflective practice, considering their own role, biases, and assumptions, and adjusting the research approach based on evolving insights.

In this study, the reflexive praxis paradigm guided the research process by encouraging the instructor to continuously reflect on their teaching practices and the impact of ChatGPT interventions. The use of reflective journal entries from both the instructor and students allowed for ongoing evaluation of how AI tools were used in the classroom, what worked well, and what needed adjustment. This paradigm was suitable for the study because it aligned with the exploratory nature of the research, allowing the instructor to adapt and refine teaching strategies based on feedback. Additionally, it ensured that the research captured real-time experiences and reflections, providing a deeper understanding of the practical applications of AI in education.

However, the reflexive praxis research paradigm could introduce inherent biases in data interpretation because of the direct involvement of the researcher. The instructor's reflections and interpretations may be influenced by personal experiences, assumptions, and expectations about the use of AI in teaching. Nonetheless, to mitigate these biases, the research team employed multiple data sources to ensure triangulation and provide a balanced perspective. These included:

- (a) Reflective journal entries from both the instructor and students
- (b) Direct quotes from students to capture their unfiltered feedback
- (c) Early Informal Evaluation of Teaching (EIEOT) survey to gather additional student perspectives.

By incorporating student reflections and feedback, the study reduced the risk of relying solely on the instructor's viewpoint. The use of direct quotes and multiple data sources provided external

validation, ensuring that the research outcomes were not solely based on the instructor's interpretations. These measures, combined with journal entries and the EIEOT survey, offered diverse perspectives, which minimized bias and enhanced the credibility and reliability of the study's findings.

Data Site and Participants

The selected method and research paradigm were considered appropriate as the instructor, with over 22 years' experience teaching mathematics in the US and the Caribbean, taught a pre-calculus course at the first-year level. The course, offered at the newly established campus of The University of the West Indies in Antigua and Barbuda, aimed to provide students with foundational mathematical tools essential for understanding concepts in Social Sciences, Health and Behavioural Sciences, Humanities and Education, Computer Science, and Artificial Intelligence. The course ran from September to December 2023. However, the research was conducted from mid-September to the end of October 2023. The cohort consisted of 70 students who met the prerequisite of achieving a satisfactory pass in Caribbean Secondary Examination Council (CSEC) Mathematics or its equivalent.

Data Collection

Data for this study were collected through reflective journal entries from both the instructor and students capturing their reflections throughout the duration of the course. Direct quotes were used from these journal entries to highlight the various ChatGPT interventions employed during teaching and assessment. Additionally, the instructor administered an Early Informal Evaluation of Teaching (EIEOT) survey during the course to gather students' feedback and recommendations on the AI-inspired interventions. See Appendix A for survey instrument.

The EIEOT is an informal survey administered by the campus during the semester as a quality assurance evaluative tool to gather insights on the students' experience and implement interventions, where necessary. This survey facilitated anonymous feedback from students, which served as a catalyst for a cycle of: (a) student feedback, (b) review of students' feedback, and (c) implementation remedial actions, including students' recommendations in classroom practices, if necessary. This iterative process empowered students to become active stakeholders in providing feedback and shaping the didactical contract with their instructor, thereby enhancing their mathematical learning experiences during the course.

Confidentiality and Anonymity

The research aligns with The University of the West Indies Research Policy which permits studies of this nature to be exempt from the review process. According to the policy, "educational research involving normal educational practices, e.g. classroom instruction, strategies, curricula management techniques" is exempt from the ethics review process provided that students are not identifiable (UWI, 2011, p. 11). All students who participated in this exercise provided voluntary informed consent and are anonymized.

The Data Collection Course for Teaching with ChatGPT

The course centred on fundamental mathematical concepts and their practical applications, emphasizing mathematical reasoning and problem-solving skills. Students reviewed essential mathematical concepts early in the course, including operations with indices, factorization, solving linear equations, the use of brackets, simplification of fractions, and handling directed numbers. The course ran for 12 weeks, with 2 hours of lecture and 1 hour of tutorial session each week (See Table 1).

Table 1
Teaching Methods for Pre-calculus Course

| Method | Description |
|-------------------------------|--|
| Lectures Duration: 2 hours | Interactive lectures will be used to introduce the main concepts of the course. |
| Tutorials Duration: 1 hour | Discussions and problem-solving sessions to facilitate student engagement in group or individual problem-solving processes. Activity sheets and practice exercises, pop-quizzes and various interactive formative assessments. |

The teaching methods employed included interactive lectures to introduce main concepts and tutorial sessions for discussions and problem-solving. The course was designed to enable students to acquire competencies in describing and analyzing relationships among functions, equations, and inequalities. This included discerning and differentiating between various types of functions, equations, and inequalities, and identifying and utilizing appropriate approaches to solve equations and inequalities of varying complexities within real-world problems. Students were also expected to demonstrate versatility in problem-solving, interpreting solutions within real-world contexts, and tackling complex challenges using calculus methods. The instructor integrated ChatGPT into the course instruction and activities to enhance student learning. In the following section, the findings and analysis of the implementation of ChatGPT, along with supporting evidence and artifacts, are presented.

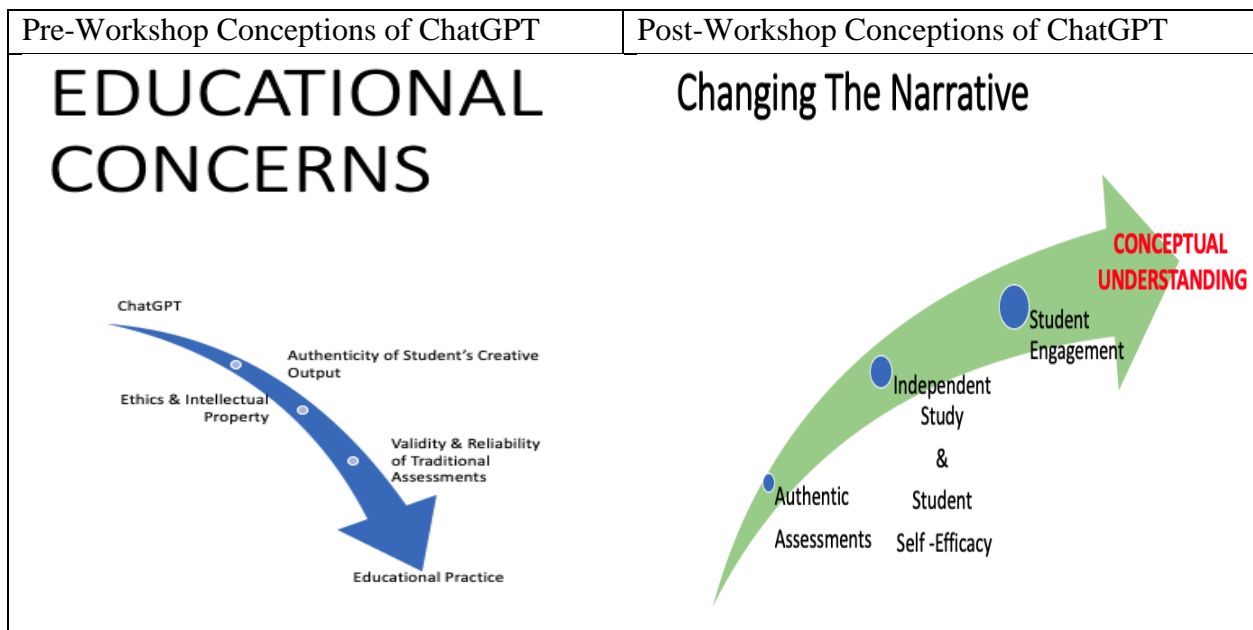
Findings And Analysis

In this section we provide findings derived from the thematic analysis of journal entries by both the instructor and students. For themes associated with students' journal entries and survey responses, representative quotes are used accordingly. To protect students' identities, pseudo-labeling is used when presenting these representative quotes.

As discussed earlier, the instructor participated in a workshop on how to integrate AI in education. Figure 2 presents an artistic artifact of the instructor’s impressions before the workshop. This is referred to as an “educational concern”. The impressions after the workshop are captioned as “changing the narrative”, emphasizing the instructor’s desire to maximize the benefits of ChatGPT in his instruction.

Figure 2

Instructor’s Perceptions of ChatGPT Pre and Post-Professional Development Workshop



The downward arrow in the pre-workshop conceptions of ChatGPT reflects the instructor's concern that ChatGPT could negatively impact teaching practices in mathematics. This apprehension was noted in journal entries during the course.

I view any new technological advancement as having both merits and limitations. I must admit the current hype and discussion among fellow academics molded my initial thoughts that this AI will change the way we traditionally assess students and it seems that it does all the thinking so what is left for the students. If I ask students to create a diagram explaining a mathematical concept, will they do it or just leave it to ChatGPT which seems more advanced than relying on google etc.?

The instructor's quote shows a balanced view on technological advancements, like ChatGPT. The instructor recognizes that while it is innovative, such technologies have both pros and cons. Initially swayed by fellow educators' excitement, the instructor believed ChatGPT could be used to revolutionize student assessments in higher education.

The instructor and other participants shared a common concern before the workshop: If AI, like ChatGPT, can effectively handle complex tasks and generate answers, what role is left for students in the learning process? The concerns expressed by the participants in the workshop align with those highlighted in the literature (Perkins, 2023) regarding academic integrity and authentic assessment. This caused apprehensions about students relying too heavily on AI for tasks like creating diagrams to explain mathematical concepts, potentially hindering their active engagement and critical thinking. The instructor's thoughtful consideration highlights the need to balance efficiency with ensuring students are actively involved in learning.

After the workshop, the instructor's perspective on ChatGPT shifted positively, symbolized by the upward trajectory of the arrow. He now sees ChatGPT as a powerful tool for use in enhancing students' understanding of mathematics. He viewed ChatGPT as an essential tool for crafting authentic assessments and fostering self-efficacy and autonomous learning. Using ChatGPT to provide tailored support in mathematics education will enhance student engagement thereby improving conceptual comprehension. Overall, the instructor regards ChatGPT as a transformative tool in education.

In a poignant post-workshop journal entry, the instructor articulated a profound conviction:

In considering what I learned in this workshop I think ChatGPT, despite the concerns, can be an essential tool in bringing 21st century AI tools in my teaching. I can see where it can support my creation of authentic assessments whereby students are engaged with real-world problems that allow them to think critically and apply the mathematics concepts I teach. I can also see ChatGPT's role in helping them generate practice questions that reinforce what we did in class whenever they are studying alone or in groups. I can also see the benefits in enhancing my current lesson plans to incorporate more group discussions and collaborative activities that appeal to their interests. I think all of these benefits will be rewarding in my classes this semester.

The instructor sees ChatGPT as a valuable tool for modernizing teaching methods. It helps create authentic assessments that engage students with real-world problems, fostering critical thinking and practical application of mathematical concepts. For students, ChatGPT supports independent study by generating practice questions aligned with class material. This encourages students to take ownership of their learning and reinforces classroom concepts through self-directed practice. Additionally, ChatGPT facilitates enhanced lesson planning, promoting engagement and a deeper understanding of the subject matter through group discussions and collaborative activities. Overall, the instructor expects these AI capabilities to enrich their teaching approach in the upcoming semester, demonstrating how AI can enhance traditional teaching methods. The following section demonstrates how the instructor integrated ChatGPT's features into teaching an undergraduate pre-calculus course with 70 students in semester 2, 2023, after completing professional development training in December 2022.

Introducing Students to ChatGPT within Higher Educational Context

The instructor introduced ChatGPT to students in a comprehensive orientation session during the first week of the semester. The session covered the platform's features, account setup, and ethical use. The instructor's emphasis on informing students about ChatGPT's capabilities and limitations reflects the importance of transparency and ethical awareness when integrating AI tools into educational practices. This is consistent with the recommendations of Foltynek et al. (2023), who argue for the development of educational policies that guide the ethical use of AI in academia.

The instructor's live demonstration highlighted ChatGPT's applications beyond mathematics. Students were organized into groups for collaborative exploration, promoting independent study and quiz preparation. During the semester, the instructor administered the Early Informal Evaluation of Teaching (EIEOT) survey to the class to garner students' views on teaching and learning at that stage. This feedback on the instructional practices was generally positive. Below are selected students' quotes on ChatGPT integration as articulated in the EIEOT survey.

Student A: *I never realized that I can use ChatGPT to assist me with mathematics. I actually uploaded my notes and asked it to create questions on the notes I had written about Sets and interval notations. This really helped me, and I actually did well on that quiz on this topic the following week.*

Using ChatGPT for academic assistance, especially in mathematics, was a surprising and beneficial experience for this student. Initially unaware of ChatGPT's full potential, the student proactively uploaded the notes and asked ChatGPT to generate questions on Sets and Interval Notations. This assistance significantly contributed to the student's academic success, as he performed well on a subsequent quiz. The student's experience highlights ChatGPT's versatility in creating custom learning materials and practice questions, enhancing their understanding and success in mathematics. Another student reflecting on the EIEOT survey, stated:

Student B: *I really enjoy how I used ChatGPT to come up with questions for the question back for our upcoming quizzes on functions. I liked how it was able to tailor the questions in complexity so that you had a range of questions in terms of difficulty. I was pleased that I saw a few of those questions on our practice worksheet. I felt like I contributed to our collective learning.*

The students' feedback highlights their positive experience using ChatGPT to create practice questions for quizzes, particularly on the topic of functions. They appreciate ChatGPT's role in generating quiz questions, noting its value and accessibility in supporting their learning. They find ChatGPT's ability to tailor questions to varying levels of complexity advantageous, allowing them to create a comprehensive set of questions. The student also notes that the questions generated by ChatGPT aligned well with their practice materials, aiding their focus on essential topics.

Additionally, they express a sense of accomplishment and contribution to the learning community through their use of ChatGPT, potentially by sharing these questions with classmates. Overall, the student's experience demonstrates how ChatGPT can enhance personalized learning and preparation for quizzes while fostering collaboration within the academic environment. Another student in their reflection stated the following:

Student C: *I think the ChatGPT practice questions are good but I realized that you still need to check the answers cause[because] it could give you an incorrect answer or you needed to push it further to explain why that answer was selected.*

The student finds ChatGPT beneficial for generating tailored practice questions but emphasizes the importance of verifying answers independently. While acknowledging its usefulness, they caution that ChatGPT's responses may lack accuracy or thorough explanations. They suggest improving ChatGPT's explanatory capabilities for a more comprehensive understanding. Overall, the student's perspective highlights ChatGPT's usefulness in question generation but emphasizes the need for caution and suggests enhancements for better educational support.

Teaching-facing AI

In utilizing teaching-facing AI like ChatGPT, instructors can streamline their workload by generating assessments, lesson plans, and activities to monitor student progress (Baker & Smith, 2019). This approach allows for adaptive and personalized pedagogy, as seen in the creation of differentiated instructional plans. By integrating ChatGPT, the instructor transformed the design of formative assessments, gaining valuable insights into student strengths and areas for improvement. An example of such a plan is presented in Appendix B.

Additionally, the instructor used ChatGPT to generate a quiz on interval notation of sets, tailored to real-world applications like banking or online shopping. By leveraging student interests collected at the start of the course, the instructor crafted questions that engaged students and assessed their comprehension. This innovative approach is exemplified in Figure 3, which showcases three questions created by ChatGPT to enhance assessment techniques.

Figure 3

Prompt and Response for ChatGPT generated Quizzes

Create a quiz with 5 multiple choice questions that assess students understanding of interval notation of sets using real-world examples in banking and finance or shopping online

Certainly! Here's a quiz with 5 multiple-choice questions to assess students' understanding of interval notation of sets using real-world examples in banking, finance, or online shopping:

Quiz: Interval Notation in Real-World Scenarios

Question 1:

You want to buy a smartphone online, and the price range you're willing to consider is between \$300 and \$500. Which interval notation represents this price range?

- A) [300, 500]
- B) (300, 500)
- C) [300, 500)
- D) (300, 500]

Question 2:

You are looking for a savings account with an interest rate greater than or equal to 2% but less than 3%. Which interval notation represents this interest rate range?

- A) [2%, 3%]
- B) (2%, 3%)
- C) [2%, 3%)
- D) (2%, 3%]

Question 3:

You have a coupon that offers a discount of 20% off your entire purchase. You want to use it when your total purchase amount is at least \$50. Which interval notation represents the purchase amount required to use the coupon?

- A) [50, ∞)
- B) (50, ∞)
- C) (-∞, 50]
- D) (-∞, 50)

Addressing Students' Misconceptions Through Gamification

During the course delivery, the instructor noticed that some students struggled with quadratic equations and decided to incorporate gamification to make learning more engaging. The goal was to turn mastering quadratic equations into an enjoyable adventure, helping students overcome misconceptions. By combining technology and pedagogy, the classroom became an enthusiastic environment for cultivating mathematical skills. Figures 4, 5, and 6 show examples of the gamification artifacts used by the instructor to assess students' understanding. Figure 6 illustrates the instructor suggesting ways to modify the game's difficulty to accommodate students with different proficiency levels.

ChatGPT proved invaluable in boosting student engagement and assisting the instructor in assessing students' proficiency in solving quadratic equations. ChatGPT also aided in planning lessons and implementing interactive gamification during tutorial sessions, helping monitor student progress in this area throughout the semester. These gamification features align with Sims' (2023) advocacy for incorporating AI in game-based instruction within higher education.

Figure 4

Prompt and Response for ChatGPT's Gamification Instructions

Create a game to test college students knowledge of and applying the quadratic formula

Certainly, here's a fun and interactive game to test college students' knowledge and application of the quadratic formula. Let's call it "Quadratic Quest."

Objective: To solve quadratic equations using the quadratic formula while racing against time.

Materials Needed:

- Whiteboard or chalkboard
- Markers or chalk
- Stopwatch or timer
- List of quadratic equations

Gameplay:

Figure 5

ChatGPT Gamification Example for Quadratic Equations

Gameplay:

- Setup:**
 - Divide the students into teams of two or more.
 - Draw a large grid on the whiteboard or chalkboard, creating a game board with columns and rows.
 - Label the columns A, B, C, D, etc., and the rows 1, 2, 3, 4, etc.
 - At the top of the board, write "Quadratic Quest."
- Equation Selection:**
 - Prepare a list of quadratic equations of varying difficulty levels. Each equation should be assigned a point value based on its complexity.
- Game Rounds:**
 - Each team takes turns choosing a cell on the game board by calling out a combination of a column letter and a row number (e.g., "B3").
 - The instructor or a designated scorekeeper writes the chosen point value on that cell.
- Solving Equations:**
 - When a team selects a cell, they must solve the quadratic equation associated with that cell's point value within a time limit (e.g., 2 minutes).
 - To earn the points, the team must correctly apply the quadratic formula to find the solutions (real or complex) for x .
 - If they answer correctly within the time limit, they earn the points, and the cell is marked with their team's color or symbol.
- Scoring:**
 - Keep a tally of each team's points on the board.
- Winning:**
 - The game can be played for a set duration (e.g., 30 minutes) or until all the cells are chosen.
 - The team with the most points at the end wins the Quadratic Quest game.

Figure 6

ChatGPT Suggested Differentiated Gamification of Quadratic Equations

Variations:

- To make the game more challenging, you can include quadratic equations with coefficients that require factoring before applying the quadratic formula.
- Add "challenge cells" with bonus points for teams who can solve equations mentally or without showing their work.
- Incorporate a final round where teams solve a particularly complex quadratic equation for a large point reward.

This game not only tests students' knowledge of the quadratic formula but also encourages teamwork and quick thinking. It's a dynamic way to reinforce quadratic equation-solving skills in a competitive and engaging manner.

System-Facing AI and Non-Traditional Authentic Assessments

System-facing AI in higher education institutions plays a crucial role in monitoring and evaluating students' performance patterns. AI prediction models, including early warning systems, recommender systems, tutoring, and learner models, offer valuable capabilities. The instructor found the ability to provide timely feedback and interventions tailored to students at risk particularly beneficial. During the semester, weekly quizzes were introduced in tutorial sessions to offer formative feedback. These quizzes included various question types, such as short response, true or false, multiple-choice, and error analysis questions, to identify weaknesses and enhance conceptual understanding. For error analysis assessments, students were presented with worked solutions or explanations and asked to identify errors, provide reasons for their correctness, and offer correct solutions. This form of authentic assessment allowed students to articulate their opinions, engage in peer reviews, and use their knowledge to assess problem-solving. The ChatGPT output in Figure 7 illustrates an example of an error analysis question related to solving quadratic equations, highlighting students' struggles with efficient factorization in such equations.

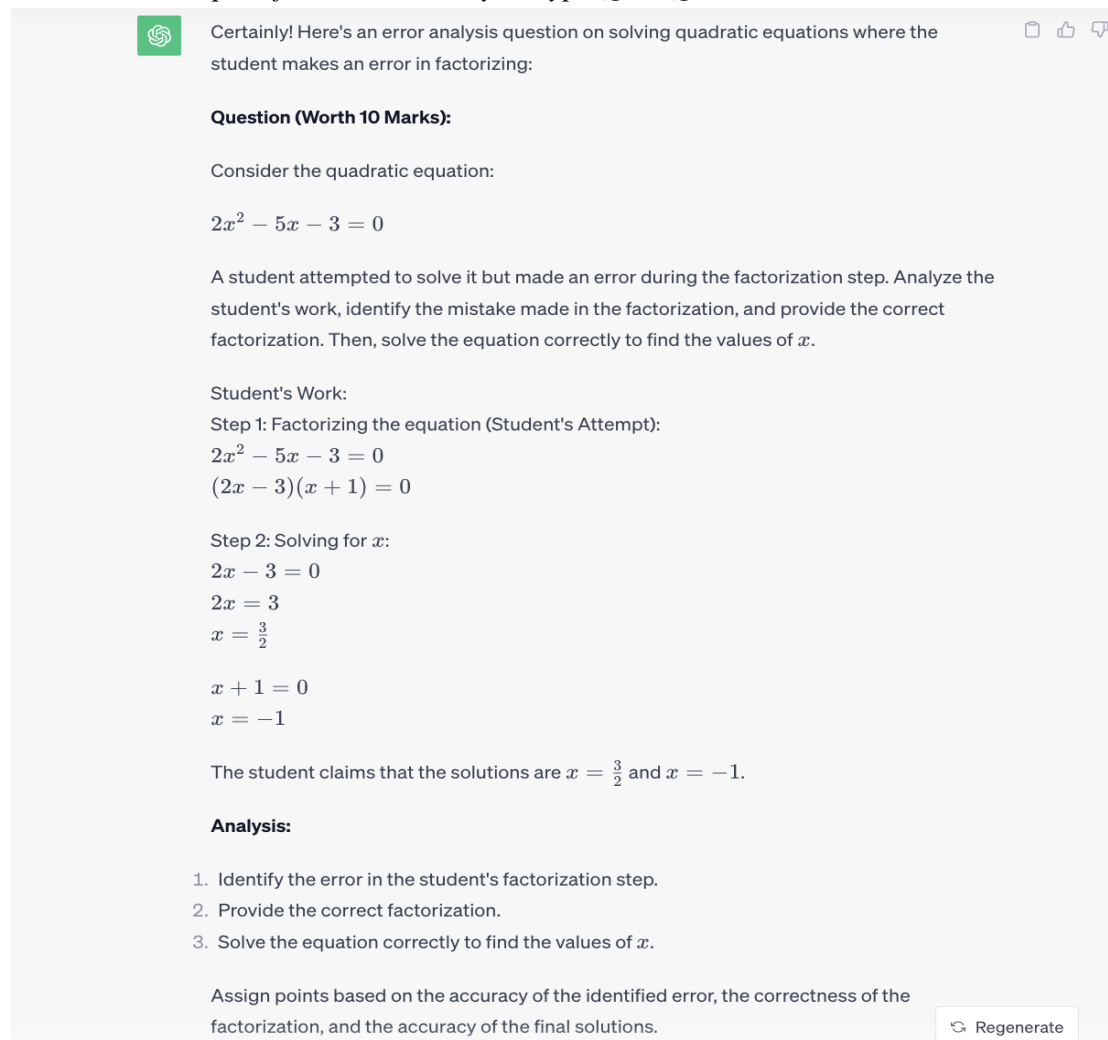
Figure 8 displays the instructor's request for a rubric to grade error analysis questions. Students also shared their views on this assessment format. When asked, "What should your instructor keep doing?" students praised the emphasis on critical thinking, collaborative learning, assessing understanding, and exploring non-traditional assessment methods. The following quote is representative of one student's feedback.

Student D: *One thing I want sir to keep doing is those error analysis questions. I found it interesting how you had to be alert and understand the material to be able to point out errors in the proposed solution in the quiz. You also had to push yourself to also come up with the correct answer. I liked this approach especially when sir allowed us to do it as a group and collaborate about identifying the errors and then coming up with the solution*

Student E values error analysis questions as they provide a deeper assessment of their understanding beyond mere problem-solving. They are pleasantly surprised by the group engagement these questions foster, noting the contrast with traditional math classes focused on notetaking. Student E appreciates the non-traditional approach of using error analysis questions, crediting their instructor for the innovative method that encourages discussion and peer learning during assessments.

Figure 7

ChatGPT Example of the Error Analysis-type Quiz Question



Certainly! Here's an error analysis question on solving quadratic equations where the student makes an error in factorizing:

Question (Worth 10 Marks):

Consider the quadratic equation:

$$2x^2 - 5x - 3 = 0$$

A student attempted to solve it but made an error during the factorization step. Analyze the student's work, identify the mistake made in the factorization, and provide the correct factorization. Then, solve the equation correctly to find the values of x .

Student's Work:

Step 1: Factorizing the equation (Student's Attempt):

$$2x^2 - 5x - 3 = 0$$
$$(2x - 3)(x + 1) = 0$$

Step 2: Solving for x :

$$2x - 3 = 0$$
$$2x = 3$$
$$x = \frac{3}{2}$$
$$x + 1 = 0$$
$$x = -1$$

The student claims that the solutions are $x = \frac{3}{2}$ and $x = -1$.

Analysis:

1. Identify the error in the student's factorization step.
2. Provide the correct factorization.
3. Solve the equation correctly to find the values of x .

Assign points based on the accuracy of the identified error, the correctness of the factorization, and the accuracy of the final solutions.

Regenerate

Student D values error analysis questions for their engagement and challenging nature, requiring attentiveness and a deep understanding of the subject. They appreciate the critical thinking and problem-solving skills these questions develop. Collaborative learning in error analysis questions enhances their comprehension as they discuss errors and solutions with peers, collectively improving their understanding.

Another student in their reflection on the error analysis type questions stated:

Student E: *I think we should get more analysis of error type questions since it really assessed our understanding of the content and also had everyone in their groups talking this was strange for me in a mathematics class. I always thought you would be just copying notes and listening to the instructor. I never thought we would be discussing and*

learning from each other during a quiz. This is a different non-traditional way of assessing us kudos to sir!

Figure 8

ChatGPT Generated Rubric Guidelines for An Error Analysis Quiz

Certainly, here's a revised grading rubric for the Error Analysis Question on Solving Quadratic Equations with a total of 10 marks:

| Criteria | Excellent (4) | Proficient (3) | Basic (2) | Limited (1) | Incomplete (0) |
|---------------------------------|--|--|---|---|--|
| Identification of Errors | Accurately identifies and clearly explains all errors made in the provided work, including the specific step where the error occurred. | Correctly identifies most errors made in the provided work and explains them clearly, but may miss one minor error. | Identifies some errors in the provided work but misses important errors or does not explain them clearly. | Identifies only a few errors in the provided work and does not explain them clearly. | Does not identify any errors or provides incomplete explanations. |
| Correction of Errors | Provides the correct solutions for all identified errors and explains them accurately. | Provides the correct solutions for most identified errors and explains them accurately, with minor errors in explanations. | Provides correct solutions for some identified errors but makes significant errors in explanations or misses corrections for some errors. | Provides incorrect solutions for most identified errors and explanations do not align with correct solutions. | Does not attempt to provide correct solutions for identified errors. |
| Clarity of Explanation | Explanations for identified errors and corrections are exceptionally clear, well-organized, and easy to follow. | Explanations for identified errors and corrections are clear and mostly well-organized but may have minor clarity issues. | Explanations for identified errors and corrections are somewhat clear but lack organization and may be difficult to follow in places. | Explanations for identified errors and corrections are unclear and disorganized, making it challenging to understand the thought process. | Explanations for identified errors and corrections are absent or incomprehensible. |

Total Points: (10 possible)

- * Excellent (9-10 points)
- * Proficient (7-8 points)
- * Basic (5-6 points)
- * Limited (3-4 points)
- * Incomplete (0-2 points)

Overall, students found error analysis questions intellectually stimulating, encouraging active engagement, critical thinking, and collaboration. They appreciated the opportunity that ChatGPT offers to identify and correct errors together, enhancing their understanding. Students commended ChatGPT for generating error analysis, noting its ability to gauge understanding, fostering group discussions, and challenge traditional classroom dynamics, leading to a more engaging and beneficial learning experience. The benefits of using error analysis in student learning align with Glovňová's (2019) assertion that error-analysis-based assessments enhance critical thinking skills in mathematics while also creating engaging learning experiences for students.

The Three Mathematical Context for Using ChatGPT

In our theoretical framing we considered the three aspects of AI in Higher Education, namely student-facing, teacher-facing, and system-facing. Table 2 presents the roles of ChatGPT which is aligned to Baker and Smith (2019) three educational contexts and the documented instructors' use during the teaching of mathematics at a higher-education institution.

Table 2
Three Mathematics Educational Context for ChatGPT

| Role in Mathematics Education | Category | Description |
|--------------------------------------|-----------------|---|
| Assisting with Authentic Assessments | Teacher-Facing | ChatGPT can help design and grade authentic assessments that evaluate students' real-world problem-solving abilities. It can generate complex math problems, assess student responses, and provide immediate feedback. This ensures that assessments align with real-life scenarios and promote deeper understanding. |
| Boosting Student Self-Efficacy | Student-Facing | By offering instant explanations and solutions to mathematical problems, ChatGPT can boost students' self-efficacy. When students receive timely and accurate assistance, they gain confidence in their problem-solving skills, which can motivate them to tackle more challenging math concepts. |
| Supporting Independent Study | Student-Facing | ChatGPT serves as a valuable resource for students engaged in independent study. It can provide explanations, examples, and step-by-step guidance for math topics, empowering students to explore and learn at their own pace. This fosters self-directed learning and autonomy. |
| Enhancing Conceptual Understanding | Student-Facing | ChatGPT can clarify complex mathematical concepts through plain language explanations and visual aids. It helps students build a strong foundation by providing additional insights and alternative approaches to problem-solving, thereby promoting a deeper understanding of mathematical principles. |
| Fostering Engagement | Student-Facing | ChatGPT can engage students through interactive conversations and gamification of math problems. It can turn learning into an enjoyable experience by presenting math |

| | | |
|-------------------------|----------------|---|
| | | challenges in an engaging and interactive manner, keeping students motivated and focused. |
| Customizing Learning | System-Facing | ChatGPT can tailor its responses to individual student needs, adapting to their skill level and learning pace. This personalized approach ensures that students receive the appropriate level of support, challenging them without overwhelming them. |
| Improving Metacognition | Student-Facing | ChatGPT can encourage students to think critically about their problem-solving strategies by asking them to explain their thought process. This metacognitive reflection can enhance their understanding and problem-solving skills. |
| Providing Accessibility | Student-Facing | ChatGPT offers accessibility features, such as text-to-speech and translations, which can help students with diverse learning needs and linguistic backgrounds access and engage with mathematical content more effectively. |

The table illustrates ChatGPT's impact on mathematics education. In the teacher-facing category, it assists in designing and grading authentic assessments, enhancing the practical relevance of evaluations. For students, ChatGPT boosts self-efficacy by providing instant explanations, supports independent study with step-by-step guidance, and enhances conceptual understanding with clear explanations and visual aids. It also fosters engagement through interactive conversations and gamification. In the system-facing category, ChatGPT customizes learning experiences by tailoring responses to individual needs, improving metacognition by encouraging explanation of problem-solving strategies, and providing accessibility features for diverse learners. This case study supports Baker (2023) argument that education rather than punitive measures is crucial in fostering academic integrity. While there are diverse perspectives on the use of ChatGPT as noted in Tauginiene et al. (2018), the study forms the basis for further studies on how ChatGPT can be used in academia in an ethical fashion and supports authentic assessment and critical thinking.

Shifting Perceptions of AI in Teaching

In alignment with Ouyang et al. (2022) and Rudolph et al. (2023), who emphasized the potential of AI tools to enhance learning experiences, this study reveals how the instructor's apprehension towards ChatGPT evolved. Initial concerns mirrored widespread fears within HE, as articulated by QAA (2023), about AI's ability to depersonalize education and diminish active student participation. However, as the instructor engaged more deeply with ChatGPT, its capacity to foster student-centered learning and critical thinking became apparent. This shift underscores the

importance of balanced, informed perspectives on AI integration in education, aligning with the framework proposed by du Boulay (2016), which emphasizes the potential of AI to enhance both teaching and learning when thoughtfully applied.

Enhancing Personalized Learning

The study's findings align with Baker and Smith's (2019) concept of student-facing AI. ChatGPT's ability to generate personalized practice questions for mathematics students illustrates its role in creating adaptive learning environments. By enabling students to tailor their practice to individual needs, ChatGPT mirrors the principles of intelligent tutoring systems (ITS), which aim to provide real-time, personalized feedback (Tan, 2020). This reinforces Ouyang et al.'s (2022) findings that AI-driven instruction can improve student engagement and performance by adapting to diverse learning styles and abilities.

Teacher-Facing AI and Workload Reduction

Teacher-facing AI, as discussed in Baker and Smith's (2019) framework, also plays a pivotal role in enhancing educators' capacities. The study demonstrates how ChatGPT facilitated the creation of authentic assessments and interactive lesson plans, reducing the instructor's workload and allowing for more innovative teaching strategies. This aligns with the argument made by UNESCO-IESALC (2023) that AI can drive efficiencies in higher education while also improving instructional quality. By using ChatGPT to gamify the teaching of quadratic equations, the instructor was able to make the learning experience more engaging and accessible to students of varying proficiencies, supporting the findings of Sims (2023), who advocated for AI's role in rethinking traditional educational practices.

Versatility and Collaboration

While the study primarily focused on mathematics instruction, the findings suggest that ChatGPT's potential extends across a variety of disciplines, reinforcing UNESCO's (2023) assertion that AI can transform both academic and administrative functions in HE. The ability of ChatGPT to facilitate collaborative learning, as students worked together to create and share practice materials, highlights its role in fostering a more interactive and engaged academic community. This aligns with QAA's (2023) call for AI to be integrated into teaching and assessment practices that promote collaboration and engagement.

Continuous Improvement and Future Directions

Finally, the study identifies areas for continuous improvement, particularly in ensuring that students verify the accuracy of ChatGPT's responses and seek to deepen their understanding of the explanations provided. This ongoing refinement is necessary to enhance the effectiveness of AI tools in educational settings, aligning with Tan's (2020) call for rigorous oversight and continuous development in AI technology to mitigate potential biases and inaccuracies. The need

for improvement also echoes QAA's (2023) recommendations for a reevaluation of assessment strategies in light of AI's growing influence in education.

Conclusion

The documented quotes and artifacts in the study's findings suggest that ChatGPT can emerge as a multifaceted educational tool, transcending the traditional boundaries of higher-education instruction. For example, its capacity to captivate and engage students extends beyond the realm of interactive conversations and delves into the realm of gamification, transforming the learning experience of students. By artfully presenting mathematical challenges in an interactive manner, ChatGPT afforded student engagement, motivation, and opportunities for honing conceptual understanding. Beyond its role in enhancing student engagement, ChatGPT also proves to be an asset in the domain of personalized learning. ChatGPT seamlessly intertwines with the instructional landscape, empowering educators to craft differentiated lesson plans that guide students on their individual learning trajectories. This adaptive and personalized approach, fostered by ChatGPT, not only supports students' self-efficacy but also amplifies its utility as a teaching-facing AI application. In essence, ChatGPT emerges as an indispensable partner in the dynamic and ever-evolving landscape of modern higher education.

The findings presented in this study provide a comprehensive look into the instructor's journey of integrating ChatGPT, an AI-driven chatbot, into higher education, particularly in the context of mathematics instruction. The study highlights the instructor's evolving perceptions and experiences, as well as the impact of ChatGPT on both teaching-facing and student-facing aspects of education. Furthermore, this study serves as an excellent demonstration of the effective utilization of ChatGPT, adhering closely to the guidelines outlined in the UK QAA. The instructor took the initiative to empower himself through training prior to introducing ChatGPT to students. A relevant recommendation would be for the institution to provide tailored training in ChatGPT to faculty and staff interested in integrating this tool into their teaching methods and functions. Quality Assurance guidelines on AI underscore the importance of engaging and empowering students in the use of AI (QAA, 2023). This was demonstrated in the study. As a second step, the instructor also engaged students through comprehensive orientation. The QAA contends that employers will not only anticipate, but also highly value graduates who are familiar with Generative AI when they enter the workforce. This stride aligns well with one of the defining attributes of The UWI's ideal graduate, which is being well-versed in information technology (IT) and should serve them well as they embark on their professional journey.

The study also met the Academic Integrity standard, a major concern for HEIs. Using the teacher-facing method, he was able to use ChatGPT to assist with providing authentic assessments for the students. Authentic assessment is, indeed, considered to be one of the ways of mitigating the challenges of academic integrity. While authentic assessment serves as a valuable tool in bolstering academic integrity, it is important to emphasize the significance of a wholistic approach. The need

for comprehensive measures that encompass clear policies, guidelines, and educational initiatives on academic integrity cannot be overstated. This multifaceted approach can help institutions maintain academic integrity while fostering meaningful learning experiences for students. In this regard, The UWI stands at the vanguard of this proactive movement in the region. Monitoring and evaluation hold significant importance, and as such, the system-facing component of ChatGPT should be integrated into The UWI Quality Management Framework (Plan-Do-Check-Act) to facilitate ongoing quality enhancement efforts. Importantly, also, the region's Accreditation Agencies must promptly catch up with the latest developments in AI and partner with HEIs to establish guidelines and standards for the implementation of ChatGPT and AI technology, generally.

Overall, ChatGPT's versatility and adaptability make it a valuable asset in modern mathematics education, benefiting both teachers and students across various aspects of the learning process. Additionally, the findings presented in this study indicate that ChatGPT has the potential to transform higher education by enhancing both student-facing and teacher-facing aspects. It can empower students in their learning journey, streamline instructional tasks for instructors, and foster engagement and collaboration within the classroom. However, ethical considerations and the need for continuous improvement should remain at the forefront of AI integration in education. This study serves as a valuable starting point for further exploration of AI's role in education and its impact on teaching and learning.

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Appendix A

Early Informal Evaluation of Teaching Survey

Course Code _____

Course Title _____

Instructor: _____ SEMESTER _____

- | | | |
|---|--|--------|
| 1. The instructor is well prepared. | always | rarely |
| | 5 <input type="checkbox"/> 4 <input type="checkbox"/> 3 <input type="checkbox"/> 2 <input type="checkbox"/> 1 <input type="checkbox"/> | |
| 2. The instructor makes good use of examples. rarely | always | |
| | 5 <input type="checkbox"/> 4 <input type="checkbox"/> 3 <input type="checkbox"/> 2 <input type="checkbox"/> 1 <input type="checkbox"/> | |
| 3. The instructor uses the technological tools effectively. rarely | always | |

- 5 4 3 2 1
4. The instructional videos (lecture recordings etc are
very helpful. always
rarely
- 5 4 3 2 1
5. The instructor shows concern for student learning. always rarely
- 5 4 3 2 1
6. The pace of the course is: too fast too slow
- 5 4 3 2 1
7. The course content is: easy
difficult
- 5 4 3 2 1
8. How often do you use the course management/communication system (CANVAS,
Piazza,)?
- always rarely
- 5 4 3 2 1

To help your learning in this class, what should the instructor start doing?

To help your learning in this class, what should the instructor stop doing?

To help your learning in this class, what should the instructor keep doing?

Appendix B

ChatGPT Differentiated Lesson Plan on Arithmetic and Geometric Progression

Prompt: Create a differentiated lesson plan for a precalculus class on Arithmetic Progression Geometric Progressions for a pre-calculus college class. Use three tiers

ChatGPT Output: Lesson Plan: Arithmetic Progressions and Geometric Progressions
Grade Level: College Pre-calculus
Duration: 3 class periods (50 minutes each)

Objective: Students will be able to distinguish between arithmetic and geometric progressions, identify their common differences or ratios, and solve problems involving both types of sequences.

Tier 1: Introduction to Sequences (1st Class Period)

- **Objective:** To introduce students to the concept of sequences and familiarize them with arithmetic progressions (AP) and geometric progressions (GP).
- **Engagement (10 minutes):** Start with a real-world scenario, such as counting money over time, to illustrate the concept of a sequence. Discuss how this relates to topics covered in previous classes.
- **Exploration (20 minutes):** Teach students the basic definition of a sequence. Define arithmetic progression (AP) and geometric progression (GP). Provide examples of each type and discuss their differences. Highlight the importance of common differences (AP) and common ratios (GP).
- **Guided Practice (15 minutes):** Work through a few examples together as a class, both in terms of identifying sequences as AP or GP and determining common differences or ratios. Encourage active participation.
- **Independent Practice (5 minutes):** Assign simple problems to students to practice distinguishing between AP and GP and finding common differences or ratios.

Tier 2: Arithmetic Progressions (2nd Class Period)

- **Objective:** To delve deeper into arithmetic progressions, focusing on finding n th terms and the sum of terms in an AP.
- **Engagement (10 minutes):** Start with a real-life application of arithmetic progressions, like calculating monthly savings in a bank account, to pique students' interest.
- **Exploration (20 minutes):** Explain how to find the n th term of an arithmetic progression using the formula. Discuss the sum of the first n terms in an AP. Present examples illustrating these concepts.
- **Guided Practice (15 minutes):** Work through problems as a class to find n th terms and the sum of terms in an AP. Encourage students to ask questions and seek clarification when needed.
- **Independent Practice (5 minutes):** Assign practice problems related to arithmetic progressions. Include a mix of finding n th terms and sum of terms.

Tier 3: Geometric Progressions (3rd Class Period)

- **Objective:** To explore geometric progressions in-depth, focusing on finding n th terms, the sum of terms, and infinite sums in a GP.
- **Engagement (10 minutes):** Begin with a real-world scenario involving geometric progressions, such as the growth of a population over generations.
- **Exploration (20 minutes):** Introduce the concept of finding the n th term of a geometric progression using the formula. Discuss how to find the sum of the first n terms in a GP and infinite sums. Provide examples to illustrate these concepts.

- **Guided Practice (15 minutes):** Work through problems as a class to find n th terms, the sum of terms, and infinite sums in a GP. Address any questions or concerns that arise.
- **Independent Practice (5 minutes):** Assign practice problems related to geometric progressions, including finding n th terms, sum of terms, and infinite sums.

Assessment:

For assessment, assign homework problems that require students to distinguish between arithmetic and geometric progressions, find n th terms, sum of terms, and infinite sums for both types of sequences. Evaluate their understanding through a quiz or exam at the end of the unit.

Extension Activities:

For students who excel in the material, provide challenging problems that require them to analyze real-world situations using arithmetic and geometric progressions. Additionally, discuss applications in finance, physics, and other fields where these progressions are commonly used.

Differentiation:

Tiered instruction allows students to work at their own pace and level of understanding. For additional support, offer one-on-one or small group sessions. For advanced students, provide extra resources and problems that go beyond the basic curriculum