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Exploring the Integration of Artificial Intelligence-Based ChatGPT into Mathematics Instruction: Perceptions, Challenges, and Implications for Educators

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Abstract: This research investigates how secondary school mathematics educators in the Nsukka Education Zone, Enugu State, Nigeria, perceive the incorporation of artificial intelligence-based ChatGPT into teaching mathematics. The study employed a sequential exploratory mixed-methods strategy, starting with a systematic survey and followed by detailed interviews. The Mathematics Teachers' Awareness and Perceptions of AI-based ChatGPT Questionnaire (MTAPACQ) used in this study was adapted from an existing online survey and administered to 80 mathematics teachers, who were selected using stratified random sampling to ensure varied representation across different local government areas. The survey explored teachers' awareness, utilisation, and perceptions of ChatGPT. Following the quantitative phase, in-depth qualitative interviews were conducted with a subset of five teachers who were familiar with ChatGPT to gain deeper insights into their experiences. The findings indicate limited awareness of ChatGPT, with only 17% demonstrating familiarity with the technology. The infrequent utilisation of ChatGPT in mathematics teaching is mainly associated with this limited awareness. Teachers who integrate ChatGPT report positive outcomes, including improved teaching effectiveness, heightened student engagement, and enhanced comprehension of complex concepts. Nevertheless, the overall perceptions of the tool's impact on mathematics teaching and learning are moderate. The identified challenges in relation to integration include technical adaptability, curriculum alignment, and the need for customisation to accommodate diverse learning styles. This study emphasises the significance of continuous professional development and ongoing support for teachers to integrate AI-based ChatGPT into mathematics instruction proficiently. The insights derived from the findings hold value for educators, policymakers, and technology developers aspiring to elevate the role of artificial intelligence in mathematics education.

Keywords: artificial intelligence; chatbots; mathematics education; mathematics teachers; ChatGPT technology

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1. Introduction

Mathematics serves as a fundamental skill essential to both education and daily life. It equips individuals with problem-solving skills, quantitative literacy, and the ability to navigate a complex, data-driven world [1,2]. Moreover, it opens up career opportunities and fosters critical thinking, creativity, and personal growth [3]. Mathematics also promotes mental discipline and is important in many daily tasks. Mathematics plays a foundational role in education, providing a framework for understanding the world and preparing individuals for a wide array of academic and professional pursuits [3,4].

Despite the pivotal role of mathematics in education and daily life, many students struggle with internal and external mathematics assessments [5,6]. Over time, mathematics researchers have pinpointed various factors contributing to this issue of underperformance among students in mathematics. These include insufficient foundational knowledge, ineffective teaching techniques that do not cater to diverse learning styles, a lack of personalised

support to accommodate varying learning paces and styles, the presence of maths-related anxiety hindering comprehension and problem-solving abilities, difficulty recognising the practical applications of what is being learned, inadequate practice leading to forgetfulness and decreased confidence, a curriculum that progresses too swiftly for some students to grasp fully, limited access to essential learning materials, a negative mindset fostering a belief in one's inherent inadequacy in mathematics, and external factors like personal challenges, health issues, or familial circumstances affecting students' focus on their studies [7–13].

Improving students' mathematics performance requires a multifaceted approach [14,15]. This includes personalised instruction, effective teaching methods, a supportive learning environment, and resources for independent study [16]. Encouraging a positive attitude towards mathematics and incorporating hands-on, real-world applications can enhance performance [17]. To further boost mathematics proficiency, teachers should identify and address learning gaps, employ diverse teaching methods, establish clear objectives, ensure lessons are relevant, foster active learning, provide ample practice, deliver constructive feedback, encourage critical thinking, utilise formative assessment, nurture a growth mindset, offer additional resources, create a supportive atmosphere, set realistic expectations, utilise technology effectively, adjust instruction based on progress, and promote self-reflection [17–22]. These strategies empower mathematics teachers to create an engaging learning environment that empowers students to excel in mathematics. Out of these suggested remedies, the effective utilisation of technology in mathematics teaching and learning is of interest to this study.

Technology enriches mathematics education by providing innovative tools, resources, and methods that complement traditional teaching approaches [23–27]. When used effectively, it can enhance comprehension, retention, and application of mathematical concepts, preparing students for success in a technology-driven world [27]. Technology offers the resources, facilities, and computing power required to create and implement artificial intelligence (AI) systems [28,29]. AI then uses these technical advancements to evaluate data, learn from it, and arrive at wise judgements or predictions [30]. They work together to advance the creation of intelligent systems, which have numerous applications in various fields [31–34]. AI is increasingly integrated into educational settings to enhance teaching and learning experiences, especially in mathematics [32,35,36].

The use of AI-based ChatGPT in teaching and learning mathematics by teachers is gaining popularity [37]. ChatGPT is a state-of-the-art AI conversational model developed by OpenAI. It uses advanced GPT-3.5 technology and has been trained on diverse internet text to generate human-like responses [38]. This enables it to engage in conversations, answer questions, and assist with various tasks. With extensive knowledge and context comprehension, ChatGPT is versatile for content creation, virtual assistance, and education support tasks [37,39]. It is proficient in a wide range of topics up to September 2021 but may lack information on events after that date [40]. ChatGPT represents a significant advancement in AI-driven conversations, potentially enhancing human–computer interactions across industries [41,42].

ChatGPT is an AI tool that can help teachers save time and create innovative lessons [37,43]. Mathematics teachers can use ChatGPT to identify real-world connections to mathematics topics, connect those to student interests, and create various instructional materials to use in the classroom [36,44]. However, there are concerns about the potential negative impact of ChatGPT on education, such as the possibility of students relying too heavily on the tool and not developing their problem-solving skills [45]. Despite these concerns, ChatGPT is a valuable tool to help teachers create innovative learning experiences and streamline their workflow [43–45].

1.1. Benefits and Challenges of ChatGPT in Mathematics Education

Integrating ChatGPT into mathematics education offers both benefits and challenges. Some benefits of using ChatGPT in mathematics education include the fact that ChatGPT

can save time for both teachers and students by automating tasks like generating quizzes, creating lesson plans, and providing instant feedback [45,46]. It also provides personalised learning experiences tailored to individual interests and learning needs [46]. Additionally, ChatGPT helps teachers create engaging and interactive lessons that align with specific learning objectives and curricular standards [46]. Moreover, it aids in developing problem-solving skills by generating word problems that connect maths topics and content [45]. Lastly, ChatGPT can enhance language skills through features like translations, grammar explanations, vocabulary practice, and conversation simulations [46].

However, some challenges are associated with integrating ChatGPT into mathematics education. These challenges include a potential lack of deep understanding on the part of ChatGPT regarding mathematics concepts, which may hinder its ability to correct misconceptions effectively [37]. Additionally, the accuracy and effectiveness of ChatGPT's solutions may vary depending on factors like the equation complexity, input data, and the instructions provided [37]. Moreover, there are apprehensions regarding the potential negative influence of ChatGPT on education, including the possibility of students over-relying on the tool and not cultivating their problem-solving abilities [47]. Educators must address student reliance on ChatGPT by implementing guidelines and best practices to guide its usage in the classroom. This proactive approach ensures students benefit from AI assistance while still developing problem-solving skills in a balanced educational environment.

1.2. Theoretical Framework

This study is anchored in the self-determination theory (SDT) propounded by Edward Deci and Richard Ryan in 1985. It delves into the internal factors that drive individuals' pursuits and endeavours. SDT asserts that people possess essential psychological requirements—autonomy, competence, and relatedness—which, when fulfilled, contribute to their overall well-being, motivation, and contentment. Intrinsic motivation stems from internal sources of enjoyment, whereas extrinsic motivation is driven by external rewards or the avoidance of penalties. Amotivation characterises a lack of drive due to a perceived disconnect between actions and their outcomes. SDT finds practical application in education, emphasising creating environments that foster autonomy, competence, and relatedness to enhance individuals' motivation and learning outcomes. When these fundamental psychological needs are met, individuals experience heightened well-being and gratification. In summary, SDT provides a comprehensive framework for comprehending and bolstering human motivation.

SDT aligns with the use of ChatGPT by mathematics teachers and offers various benefits, as outlined below:

Autonomy Support: ChatGPT empowers maths teachers by allowing them to independently seek resources and tailor their teaching methods to meet their students' needs [48]. For instance, maths teachers can use ChatGPT to explore various teaching strategies, select relevant resources, and adapt their instruction to the specific learning styles of their students.

Competence Enhancement: ChatGPT aids maths teachers in building confidence and proficiency in teaching mathematics, providing detailed explanations and resources for professional growth [37]. For example, maths teachers can use ChatGPT to gain insights into effective methods for explaining complex mathematical concepts or receive assistance in creating engaging lesson plans.

Relatedness and Community Building: ChatGPT facilitates connections among maths educators, enabling them to engage in discussions, share best practices, and feel a sense of belonging within the educational community [49]. Maths teachers can use ChatGPT to collaborate with colleagues, exchange ideas, and seek advice on teaching strategies, ultimately enhancing their sense of relatedness within the educational community.

Motivation and Engagement: ChatGPT enhances the motivation for maths teachers to engage in continuous professional development through self-directed learning opportunities [37]. For instance, maths teachers can use ChatGPT to explore new instruc-

tional approaches, access resources for professional development, and stay updated on innovative teaching methods, which can boost their motivation to excel in their roles.

Fostering Intrinsic Motivation: ChatGPT provides tools and resources that align with teachers' specific interests and areas of improvement, supporting their intrinsic motivation [50]. For example, maths teachers can use ChatGPT to receive personalised recommendations for professional development resources that align with their specific interests and areas of improvement.

By leveraging ChatGPT, mathematics teachers can enhance their autonomy, competence, and relatedness, leading to more effective and fulfilling teaching experiences. This integration offers a dynamic approach to professional development and collaborative learning within the mathematics education community.

1.3. Reviewed Studies

Studies have been conducted in different fields regarding teachers' perceptions of their use of AI-based ChatGPT. For example, Sumin and Mossholder [51] conducted a comprehensive study focusing on elementary school teachers' perceptions of ChatGPT's educational applications. Through surveys and statistical analysis involving 143 elementary teachers, the study highlighted a disparity between teachers' familiarity with ChatGPT and its actual educational utilisation. Despite the high familiarity, its usage for educational purposes remained relatively low. Concerns such as teachers' AI capabilities, workload, and potential ethical issues, including personal information leakage, emerged as significant obstacles. The study underscored the need for addressing ethical considerations, methods of educational utilisation, and technical support, alongside fostering positive beliefs about ChatGPT's educational potential among teachers. In contrast, Iqbal et al. [40] conducted a qualitative study utilising the technology acceptance model to examine the attitudes of university teachers towards the utilisation of ChatGPT. The study involved semi-structured interviews with 20 teachers from a private university in Pakistan. The findings from these interviews revealed a prevailing sense of caution among the teachers regarding the use of ChatGPT. They expressed a negative perception and attitude towards its adoption, citing concerns such as potential risks of cheating and plagiarism. Despite these apprehensions, the teachers also acknowledged potential benefits, such as facilitating the ease of lesson planning and assessment. However, it was evident that the teachers felt a lack of sufficient information and education about ChatGPT, highlighting the need for further awareness and training to enable them to make informed decisions regarding its use.

Ogurlu and Mossholder [52] conducted a qualitative study to explore the perceptions of ChatGPT among 85 educators across various educational levels, including university, high school, middle school, and elementary school. The participants were active social media users, and data were collected through an online survey. Thematic coding was employed to analyse the responses and interpret educators' concerns and perceived benefits regarding ChatGPT in education. The findings indicated that although educators had limited knowledge about ChatGPT, they expressed openness to receiving training on its educational applications. The concerns raised by educators included issues such as plagiarism/cheating, potential loss of higher-order thinking skills, overreliance on technology, lack of authenticity, decreased content comprehension, fear of the unknown, and concern for social-emotional well-being. Despite these concerns, educators showed optimism about the potential benefits of ChatGPT, including the development of teaching materials to reduce their workload, facilitate instant information access, and elevate the quality of teaching. Similarly, Mai et al. [53] conducted a survey research study to investigate language teachers' perceptions regarding the use of ChatGPT in teaching and assessment within Vietnamese universities. The study involved 43 language teachers, who were surveyed to gather insights into their knowledge, concerns, and challenges related to employing this conversational AI tool in their teaching practices. The findings revealed that while the participating teachers possessed some level of familiarity with ChatGPT, their understanding appeared to be incomplete, potentially influencing their perceptions

and instructional approaches. Interestingly, the study uncovered a nuanced perspective among the teachers regarding the utility and obstacles associated with ChatGPT, with a predominant prevalence of negative viewpoints over positive ones. Notably, variations in the teachers' perceptions were not correlated with the student groups they taught, but rather with their proficiency in effectively utilising ChatGPT. These findings underscore the critical need for comprehensive training and guidance on ChatGPT utilisation, particularly addressing concerns related to formulating appropriate commands to harness the tool effectively for pedagogical purposes.

Furthermore, studies on the awareness, usefulness, perception and challenges of AI-based ChatGPT have been conducted by researchers, and researchers such as Adarkwah et al. [54] found in their study that most educators in Ghana had limited knowledge about ChatGPT. Meanwhile, Widianingtyas et al. [55] revealed in their study that a significant proportion of teachers in Malaysia are familiar with ChatGPT and recognise its applicability in pedagogical contexts. Nevertheless, in terms of the usefulness of ChatGPT, Mondal et al. [56] revealed in their study that teachers use ChatGPT in the preparation of presentation slides, formulating essay-type, multiple choice, and viva questions, answering students' queries, marking, evaluation of answers, planning a lesson, or creating contents for blended learning. On the perception of ChatGPT by educators, Widianingtyas et al. [55] reported that teachers had a positive perception of ChatGPT's integration into their instruction. In terms of the challenges of ChatGPT, Chinoso et al. [57] and Memarian and Doleck [58] revealed in their studies that some of the problems of ChatGPT are that the results produced by ChatGPT are not cited or referenced, plagiarism, deception, misuse lack of learning, and inaccurate responses are sometimes offered to individuals or leaners.

However, there are limited review studies investigating the integration of AI-based ChatGPT into mathematics education, especially from teachers' perspectives. For instance, Getenent [59] conducted a study comparing the problem-solving abilities of ChatGPT and 58 pre-service teachers (PSTs) from an Australian regional university's School of Education. The PSTs, who were being prepared for early childhood, primary, and secondary teaching, tackled a mathematical word problem individually. Data from their submitted assignments were analysed for problem-solving strategies. ChatGPT was also tasked with the same problem, with various prompts provided. The results revealed that while PSTs employed diverse strategies, their solutions did not always align with children's levels of understanding. ChatGPT used similar strategies but predominantly produced incorrect solutions, emphasising the necessity of contextualising its performance, especially in primary school contexts. The study underscores the advantage of human problem-solvers over AI in tasks demanding contextual understanding and creativity. It highlights the importance of problem-solving strategies for PSTs and acknowledges ChatGPT's effectiveness with algebraic equations and formulas but suggests significant room for improvement in AI problem-solving strategies. In the same vein, Wardat et al. [37] examined the perspectives of students and teachers on the use of artificial intelligence-based ChatGPT in teaching mathematics in Saudi Arabia. The study employed a qualitative case study approach that utilised 30 respondents. Their results indicate that ChatGPT is acknowledged for enhancing mathematical skills and contributing to educational success by offering users foundational knowledge in mathematics and diverse subjects. However, the findings also highlight ChatGPT's limitations in comprehending geometry and rectifying misconceptions effectively. The precision and efficacy of ChatGPT's solutions seem to vary based on the equation's complexity, input data, and the instructions provided to ChatGPT.

In another study, Sánchez-Ruiz et al. [60] investigated how ChatGPT could impact blended learning approaches in engineering education, particularly in Spanish mathematics classrooms. The research aimed to understand the influence of artificial intelligence tools on students' development of critical-thinking, problem-solving, and teamwork skills. The outcomes indicated that students expressed a high level of confidence in the accuracy of ChatGPT's responses, showing a substantial percentage of correct answers compared to numerical solutions. Additionally, ChatGPT not only provided solutions but also offered

a step-by-step guide, enhancing students' grasp of the problem-solving process. Concurrently, Yilmaz et al. [61] conducted a study exploring students' perceptions of ChatGPT based on factors such as gender, grade level, major, and prior experience with the AI tool. Using a quantitative research approach with 239 participants from a science and mathematics education programme in Almaty, Kazakhstan, the study found an overall positive perception of ChatGPT among the students. Meanwhile, Wang and Demszky [62] delved into the potential cost-effective role of generative AI-based ChatGPT as an automated teacher-coach in the United States. They proposed three tasks for ChatGPT: scoring transcript segments, identifying instructional highlights and missed opportunities, and offering actionable suggestions for eliciting more student reasoning. Expert mathematics teachers evaluated ChatGPT's performance on these tasks when using elementary mathematics classroom transcripts. The results indicated that while ChatGPT provided relevant insights for improving instruction, the responses were often not novel or insightful.

From the studies reviewed above, it is evident that there is a lack of research on mathematics teachers' knowledge and usage of AI-based ChatGPT in mathematics education, particularly in African countries such as Nigeria. While ChatGPT has been successfully utilised in other fields, including education, its specific application in mathematics teaching remains underexplored. This gap in the literature highlights the necessity of investigating how mathematics teachers in Nigeria are aware of and engage with AI-based ChatGPT. Given the novelty of ChatGPT and its potential benefits in enhancing educational practices, this study aims to fill this critical gap by exploring teachers' awareness, usage, perceptions, and challenges related to AI-based ChatGPT in mathematics teaching and learning. The research objectives are to (i) assess the level of awareness among mathematics teachers regarding AI-based ChatGPT in mathematics teaching and learning, (ii) determine the frequency of utilisation of AI-based ChatGPT by mathematics teachers in their mathematics instruction, (iii) explore mathematics teachers' perceptions regarding the impact of ChatGPT on maths teaching and learning, and (iv) identify and analyse mathematics teachers' challenges in integrating AI-based ChatGPT into their teaching practices.

1.4. Research Questions

The research questions that guided this study are the following:

- To what extent do teachers know about AI-based ChatGPT in mathematics teaching and learning?
- How frequently do mathematics teachers utilise AI-based ChatGPT in their mathematics instruction?
- What are mathematics teachers' perceptions regarding the impact of ChatGPT on mathematics teaching and learning?
- What challenges do mathematics teachers encounter in integrating AI-based ChatGPT into their mathematics teaching practices?

2. Materials and Methods

2.1. Design

The research design for this study is a sequential exploratory mixed-methods design. The design involves a systematic process of collecting, analysing, and integrating quantitative and qualitative data in sequential stages to gain a comprehensive understanding of a research problem or phenomenon [63]. The design employed in this study starts with an initial quantitative data collection and analysis phase, followed by a qualitative phase for in-depth exploration and understanding. This sequential nature allows for a comprehensive examination of AI-based ChatGPT usage among secondary school mathematics teachers in the Nsukka Education Zone. The mixed-methods design is chosen to capitalise on the strengths of both quantitative and qualitative approaches, providing a broad overview through surveys and detailed insights through interviews.

2.2. Participants

The population of this study is delimited to secondary school mathematics teachers within the Nsukka Education Zone of Enugu State, Nigeria. The focus on this specific geographic area ensures a localised examination of the utilisation of AI-based ChatGPT among secondary school educators in mathematics. A stratified random sampling technique is employed to capture a representative sample from the defined population. The strata are based on the different local government areas within the Nsukka Education Zone, ensuring proportional representation from each area. This approach aims to account for potential variations in demographics and teaching environments across the Zone. The final sample comprises 80 mathematics teachers distributed across the local government areas within the Nsukka Education Zone. However, only 17% (HE-11% + VHE-6%) of the sample knew about the AI-based ChatGPT (see Figure 1), comprising approximately 14 maths teachers. Out of these 14 teachers, only 5 agreed to participate in the interview session of the study.

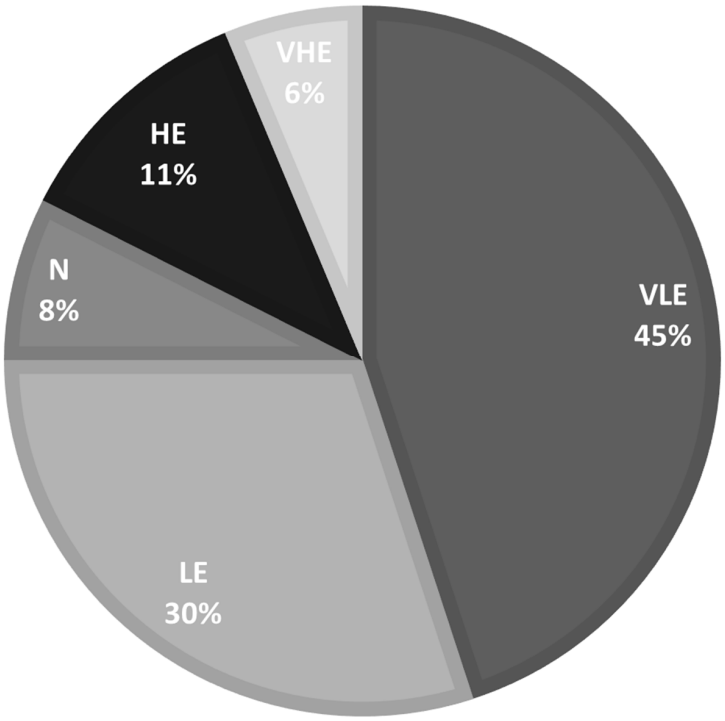

Figure 1. Mathematics teachers' knowledge of AI-based ChatGPT.

2.3. Method of Data Collection

For the quantitative aspect, data were collected through a survey questionnaire adapted from the online survey questionnaire created by Nguyen [64]. The online survey, created using Google Forms, aimed to investigate English teachers' knowledge and perceptions of ChatGPT, including its usefulness and challenges. The questionnaire consisted of three parts. The first part was a consent form to confirm participants' willingness to contribute to the research. The second part collected background information, such as years of teaching experience, whether they taught English majors or non-majors, and their prior experience with ChatGPT. The third part comprised questions designed to explore participants' perceptions of ChatGPT and its use in their teaching and assessment practices. However, the reason for adapting the online language-teaching questionnaire for mathematics teaching was due to the shared educational needs in both fields, such as complex concept explanations and technology integration. Specific questions were modified to reflect mathematics scenarios, and a pilot test with mathematics teachers validated the relevance and effectiveness of the adapted questionnaire.

The adapted survey questionnaire used in this study, titled "Mathematics Teachers' Awareness and Perceptions of AI-based ChatGPT Questionnaire (MTAPACQ)," was distributed to 80 mathematics teachers across various secondary schools in the Nsukka Education Zone. The MTAPACQ comprised two sections: Section A collected personal data from the respondents, including gender and location. Section B consisted of 8 item statements related to teachers' awareness of AI-based ChatGPT, usage patterns, perceptions, and challenges, with respondents rating each item on a five-point Likert scale ranging from "very high extent" to "very low extent" (see Appendix A).

The MTAPACQ underwent face validation by experts in mathematics education, measurement and evaluation, and technology and researchers familiar with AI in education. These experts critically reviewed the instrument to ascertain its content validity. Their feedback was incorporated to refine and clarify the survey questions, ensuring that the instrument adequately addressed the research objectives and covered a comprehensive range of relevant topics. Before full-scale administration of the instrument, a trial test was conducted with 25 mathematics teachers from a different education zone. Cronbach's alpha was employed to analyse the data obtained from the trial test to assess the internal consistency of the MTAPACQ. The reliability coefficient obtained was 0.76, indicating satisfactory internal consistency. The researchers administered the MTAPACQ to the 80 mathematics teachers, achieving a 100% retrieval rate, ensuring the completeness of the data collection process.

For the qualitative aspect, in-depth interviews were conducted with a subset of teachers to gain deeper insights into their experiences with ChatGPT. Specifically, out of the 14 teachers familiar with ChatGPT, 5 agreed to participate in the interviews. The interview guide was developed by the researchers based on a comprehensive literature review and theoretical framework. Initially comprising 8 open-ended questions, the guide was later condensed into 4 overarching themes by validation experts to align with the study's research questions. These experts reviewed the questions for clarity, relevance, and comprehensiveness, providing feedback to refine the guide. A pilot study was conducted with a small sample of participants (n = 5) to test the interview guide, helping to identify any ambiguities and ensuring the questions elicited meaningful responses. Based on the pilot feedback, minor revisions were made to the wording and order of the questions.

The final interview guide consisted of questions designed to explore specific areas of interest, such as mathematics teachers' overall perceptions, usage, challenges, and suggestions (see Appendix B). To determine the reliability of the interview guide, the inter-rater reliability was measured by having two independent researchers conduct interviews with the same subset of participants (n = 5) and evaluating the consistency of the responses. The inter-rater reliability coefficient was found to be 0.80, indicating high reliability. This thorough process ensured that the interview guide was both reliable and valid for capturing meaningful insights. The final interview guide questions were then administered to the 5 mathematics teachers who agreed to participate in the interview session.

2.4. Data Analysis

Quantitative Analysis: The quantitative data from the survey were analysed using SPSS software version 29. Descriptive statistics, specifically the mean and standard deviation, were utilised to address the research questions. A criterion mean rating of 3.0 was established. Mean ratings of 3.0 or higher indicated that respondents accepted a questionnaire item to a high extent (HE) (3.0–3.99) or very high extent (VHE) (4.0 and above). Conversely, mean ratings below 3.0 indicated that respondents accepted the statement to a low extent (LE) (2.0–2.99) or very low extent (VLE) (1.99 and below).

Qualitative Analysis: The qualitative data from the semi-structured interviews were analysed using thematic analysis. This process began with transcribing the interview recordings verbatim to ensure accuracy. The transcripts were then read multiple times, and initial codes were generated for significant pieces of information related to the research questions. These initial codes were grouped into potential themes based on patterns and

recurring topics identified across the interviews. The themes were then reviewed and refined to ensure they accurately represented the data. This review involved checking the themes against the coded data extracts and the entire dataset. Once the themes were clearly defined and named to reflect their essence and relevance to the research questions, the final themes were used to structure the qualitative findings. Selected quotes from participants were included to provide rich, contextualized evidence supporting the study's conclusions.

2.5. Ethical Considerations

Regarding the ethical considerations, this study's ethical conduct received approval from the Post Primary Management Board in the Nsukka Education Zone. Following this, the school principals explicitly permitted the research to occur within their institutions. Additionally, in adherence with ethical protocols, informed consent was diligently obtained from all the participants, emphasising a steadfast dedication to maintaining ethical standards throughout the research process.

3. Results

The findings and analysis of the data are presented in accordance with the research questions. This section introduces the results in a written form before presenting the tables and detailed statistical data.

Research Question 1. To what extent do teachers know about AI-based ChatGPT in mathematics teaching and learning?

Results from the survey (Table 1) indicate that mathematics teachers have a very low awareness of AI-based ChatGPT, with a mean rating of 1.93 (SD = 1.22). This finding is supported by qualitative data, where several teachers mentioned their initial encounters with ChatGPT through personal exploration, workshops, and colleague recommendations. For example:

Table 1. Teachers' awareness, usage, perceptions, and challenges in terms of AI-based ChatGPT in mathematics teaching and learning.

S/N	Item Statement	Mean	Standard Deviation	Decision
	Awareness of AI-based ChatGPT			
1.	To what extent are you aware of AI-based ChatGPT?	1.81	1.18	
2.	To what extent are you familiar with the technological tool ChatGPT?	2.04	1.25	
	Grand Mean	1.93	1.22	VLE
	Usage Patterns of AI-based ChatGPT			
3.	How frequently do you integrate ChatGPT into your teaching practices?	1.78	1.21	VLE
	Perceptions of ChatGPT Impact			
4.	To what extent is ChatGPT impacting teaching efficiency in mathematics?	2.35	1.30	
5.	I think ChatGPT is a useful tool for teaching and learning mathematics	3.28	0.78	
6.	I am satisfied with the responses I get from ChatGPT in handling my math lesson activities.	3.25	0.68	
	Grand Mean	2.96	0.92	LE
	Challenges in Utilising ChatGPT			
7.	To what extent have you encountered challenges in integrating ChatGPT into your mathematics teaching practices?	3.16	0.49	HE

MT 1: "I stumbled upon ChatGPT during my quest for innovative AI tools in education, struck by its potential to revolutionise how students grasp complex math concepts and the assistance it has rendered me."

MT 3: "I attended a workshop that ventured into the frontier of AI in education technology. ChatGPT stood out as a beacon for elevating math instruction through the magic of natural language interactions."

This finding aligns with the autonomy component of SDT, as teachers' discovery of ChatGPT through self-initiated efforts indicates a high degree of self-motivation and control over their professional development. The overall low awareness is visually represented in Figure 1.

Research Question 2. How frequently do mathematics teachers use AI-based ChatGPT in mathematics instruction?

The frequency of ChatGPT usage in mathematics instruction is also very low (mean = 1.78, SD = 1.21), as shown in Table 1. Interview responses revealed that while few teachers used ChatGPT, those who did reported positive outcomes:

MT 1: "ChatGPT has been a game-changer in my teaching. One notable instance was during a lesson on trigonometry. I integrated ChatGPT to provide real-time explanations for complex concepts like trigonometric identities. The outcome was remarkable—students grasped the material more effectively and expressed heightened enthusiasm for tackling challenging problems."

MT 5: "ChatGPT was pivotal in a geometry lesson where we explored the Pythagorean Theorem. Students could interactively engage with ChatGPT to understand the theorem's applications and proofs."

These examples demonstrate that although usage is infrequent, the potential benefits of integrating ChatGPT into teaching practices are significant. This low utilisation is depicted in Figure 2. However, from an SDT perspective, these instances of ChatGPT use highlight the competence component, where teachers feel effective and skilled in their teaching roles by leveraging innovative tools to enhance student understanding.

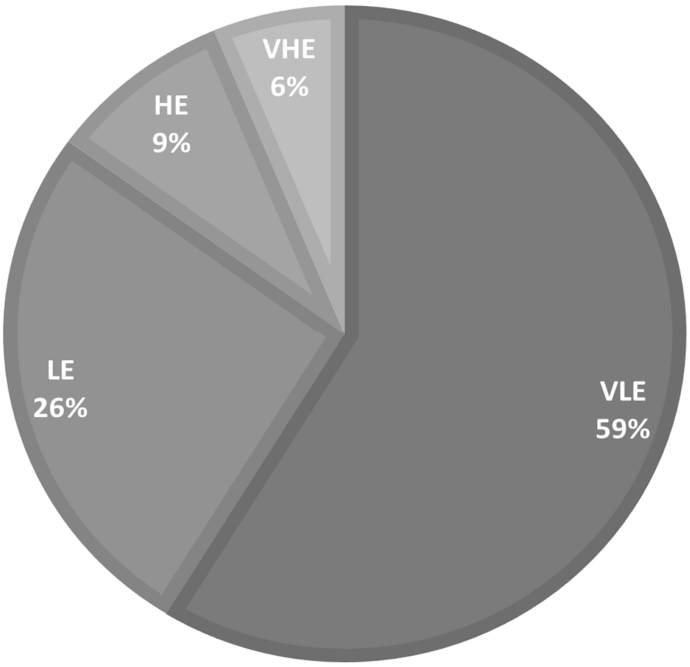

Figure 2. Mathematics teachers' utilisation of AI-based ChatGPT in mathematics instruction.

Research Question 3. What are mathematics teachers' perceptions regarding the impact of ChatGPT on mathematics teaching and learning?

Teachers' perceptions of ChatGPT's impact on teaching and learning are mixed, with a grand mean rating of 2.96 (SD = 0.92), as indicated in Table 1. Some teachers appreciated the efficiency gains:

MT 1: "ChatGPT has significantly enhanced teaching efficiency in mathematics education by providing instant and personalised explanations. This tool allows for quick

clarification of concepts, saving valuable class time and ensuring that students receive immediate support tailored to their needs."

MT 2: "ChatGPT positively streamlines the grading process for math assignments. With its ability to generate instant feedback on problem-solving attempts, educators can focus on targeted interventions rather than spending excessive time on manual grading."

Others raised concerns about the tool's limitations:

MT 3: "In some cases, the integration of ChatGPT might lead to challenges in adapting to diverse learning styles. If not properly customised, it may not effectively address the specific needs of every student, potentially creating a barrier rather than a facilitator in the teaching process."

MT 4: "Over-reliance on ChatGPT could lead to a lack of human connection in teaching. While it offers efficient solutions, the personal touch and nuanced understanding that educators bring to the classroom might be compromised."

These insights highlight the varied perceptions and underscore the need for tailored implementation strategies. The positive perceptions of ChatGPT's impact align with SDT's competence aspect, as teachers feel more capable and supported in their instructional roles. Conversely, the concerns about its limitations reflect the need for enhanced resources and training to fully realise these benefits.

Research Question 4. What challenges do mathematics teachers encounter in integrating AI-based ChatGPT into their mathematics teaching practices?

The extent of the challenges encountered by teachers in integrating ChatGPT is significant, with a mean rating of 3.16 (SD = 0.49), as shown in Table 1. Teachers reported issues such as technological limitations and the need for professional development:

MT 1: "One obstacle in using ChatGPT for math instruction was ensuring it could handle various mathematical problem types. To overcome this, I conducted extensive testing with different problem-solving scenarios and provided feedback to refine ChatGPT's problem-solving capabilities."

MT 2: "Personally, I find it a bit challenging to seamlessly integrate ChatGPT into my lesson plans while ensuring it complements my teaching style. To overcome this, I collaborated with other educators to share strategies and best practices for seamlessly incorporating ChatGPT into existing teaching materials."

These challenges and their corresponding solutions, such as collaboration with colleagues and professional development, illustrate the effort required to effectively integrate new technology into educational practices. These challenges highlight the need for relatedness in SDT, where support from colleagues and a collaborative professional environment help teachers overcome obstacles and feel more connected and supported in their roles.

4. Discussion

This study explored teachers' awareness, usage, perceptions, and challenges related to AI-based ChatGPT in mathematics teaching and learning. The results of the data analysis provide valuable insights into the following aspects, as discussed below.

Awareness and Familiarity. The data suggest that math teachers, on average, have a low awareness of and familiarity with AI-based ChatGPT. The mean rating of 1.93 indicates that teachers in the area of study are not extensively informed about this technology in the context of mathematics education. This low level of awareness could be attributed to several factors, such as a lack of training, insufficient exposure to educational technology, or limited dissemination of information about AI-based ChatGPT in the educational community. This finding lends credence to the finding of Adarkwah et al. [54], who, in their study, confirmed the minimal awareness of ChatGPT among Ghanaian educators meant they did not have a conceptual understanding of ChatGPT and how it could be applied to learning, teaching and personal development. On the contrary, the results of Widianingtyas et al. [55] revealed that a significant proportion of teachers in Malaysia are familiar with ChatGPT and recognise its applicability in pedagogical contexts. Similarly, research by Kitcharoen et al. [65] emphasised the need for comprehensive professional development to improve teachers'

familiarity with emerging technologies. However, the semi-interview responses of maths teachers who know the technology further reveal that their awareness and familiarity with the AI-based ChatGPT are gained through diverse channels, including personal exploration, virtual workshops, and colleague recommendations.

Utilisation Patterns. This study indicates that the frequency of utilising ChatGPT in mathematics instruction is very low (mean = 1.78). The limited integration of AI-based ChatGPT could be due to the challenges teachers face with technological issues, or it could be a reflection of the low awareness and familiarity of the AI tool. Strategies for promoting more frequent utilisation could include targeted training programmes, peer collaboration, and the development of user-friendly interfaces that facilitate easy integration into existing teaching practices. However, the semi-interview responses from maths teachers with knowledge of AI-based tools highlight instances where teachers have successfully integrated ChatGPT into their teaching practices. These instances include real-time explanations of trigonometry, fostering interactive online learning during remote sessions, explaining intricate topics like quadratic functions, and strategic use in homework assignments. This finding supports the findings of Wardat et al. [37], who, in their study, revealed the experience of maths teachers who utilised ChatGPT and the AI-based tool is recognised for its improved math capabilities and ability to increase educational success by providing users with basic knowledge of mathematics and various topics. The finding also lends support to the finding of Mondal et al. [56], who, in their study, revealed that teachers use ChatGPT in the preparation of presentation slides, formulating essay-type, multiple choice, and viva questions, answering students' queries, marking, evaluation of answers, planning a lesson, or creating content for blended learning. Additionally, similar studies by Jian [66] and Xu [67] have shown that AI tools can enhance classroom engagement and facilitate personalised learning when effectively integrated.

Perceptions of Impact. Teachers' perceptions regarding the impact of ChatGPT on mathematics teaching and learning are rated as a low extent (mean = 2.96). The reasons behind these low perceptions need further exploration. It could be that teachers are uncertain about the effectiveness of AI-based ChatGPT in enhancing teaching efficiency. Addressing these concerns may involve showcasing successful case studies, providing evidence of improved outcomes, and actively involving teachers in implementing ChatGPT in the classroom. However, despite the low perception, the semi-interview responses from maths teachers who know ChatGPT shed light on the positive impacts identified. These include enhanced teaching efficiency, streamlined grading processes, and contributions to lesson-planning efficiency. Some concerns are raised about challenges in adapting to diverse learning styles and the potential compromise of the human connection in teaching. This finding corroborates the result of Widianingtyas et al. [55], who, in their study, reported a positive perception of teachers concerning the integration of Chat GPT in their instruction. The finding also aligns with the research conducted by Wang and Demszky [62], wherein mathematics educators assessed ChatGPT's effectiveness in elementary mathematics classrooms. Their findings revealed that although ChatGPT offered valuable insights for enhancing instruction, the responses were frequently lacking in novelty and depth. Furthermore, a study by Wardat et al. [68] highlighted the potential of AI tools to significantly improve student engagement and learning outcomes, provided that teachers receive adequate support and training.

Challenges in Integration. This study reveals that maths teachers who know of the AI tool encountered challenges in integrating ChatGPT into their mathematics teaching practices to a high extent (mean = 3.16). The semi-interview responses provide specific details about these challenges, such as handling various mathematical problem types, seamless integration with existing lesson plans, results produced that are not cited or referenced, inaccurate responses, integration into collaborative problem-solving sessions, and adapting to diverse learning styles. Some of the findings on the challenges corroborate the results of Chinoso et al. [57] and Memarian and Doleck [58], who, in their respective studies, revealed that some of the problems of ChatGPT are that the results produced by ChatGPT

are not cited or referenced, plagiarism deception, misuse lack of learning, and inaccurate responses are sometimes offered to individuals or leaners. The maths teachers share strategies for overcoming these challenges, emphasising the importance of customisation, technical collaboration, ongoing professional development, OpenAI review of ChatGPT to provide accurate responses and to cite and reference the produced information, strategies for student engagement, and adaptability in problem-solving capabilities. Moreover, recent research by Marín and Castañeda [69] stressed the importance of developing robust digital literacy among teachers to navigate and mitigate the challenges posed by new technologies like ChatGPT.

5. Conclusions

In conclusion, while this study indicates a low level of overall awareness, usage, and positive perceptions of the impact of ChatGPT among mathematics teachers, the qualitative responses provide a nuanced understanding. Teachers who are aware of and have utilised ChatGPT perceive it as a valuable tool for enhancing teaching efficiency and student engagement. The challenges identified underscore the need for targeted strategies to address technical, pedagogical, and customisation issues. This study provides a foundation for further research and the development of support mechanisms to facilitate the effective integration of AI-based tools like ChatGPT into mathematics education. However, educators, administrators, and policymakers should proactively educate themselves and their students on the ethical use of ChatGPT. It is also important for educators to recognise the limitations of AI tools, understanding that every technology offers benefits and challenges, along with its inherent risks.

5.1. Educational Implications

This study emphasises significant educational implications for integrating AI-based ChatGPT into mathematics teaching in the Nsukka Education Zone of Enugu State, Nigeria. The identified gaps in teachers' awareness, usage patterns, perceptions, and challenges provide valuable insights for strategic educational interventions. This study calls for targeted professional development initiatives to enhance mathematics teachers' awareness and proficiency in AI-based tools, specifically ChatGPT. It recommends carefully crafted workshops, training sessions, and collaborative learning opportunities to bridge knowledge gaps and equip teachers with essential skills to incorporate these technological advancements effectively. Collaboration between educators and developers is encouraged to design user-friendly interfaces for AI tools, overcoming barriers hindering teachers from readily adopting ChatGPT. In order to overcome teachers' concerns regarding the effectiveness of AI, this study proposes promoting evidence-based advocacy. This involves presenting successful case studies and demonstrations to build confidence and foster positive perceptions. The importance of comprehensive training programmes extending beyond technical aspects is underscored, addressing broader concerns and empowering teachers to navigate obstacles in AI integration.

5.2. Limitations

This study is not without limitations. The research recognises a possible limitation concerning its sample size, which could limit how broadly the findings can be applied. The results are derived from a particular set of participants and may not comprehensively reflect all the mathematics teachers across various regions or educational environments. Therefore, future studies could enhance the robustness of their findings by incorporating a more diverse participant sample. This would involve considering mathematics teachers from various regions and educational settings, ensuring a broader representation of perspectives. The research is geographically specific, focusing on the Nsukka Education Zone in Enugu State, Nigeria. This specificity might limit the applicability of the study's implications to a broader range of cultural and educational contexts. Therefore, future studies might consider expanding their geographical scope to broaden the applicability

of research implications. Including multiple educational zones or states could provide a more comprehensive understanding of the impact of AI integration. Acknowledging the potential for self-reporting bias, mathematics teachers provide the data on which the study depends. Participants might have offered socially desirable responses or unintentionally misrepresented their experiences with AI tools. Therefore, exploring cross-cultural variations in integrating AI tools in mathematics education would contribute to a more comprehensive understanding. Future studies could investigate how cultural nuances influence the effectiveness and acceptance of AI-based ChatGPT.

Recommendations for Implementation:

- Educational authorities and institutions should spearhead the organisation of regular and targeted training programmes, focusing on AI-based tools. These initiatives are crucial for equipping mathematics teachers with foundational knowledge and practical skills, fostering a culture of continuous learning in the rapidly evolving landscape of educational technology.
- It is imperative to establish robust collaboration channels between educators and AI developers. This partnership can foster a mutual understanding of the unique needs and challenges within the educational context, leading to the development of AI tools that seamlessly align with teachers' requirements.
- Promoting and facilitating peer collaboration among mathematics teachers is essential. Platforms that encourage sharing experiences, insights, and best practices in integrating AI tools can provide valuable support and encouragement. Peer-to-peer learning is pivotal in overcoming challenges and cultivating a positive attitude towards AI integration.
- Prioritising the establishment of robust technical support systems is vital for educational institutions. Providing prompt and effective technical assistance can significantly enhance teachers' confidence in using AI tools, addressing issues as they arise and ensuring a smoother integration process.

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Appendix A

Mathematics Teachers' Awareness and Perceptions of AI-based ChatGPT Questionnaire (MTAPACQ)

SECTION A: Demographic information

1. Gender: Male ☐ Female ☐
2. Location: Urban ☐ Rural ☐
3. Qualification: NCE ☐ BSc (Ed.) ☐ MSc/MED ☐ PhD ☐

SECTION B:

Instruction: You are kindly requested to tick (√) the spaces provided in the questionnaire. This section is in four segments—namely, Awareness of AI-based ChatGPT, Usage Patterns of AI-based ChatGPT, Perceptions of ChatGPT Impact, and Challenges in Utilizing ChatGPT.

For each of the statements below, please show to what extent by placing a tick in the appropriate column to show your perspective about the issues on the usage of ethnomathematics approaches/materials in the teaching and learning of mathematics. The weightings are as follow: 5 = Very High Extent (VHE), 4 = High Extent (HE), 3 = Neutral (N), 2 = Low Extent (LE), 1 = Very Low Extent (VLE).

S/N	ITEMS	VHE	HE	N	LE	VLE
	Awareness of AI-based ChatGPT					
1.	To what extent are you aware of AI-based ChatGPT?					
2.	To what extent are you familiar with the technological tool, ChatGPT?					
	Usage Patterns of AI-based ChatGPT					
3.	How frequently do you integrate ChatGPT into your teaching practices?					
	Perceptions of ChatGPT Impact					
4.	To what extent is the impact of ChatGPT on teaching efficiency in mathematics?					
5.	I think ChatGPT is a useful tool for teaching and learning mathematics					
6.	I am satisfied with the responses I get from ChatGPT in handling my math lesson activities					
	Challenges in Utilising ChatGPT					
7.	To what extent have you encountered challenges in integrating ChatGPT into your mathematics teaching practices?					

Appendix B

Transcription of Semi-Structured Interview

1. Could you elaborate on your level of awareness regarding AI-based ChatGPT and how you first learned about it?
   MT 1: I stumbled upon ChatGPT during my quest for innovative AI tools in education, struck by its potential to revolutionise how students grasp complex math concepts and the assistance it has rendered me.
   MT 2: In my search for powerful teaching aids in math, ChatGPT emerged as a revelation, showcasing its knack for tailoring explanations and providing invaluable assistance in solving mathematical puzzles.
   MT 3: I attended a workshop that ventured into the frontier of AI in education technology. ChatGPT stood out as a beacon for elevating math instruction through the magic of natural language interactions. It has been wonderful using it as a guide in my lesson preparations.
   MT 4: I was ushered into ChatGPT by my esteemed colleagues in math education, who underscored its pivotal role in nurturing students' comprehension of mathematical principles.
   MT 5: I learned about the AI-based tool when I joined conversations with my fellow math educators who passionately discussed ChatGPT, unveiling its transformative role in crafting interactive and personalised learning adventures.
2. If you have used ChatGPT in your teaching, could you describe specific instances or lessons where you integrated ChatGPT, and the outcomes observed?
   MT 1: Absolutely, ChatGPT has been a game-changer in my teaching. One notable instance was during a lesson on trigonometry. I integrated ChatGPT to provide real-time explanations for complex concepts like trigonometric identities. The outcome was remarkable - students grasped the material more effectively and expressed heightened enthusiasm for tackling challenging problems.

MT 2: In remote learning, I seamlessly integrated ChatGPT as a resource for instant clarification on math problems. Students could ask questions during virtual lessons, and ChatGPT provided immediate responses. The outcome was a more interactive online learning environment, fostering student engagement and participation.
MT 3: During a unit on functions, I employed ChatGPT to explain intricate topics like quadratic functions and graphing. The outcome was increased student comprehension, particularly among those who found the concepts challenging. The interactive and conversational nature of ChatGPT helped demystify complex mathematical ideas.
MT 4: Incorporating ChatGPT into homework assignments was a strategic move. I provided students with varied practice opportunities by generating additional math problems using ChatGPT. The observed outcome was improved problem-solving skills and a notable increase in student interest and enthusiasm for completing assignments.
MT 5: ChatGPT was pivotal in a geometry lesson where we explored the Pythagorean Theorem. Students could interactively engage with ChatGPT to understand the theorem's applications and proofs. The outcome was a classroom filled with students who comprehended the theorem and were eager to explore more geometric concepts collaboratively.

3. In your view, how does ChatGPT positively or negatively affect teaching efficiency in the context of mathematics education?
MT 1: ChatGPT has significantly enhanced teaching efficiency in mathematics education by providing instant and personalised explanations. This tool allows for quick clarification of concepts, saving valuable class time and ensuring that students receive immediate support tailored to their needs.
MT 2: ChatGPT positively streamlines the grading process for math assignments. With its ability to generate instant feedback on problem-solving attempts, educators can focus on targeted interventions rather than spending excessive time on manual grading. This enhances efficiency and allows for more timely and constructive feedback.
MT 3: In some cases, the integration of ChatGPT might lead to challenges in adapting to diverse learning styles. If not properly customised, it may not effectively address the specific needs of every student, potentially creating a barrier rather than a facilitator in the teaching process.
MT 4: Over-reliance on ChatGPT could lead to a lack of human connection in teaching. While it offers efficient solutions, the personal touch and nuanced understanding that educators bring to the classroom might be compromised, potentially affecting the overall effectiveness of the learning experience.
MT 5: ChatGPT positively contributes to lesson planning efficiency. Educators can use the tool to quickly generate additional practice problems, quizzes, and explanations, saving time on resource creation. This allows more focus on instructional strategies and addressing student needs during class.

4. If you have faced challenges integrating ChatGPT into your teaching, could you describe these challenges in detail and state how you addressed or overcame the challenges?
MT 1: One obstacle in using ChatGPT for math instruction was ensuring it could handle various mathematical problem types. To overcome this, I conducted extensive testing with different problem-solving scenarios and provided feedback to refine ChatGPT's problem-solving capabilities. This iterative process helped enhance ChatGPT's versatility, making it a more adaptive and valuable resource for addressing diverse math challenges in the classroom. Again, another challenge observed was that the results produced by ChatGPT are not cited or referenced, increasing the chances of plagiarism. OpenAI can review the chatbot by reworking ChatGPT to cite and reference their sources of information.
MT 2: Personally, I find it a bit challenging to seamlessly integrate ChatGPT into my lesson plans while ensuring it complements my teaching style. Striking the right balance between traditional methods and this new technology is something I'm work-

ing on. To overcome this, I collaborated with other educators to share strategies and best practices for seamlessly incorporating ChatGPT into existing teaching materials, ensuring a cohesive learning experience. Also, I feel there's a gap in my training regarding AI integration. Continuous professional development in this area is crucial. I'd benefit from more workshops or courses to boost my confidence and competence in effectively using ChatGPT.

MT 3: I've faced problems when the school's technology, like the internet or devices, isn't working well. Sometimes, it's too slow, or the devices don't work with the teaching tools like ChatGPT. This causes interruptions in the lesson. I'm currently dealing with these issues and trying to improve our technology resources so that using tools like ChatGPT becomes smoother in the future. I also noticed another challenge of inaccurate responses from the AI tool. As a solution to this challenge, IT personnel in charge of ChatGPT can revise the tool to produce correct responses.

MT 4: I had a hard time adding ChatGPT to group problem-solving activities with students. Making the AI tool work smoothly while the students were working together to solve problems was tricky. To address this, I developed structured activities that encouraged students to work together while using ChatGPT as a supplementary tool for guidance. This approach facilitated teamwork and enhanced students' collaborative problem-solving skills, turning the initial challenge into an opportunity for fostering effective group learning in mathematics.

MT 5: I've always tried to make math lessons fit each student's individual needs. But now, using ChatGPT to match how each student learns is challenging. It's like trying to figure out how to use this new technology in a way that helps every student learn better, considering their different styles of learning. To address this, I conducted a survey to understand individual preferences. By customising the way ChatGPT interacted with students based on their preferences, I was able to create a more inclusive and effective learning environment.

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