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Thematic Modeling of Pre-service Mathematics Teachers' Reflections on ChatGPT Use: Appraisals, Ethical Challenges and Aspirations

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Abstract

The global proliferation of generative AI is being debated because of its implication on education. Despite rapid adoption of ChatGPT-3.5 in educational settings, research is scarce as educators and institutions are not fully prepared to face the potential unforeseen and long-term consequences of ChatGPT on student learning dispositions. This study explored pre-service mathematics teachers' experiences with ChatGPT and their perceptions regarding its affordances, ethical issues, and potential uses in education and future teaching. Using a convenience sampling, 25 second- and third-year pre-service mathematics teachers (22 female and 3 male) participated in the study. Qualitative data were collected from semi-structured online interview forms and a subsequent focus group discussion, which were analyzed using thematic analysis methodology. A perceptual model of ChatGPT adoption (PMCA) including five main themes were developed: familiarity with ChatGPT, positive appraisals, dissatisfactory experiences and ethical concerns, aspirations to use in mathematics teacher education, and aspirations to use for prospective teaching. The research results showed that teacher candidates found using ChatGPT in their education useful, but they also expressed their concerns about the difficulties and ethics of using ChatGPT. This study aims to provide empirical evidence for educators, policy makers, and future research to contribute to the current conversations about AI in teacher education programmes.

Key words: Artificial intelligence, Teacher education, Ethics, Thematic analysis

Introduction

Innovative technologies have been developed around the world and their incorporation into educational settings is an ongoing global effort. Yet, there is still a 'notable absence' of studies about the use of Artificial Intelligence (AI) in pre-service teacher education (Celik, 2023; Celik et al., 2022). Additionally, many intelligent systems are being used in mathematics settings (Moore et al., 2023) whereas researchers have highlighted that most of AI-related studies and developments lack educational perspectives (Celik et al., 2022; Cope et al., 2021; Zawacki-Richter et al., 2019). Moreover, controversial theoretical discussions on the impact of unprecedented opportunities and ethical concerns, such as jeopardizing academic integrity (e.g., Cotton et al., 2023; Hung & Chen, 2023) surrounding the use of ChatGPT, an artificial intelligence, in all levels of education necessitates the exploration of this emerging research avenue in teacher preparation programs.

ChatGPT is a generative artificial intelligence language model that operates based on machine learning techniques to generate responses over the textual data that it is trained on. The implications of ChatGPT usage in education are still in its emerging stage. Some recent studies have examined undergraduate students' perceptions and experiences regarding ChatGPT, including computer engineering students (Shoufan, 2023) and elementary school teachers (Lozano & Fontao, 2023). Tapan-Broutin (2023) observed pre-service mathematics teachers'(PMTs) initial unsupervised interaction with the application and reported that their highest level of curiosity was on humanoid (i.e., emotional and empathetic) aspects of ChatGPT and on academic assistance capability thereof. However, there are very limited research on PMTs' perceptions of ChatGPT and their intention to use it for college education and future teaching. Moreover, most of previous research on AI primarily utilized quantitative methods and lacked critical reflections and challenges pertaining to the use of this novel technology in higher education (Zawacki-Richter et al., 2019). Therefore, this qualitative study aims to contribute to literature by examining the use of generative AI in education. It investigates PMTs' familiarity with ChatGPT, their perception of its utility in college education and teaching mathematics, and ethical concerns surrounding its use. The findings aim to guide prospective teachers, educators in higher education, and future research on effective teacher education programs utilizing AI's benefits while taking ethical considerations into account.

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Theoretical Background

Artificial Intelligence and Its Affordances in Education

The most plausible definition of *AI* is "computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction, and use of data for complex processing tasks" (Popenici & Kerr, 2017, p. 2). AI is intertwined with education and has the potential to transform education systems that is long overdue. Harnessing its potential can effectively support UNESCO's pedagogical goals of *The Global Education 2030 Agenda* by ensuring more equitable and inclusive educational systems through its accessibility and connectivity (Holmes & Miao, 2023). AI can support student learning through monitoring students, group management (i.e., group formation, group moderation and group facilitation), automated assessment and data-driven decision-making (Crompton & Burke, 2022). Specifically, some positive affordances of various AI technologies include timely feedback and individualized content (Anderson et al., 1995; Chen et al., 2023), personalized support for large-scale online learning environments (Seo et al., 2021), identifying and supporting students with learning difficulties (Moore et al., 2023), assisting teachers with improved planning and assessment of their pedagogy (Celik et al., 2022), scaffolding student learning process and improving student critical thinking of AI suggestions (Kim et al., 2022), and offering immediate and ongoing formative assessment (Reiss, 2021). AI technologies can also support teachers with the generation of curriculum content, activities, and assessment (Cooper, 2023). Gaining competence in using educational technology has also been shown to increase pre-service teachers' self-efficacy (Joo et al., 2018). Similarly, teachers with more knowledge about the affordances of AI are more aware of their contributions to their instructions (Celik, 2023), which may increase the likelihood of incorporating AI into their teaching as an instructional component. Although the potential use of AI has not been harnessed to a large extent, mathematics teachers can be empowered by leveraging the affordances of AI—specifically, the affordances of ChatGPT in this study—to meet their instructional needs (Luckin et al., 2022) and have students reap the aforementioned benefits in their learning.

Difficulties of Applying AI into Education

Difficulties and ethical concerns related to the use of AI in education abound in the literature. The application of AI in education not only creates the desired affordances mentioned above, but also raises ethical challenges such as individual privacy issues, potential built-in algorithmic biases, reliability of responses, and equitable access opportunities (Reiss, 2021; Roscoe et al., 2022). Its application in the educational field also has its own inherent technical and technology-adoption-related difficulties.

The literature indicate that AI technologies are run by AI algorithms and supplied data, which can transmit the biases of the suppliers, users, and developers of the technology (Popenici & Kerr, 2017). AI-based technologies can make systematic and repeatable errors (Celik, 2023), widen educational inequalities and focus on a narrow conceptualization of education (Reiss, 2021), and compromise academic integrity (Cotton et al., 2023; Hung & Chen, 2023). Furthermore, teachers are concerned that AI technologies might diminish students' critical thinking, creative problem solving, and independent learning abilities (Wogu et al., 2018). According to teachers, some of the most common challenges to incorporating AI technologies into teaching are questionable reliability of AI algorithms, inadequate technical capacity, insufficient AI-related technical infrastructure within schools, teachers' lack of technological knowledge, and their lack of interest in the technology (Celik et al., 2022).

Ethical Concerns: Responsible Use of AI for Academic Integrity

Academic integrity is an irreplaceable component of scholarly works. One of the main ethical concerns regarding the use of ChatGPT is its impact on plagiarism in academic settings. Academic institutions have already begun to implement ethical guidelines and precautions. For example, New York, Los Angeles, and Baltimore banned ChatGPT from all public-school networks and devices (Cotton et al., 2023). This precaution is partly due to ChatGPT's practice of collecting user data that violates the *Children's Online Privacy Protection Act (COPPA)* for users under 13 years of age. Additionally, ChatGPT's 'Terms of Use' state that users must be older than 18 years. Before the release of ChatGPT, 22% of college students at an Austrian university anonymously reported that they had committed plagiarism (Hopp & Speil, 2021). One of the methods of committing plagiarism is 'contract cheating' services, which is already a challenging and prevalent problem in higher education (Ahsan et al., 2021). Partly due to the widespread use of online assessments—especially, it peaked during the COVID-19 pandemic—plagiarism permeates and threatens academia in relation to college students' learning, critical thinking, skill development, attitudes, and moral development. Free and easy access to ChatGPT, along with its ability to produce creative writings, solutions to mathematics problems, explanations, and summaries multiply the risks associated with contract cheating. Even at a prestigious institution like Stanford University, shortly after the release of ChatGPT, 17% of students used it to assist with

assessments and exams, and 5% admitted submitting ChatGPT-generated materials without editing (Cu & Hochman, 2023). In addition to plagiarism and cheating reported in the literature, concerns about privacy (Shin et al., 2022), reduced agency for learning (Berendt et al., 2020), and in-service teachers' misconceptions about AI technologies (Antonenko & Abramowitz, 2023) are cited as barriers that may hinder the effective development and adaptation of AI applications in educational settings.

Objectives and Research Questions

To address the aforementioned gaps, this study uniquely focuses on pre-service mathematics teachers' perceptions of ChatGPT because of their essential role at the nexus of their educational transformation. The objective of this study was to investigate pre-service mathematics teachers' perceptions and reflections on the ease of use, potential avenues for incorporation, challenges, and ethical concerns related to the use of ChatGPT. The design of this research is organized to find answers to the following research questions.

1. Are pre-service mathematics teachers familiar with ChatGPT?
2. How do pre-service mathematics teachers perceive ChatGPT in terms of its ease of use, usefulness, and technical and ethical challenges?
3. How do pre-service mathematics teachers aspire to use ChatGPT for their academic learning at the university and for their future teaching?

Method

The purpose of this study was to determine PMTs' perceptions and reflections related to the use of ChatGPT-3.5 using online forms consisting of open-ended questions and a follow-up focus group session. The main rationale for investigating this emerging phenomenon with a qualitative research design is to flexibly explore PMTs' perspectives through in-depth analysis of rich data obtained from their natural setting, and to extract practical implications for teacher education and educational policy using thematic analysis.

The study utilized a convenience sample comprising of second-year and third-year middle school PMTs who had been enrolled in a methods course at a university located in the southeastern part of Türkiye. Qualitative data were collected in the Summer of 2022-2023 academic year whereby participants responded to a semi-structured form containing seven semi-structured questions. The form was sent to 27 PMTs and the response rate was 92.9% (N=25; 3 male and 22 female PMTs; 22 sophomore and 3 junior level). Data collection was completed with a follow-up focus group session. For the participants in the study, the average GPA was 2.79 on a scale of 4 (min=2.33, max=3.42). They were not offered any incentives. Before the collection of the data, ethical approval was obtained. Participants were informed of the study details and reassured of the confidentiality of their responses and identity.

Procedure

Teachers comprehend the pedagogical contributions of AI more effectively when their technological, pedagogical and content knowledge (TPACK) increases (Celik, 2023; Edwards et al., 2018). Because PMTs were asked to anticipate the potential use of ChatGPT in mathematics teacher education and prospective teaching, and because pre-service teachers have difficulty envisioning future scenarios using emerging technologies due to a lack of knowledge and skills about the technology (Liu, 2012), PMTs were first trained about AI and its applications in mathematics teaching and learning for two sessions by the researcher. Then, PMTs were given a task regarding the multimodal use of ChatGPT application (See Appendix 1). These included the course content and assignment development, inclusive education practices and mathematical problem solving. Having completed the tasks, a semi-structured form (see Appendix 2) that consisted of semi-structured questions was distributed. The questions in this form along with the questions asked during focus group session were created based on insights into the identified gaps and concerns in the literature. The suitability of the questions (i.e., clarity, relevance and the scope of the semi-structured questions) was discussed with two colleagues to increase content validity and necessary adjustment were made based on their recommendations.

To increase the credibility of the findings and clarify pre-service teachers' responses to the questions and additional reflections, the data was triangulated by conducting a virtual focus group meeting (Vaughn et al., 1996) using Zoom video-conference software. This focus group session was also intended to reveal nuanced perspectives that were socially and interactively constructed by the cohort (Cohen et al., 2013). Some questions asked during the focus group session included "How do ChatGPT's explanations and recommendations differ from what mathematics educators can offer? What would be the advantages and disadvantages of each?" and "Do you have any ethical concerns or thoughts regarding the use of artificial intelligence such as ChatGPT in teaching and learning mathematics?" Answers to these questions were delineated with unstructured follow-up questions. Because focus group discussions have the disadvantage of being dominated by a few vocal

participants (Green & Thorogood, 2014), participation in the online meeting was voluntary and all participants were encouraged to participate in the discussions. Nine PMTs—all female sophomores—voluntarily participated in this meeting. Audio and written responses were transcribed for further analysis. The corpus of data consisted of PMTs' written responses to online interview questions. Data obtained from focus group discussions were used as complementary data.

Analytical Framework

Thematic analysis is a qualitative research methodology within interpretivist paradigm that assists in exploring the experiences, perspectives, and concerns of participants (Braun & Clarke, 2006) by applying fundamental cognitive processes of 'categorizing, prototyping and metaphorical mapping' in a methodical way that is flexible, logical, disciplined, creative and rigorous (Liu, 2023). Unlike earlier weak or narrow AI applications such as artificial neural networks and computer vision, the development of strong AI or human-like AI applications is the new niche (Pham & Sampson, 2022). ChatGPT, with its human-like abilities to perform certain tasks, falls into the latter classification. Thus, thematic analysis is a well-suited method to unravel the unexplored aspects of this unprecedented strong AI with rich in-depth data in a comprehensive fashion.

During the analysis of online form responses, descriptors were produced. The student background variables included gender, university level, GPA, and familiarity with ChatGPT (See Table 1). PMTs' online form responses were analyzed as per Braun and Clarke's (2006) principles and procedures for thematic analysis. Initial codes were created for the answers and reviewed with an external reviewer. An exploratory inductive approach was used to create subtopics, topics, and themes. This iterative process involved reviewing, refining, merging, and separating codes, subtopics, and topics. Because the data were collected and analyzed using a qualitative research design and analysis, statistical sample size is mostly irrelevant (Flick, 2009). Sufficiency of the sample is gauged by 'theoretical saturation', which occurs when adding new samples do not yield a novel category of the codes (Glaser & Strauss, 1967). After analyzing the responses to online forms, the focus group session was transcribed and analyzed similarly. All qualitative analyses were conducted using Dedoose software.

Table 1. Demographic characteristics of participants (N=25)

Descriptor	Options	Descriptive Statistics
Gender	Male	N=3
	Female	N=22
University Level	Sophomore	N=22
	Junior	N=3
GPA	Continuous scale of 0 to 4.0	$\bar{X} = 2.79$ min = 2.33 max = 3.42
CHatGPT Familiarity	Never used/heard before	N=16 (64%)
	Heard but never used before	N=4 (16%)
	Used before	N=5 (20%)

Establishing the Trustworthiness of the Findings

In qualitative research, evidence for *trustworthiness* is established to increase the rigor and objectivity of the analysis of self-report data. Trustworthiness can be conceptualized by the criteria of credibility, dependability, transferability, and confirmability (Lincoln & Guba, 1985). The *credibility* of the findings was established by i) researcher triangulation by exchanging ideas on the appropriateness of the codes with an external reviewer during the initial coding process, which is conducted on seven semi-structured forms and finalized by consensus, and ii) data triangulation with the focus group session (Lincoln & Guba, 1985). Qualitative research embodies subjectivity but potential biases were cross-checked by the external reviewer in initial coding. Data dependability was ensured through hierarchical, systematic, and transparent coding process (Flick, 2009). The criteria of *transferability* can be assessed by using the descriptors of the participants in Table 1, where the

results should be transferable (or generalizable) to pre-service mathematics teachers in similar teacher education programs. In addition, the *confirmability* criterion is concerned with clear delineation and justification of the case in which interpretation and conclusions are derived from the data (Nowell et al., 2017). Clear descriptions of themes developed after data saturation and comparison of findings with the literature in the discussion section also provide evidence of transferability and confirmability. Finally, to ensure consistency and cohesion of the empirical findings, an interpretivist epistemological approach was applied throughout the data analysis procedure (Holloway & Todres, 2003).

Ethics Approval

The study received ethical approval from Gaziantep University Social and Humanities Sciences Ethics Committee (342157-6.7.2023) for this research.

Findings

Although a convenience sampling was used for data collection, theoretical saturation was achieved in the final responses. In other words, the analysis did not yield additional category of codes (i.e., topics and themes) during the analysis of the final responses. As a result, thematic analysis yielded five main themes derived from 354 initial codes. These themes are familiarity with ChatGPT, positive appraisals on using ChatGPT, dissatisfactory experiences and ethical concerns about using ChatGPT, aspirations to use it for mathematics teacher education, and aspirations to use it for prospective teaching. The themes and topics of each theme in the ad hoc *perceptual model for ChatGPT adoption (PMCA)* are shown in Figure 1. Pseudonyms (i.e., P1 - P25) will be used to represent the participants in order to keep their identities confidential. Finally, inside direct quotations, additional words/phrases have been added in brackets to avoid shifting the meaning by capturing certain nuances in the languages.

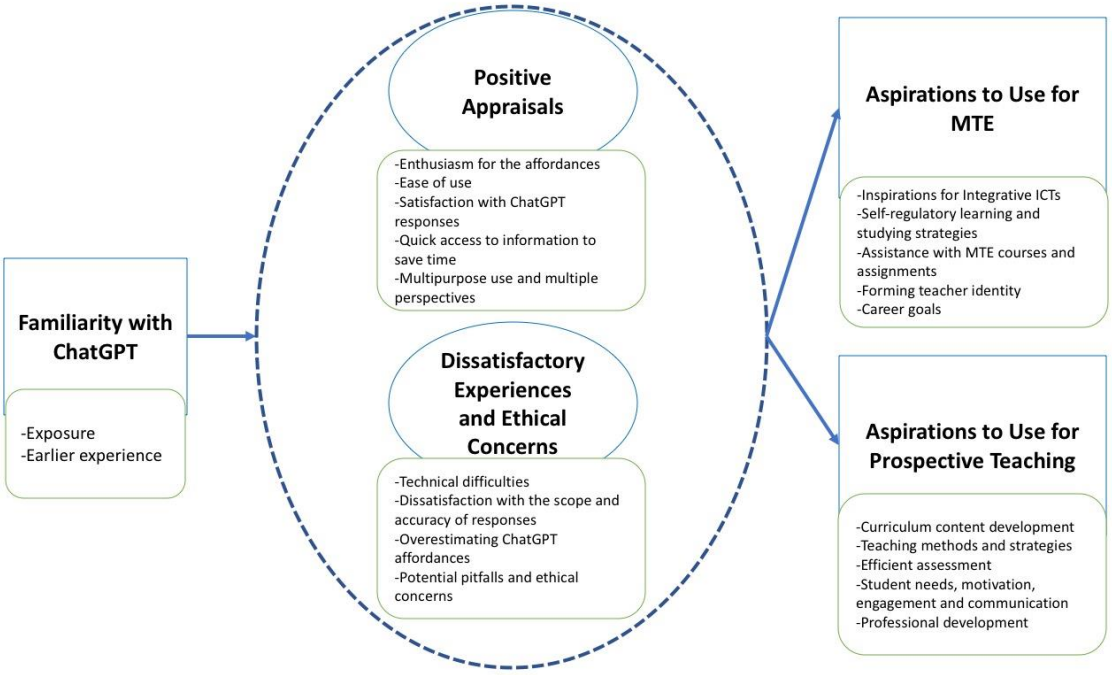

Figure 1. Mathematics teacher education perceptual model for ChatGPT adoption (PMCA)

Note: MTE: mathematics teacher education; ICT: Information and communication technology

Familiarity with ChatGPT

The first research question was to determine PMTs' familiarity with ChatGPT. The first topic under this theme is exposure. Out of 25 students, only nine PMTs had heard of the application before, of which five had used it before for university assignments and to satisfy their curiosity. The other four participants had heard of the application but had never used it. One participant (i.e., P25) admitted to using another AI application, but she was not familiar with ChatGPT. Although 20% of the students in the sample had already started using ChatGPT for higher education before the Summer of 2023, familiarity with and adoption of the application seems almost inevitable due to the widespread use of information and communication technologies (ICT).

The second topic generated under this theme is earlier experience. PMTs with prior experience mostly used the tool to understand some concepts, do homework, solve advanced math problems, or understand the proofs for mathematical formulas. Some PMTs had used it to test the emotional capabilities of the application such as, "Frankly, I wondered what kind of feedback I would get from an AI when asked about human emotions, abilities, etc. I asked questions in line with that curiosity and purpose" (P17). These different initial preferences for the use of ChatGPT and its integration into the education of individuals show its potential for personalized learning.

Positive Appraisals on Using ChatGPT

The PMTs clearly expressed their *enthusiasm for its affordances*. They were generally amazed by its capabilities, the point at which it had reached with its affordances. Some respondents expressed disappointment that they had not known about it before.

> "…because it gives me ideas about my questions in my academic learning. My question is: Why didn't I know before? Which applications can I use to improve my teaching approach?" (P24)

Awareness of ChatGPT led to questioning of other ICT tools that could aid university education, specifically in learning math, doing homework, and enhancing teaching skills. The responses generally indicated that PMTs perceive ChatGPT as a "supplemental" study assistant for their learning and teaching. Some respondents expressed an eagerness to engage with it afterwards and brainstormed about how they could use it to develop their prospective teaching.

ChatGPT is considered user-friendly due to its chatbot design. Seven PMTs had no technical issues initially. Some faced minor setbacks but overcame them by giving clearer input and utilizing ChatGPT features. They also liked its versatility and free access on mobile devices and computers.

The PMTs mostly expressed *satisfaction with ChatGPT-generated responses*. Most PMTs preferred its direct, clear, and concise answers to their questions and found this feature superior to other search engines. They also found the step-by-step procedural solution for problem-solving helpful.

> "Unlike other search engines and browsers, the application gives clear, single and understandable answers to the question I ask. In this way, there is a fun and effective transfer of information in a conversational atmosphere. Because of these aspects, I can say that it is a very useful application and I was a little sad that I had not discovered it before." (P18)

The excerpt exhibits human-like features of ChatGPT that positively impacted the PMTs' perception, setting it apart from other search engines. While a few PMTs found its answers partially satisfactory, the majority perceived them as comprehensive, explanatory, and accurate, and providing multiple solutions and perspectives.

> "For example, in the first question of the course content preparation section, I was tasked with creating a performance assignment. The initial submission contained convoluted instructions. Therefore, when I directed the question to artificial intelligence again, the instructions were given in more detail and at the same time a detailed example was given and this enabled me to better grasp the subject." (P18)

One of the pitfalls that the PMTs failed to realize was ChatGPT's response accuracy. Some PMTs were completely satisfied with the accuracy despite potential errors. Whereas students might trust ChatGPT without considering biases and errors, five PMTs believed in the accuracy without recognizing limitations, but almost half of the PMTs admitted this limitation.

Another emerging topic was *quick access to information to save time*. Compared to searching for information on search engines, its quick access to information was perceived as a distinct advantage. They expressed their satisfaction with the rapid creation of content, solutions, translation, and presentation slides. One participant stated that

> "Especially from the questions above [given practice questions], I realized better that it is a very necessary application in terms of teaching. Because, as we know, since the entity, who we are responsible for in teaching, is human, almost everything can occur improvisationally and you may feel the need to meet your instant information needs in a deep and explanatory way." (P17)

As noted by this respondent, teachers frequently receive questions from their students. Respondents pointed out that ChatGPT can assist in brainstorming ideas, demonstrate various approaches to solving problems, swiftly produce particular exercises and lesson plans, and offer specific examples in such situations.

As per the PMTs, an additional perceived benefit of the application is its versatility, i.e., *multipurpose use and multiple perspectives* in meeting diverse individual needs. They specifically expressed its ability to answer questions on a wide range of areas, such as mathematics, alternative teaching methods, technical inquiries, real-life problems (including politics), and other aspects of life. Additionally, during the focus group session, PMTs reiterated these useful features of ChatGPT, such as step-by-step solutions for math problems, multiple solutions that foster diverse perspectives, and the creation of thorough assessment tools (such as project and performance-based assessments) with clear instructions.

> "I asked it to generate solutions to the questions I asked several times and thus aimed to see the difference. In this way, [prospective] students can better understand the subject by seeing different interpretations instead of seeing a single point of view." (P18)

In addition, they find the answers provided by the platform to be more informative than those provided by an educator. Thus, these findings suggest that some of the PMTs' needs for guidance and mentorship can be met by ChatGPT or AI applications designed for this purpose.

Dissatisfactory Experiences and Ethical Concerns

The PMTs reported technical difficulties with receiving responses, specifically irrelevant and less-efficient responses when a non-English input was entered. Several PMTs encountered the problem. When Turkish was chosen, unsatisfactory responses and occasional errors occurred. However, choosing English resulted in more logical responses, even with Turkish input. The issue might also happen with other languages. The PMTs reported technical problems with browser or device configurations, server-related issues, and glitches with ChatGPT. The problems included tab closures, errors on different devices, delayed responses, and incorrect answers. Several PMTs also mentioned incomplete responses. However, some PMTs discovered that when the application was prompted with the input "continue generating the response," they received the remaining incomplete responses. These issues and the PMTs' creative problem solving experiences to overcome some of these challenges were re-stated in the focus group session.

Some users expressed dissatisfaction with the application's scope and accuracy of responses. Possibly due to asking vague or general questions without specified parameters, some PMTs found ChatGPT's responses to be insufficient, overly lengthy, and overly broad.

> "The downside is that even though it answers questions, the answers it gives sometimes do not satisfy you. By constantly reminding you that it is artificial intelligence, it actually causes some answers to leave you unsatisfied. But as human beings, I guess we don't want any question marks to remain in our minds." (P9)

Some PMTs expressed concerns regarding response accuracy. While response accuracy to verbal questions was not questioned, some mathematics question answers were criticized, with one respondent stating, "I am uncertain about the correctness of the answers because some of the equation questions I asked were not answered correctly" (P23). Other dissatisfactions related to teaching and learning included ChatGPT's inability to generate mathematical representations, inappropriate answers regarding students' developmental level of understanding, and insufficient capabilities to generate higher-level knowledge. The PMTs acknowledged that ChatGPT's responses are suitable for attaining general knowledge; however, they found it inadequate for fostering and supporting higher-order thinking and learning. Moreover, during the focus group session, they emphasized ChatGPT's ability to provide extensive information but noted its incapacity to offer emotional and personalized responses, hindering the attainment of solutions for students' problems by neglecting their emotional and psychological state.

> "Since ChatGPT is an artificial intelligence, it is insufficient in conveying emotions, for example, a student has a prejudice against mathematics, it can guide us for this, but our approach to the student needs to take into account the student's emotions." (P21)

In this session, the PMTs also complained about errors or fake citations generated by ChatGPT, as well as non-existent links.

Some PMTs overestimated the affordances of ChatGPT by expecting it to exhibit human-like emotions, perceiving its responses as infallible, and anticipating access to all research articles. ChatGPT can summarize known publications but lacks access to research articles not in its training data or published after 2021 during the study. Additionally, one question in the online form required the PMTs to draft inquiries they would like to pose to ChatGPT. Some of the questions they pose were very general or unclear questions without elucidation such as "How will our internship training be like?" (P22) and "What are the subjects that we will see in mathematics but have not learned yet?" (P23). Some PMTs may inadvertently engage in such tacit assumptive

discourse in their prospective teaching which can exacerbate misunderstanding and miscommunication in teaching mathematics.

Numerous potential pitfalls and ethical concerns were raised by the PMTs. One concern was the potential for AI to replace teaching jobs. One PMT (P19) recognized that AI may lead to decreased employment opportunities in various fields. Additional concerns centered around two subtopics: potential misuse by pre-service teachers and the adverse effects such misuse could have on students. The PMTs generally recognized that ChatGPT ought to serve as a supplemental tool rather than an ultimate solution.

The PMTs acknowledged that ChatGPT can be misused for assignments that do not necessitate higher-order thinking and posed inquiries regarding preventative measures (e.g., P11). Although ChatGPT's potential use for cheating on exams and assignments was not explicitly mentioned in verbatim in responses to interview questions, in the focus group session, multiple PMTs expressed these concerns. They pondered the prevalence of cheating in their prospective teaching and anticipated that the availability of plagiarized material and "ready-made information" via ChatGPT could compromise academic integrity and diminish inquiry, creativity, and critical thinking skills.

> "In this ChatGPT application we just ask the question and it gives us the answer. This limits our research skills a lot…For example, we read the assignments and questions given to us from Google Scholar, we search for different articles. While researching that question, we also learn different things. But if we ask directly to the application, we will have a very lazy brain, [a brain] that will want to find the answer directly." (P18)

Likewise, they highlighted the risk of students' excessive dependence on ChatGPT, which may diminish inquiry skills, curiosity, and self-assurance. ChatGPT may therefore limit the cognitive developmental trajectory of PMTs and their future students by depriving them of developing rigorous research skills, perseverance and discovery experiences, and, as noted, unintended learning.

Aspirations to Use for Mathematics Teacher Education (MTE)

Through exploration of the capabilities of ChatGPT, some PMTs expressed *aspirations for integrative ICT*. Several PMTs requested information on using more ICTs for enhancing university education and teaching practices. Queries were also made to ChatGPT regarding suitable websites, software, and resources for teaching mathematics efficiently. These PMTs have already completed courses on 'Information Technology' and 'Instructional Technologies'. Therefore, ChatGPT's user-friendliness and apparent benefits might have augmented their readiness to incorporate useful ICTs in mathematics teaching and learning.

One aspect of ChatGPT that can enhance PMTs' learning is rapid information access for *self-regulatory learning and studying strategies*. Certain PMTs reported that ChatGPT offers effective information on subjects and resources that they have limited access to. The majority of the PMTs emphasized their intention to use ChatGPT for the self-regulation of their learning. For example, they intend to employ it for time management: to learn time management skills while studying and to reduce the time spent on research for their assignments and learning. Multiple PMTs asked questions similar to "How can I study efficiently?" (P13). In addition, they expressed interest to use ChatGPT for challenging college-level courses. The intentions of using ChatGPT in a math teacher training program highlight challenges encountered by the PMTs. PMTs show interest in addressing test anxiety, improving focus, managing stress, enhancing creativity, and developing communication and social skills to gain social support.

While many PMTs expressed interest in utilizing ChatGPT to receive *assistance with MTE courses and assignments* (e.g., developing activities, creating learning materials, constructing presentations, researching concepts, and translating assignment-related texts), misuse of the tool could undermine academic integrity. Although some students intended to gain ideas for organizing assignment content, others indicated their desire to use the information directly. Moreover, the PMTs expressed their interest in obtaining summary information about challenging topics, course content, and relevant books and articles as a shortcut to grasping the core information of their research resources. One PMT stated that "In my university life, I can use it to get deep explanatory and summarized information to understand the terms, applications, topics that professors deliver but I have difficulty understanding" (P17). Taking university-level mathematics courses, such as Analysis (Calculus), Linear Algebra, Abstract Algebra, and Analytic Geometry, are mandatory for the PMTs and present a significant challenge even for pre-service math teachers. The PMTs have expressed a desire to use ChatGPT for gaining conceptual understanding of advanced mathematical concepts, justifying and proving formulas and theorems, solving advanced math questions, double-checking their solutions, and preparing for their exams. Additionally, the PMTs have expressed their desire to utilize ChatGPT for pedagogical courses to develop presentation content and gain a deeper understanding of pedagogical concepts and theories.

One of the most unexpected results was the PMTs' desire to utilize ChatGPT in *forming their teacher identity*. The PMTs asked questions about techniques for self-motivation in learning, with three posing nearly identical queries, such as "How can motivation be maintained and increased during my academic education?" (P4) Some PMTs have raised concerns about connecting the content of courses to real-life situations. The purpose and applications of such courses have been brought into question. In particular, the usefulness of college-level math courses (especially, Analysis and Algebra) has been questioned. Some PMTs were uncertain about receiving sufficient education and training, and asked questions to justify the mathematics teacher education programs: "Will the education I receive at campus be enough for me to reach an adequate level of teaching?" (P15)

Some PMTs also asked about improving their teaching competency, requesting recommendations for pedagogical books and ways to become a better math teacher. Data were collected from sophomore and junior PMTs at the end of the academic year. The participants were on the cusp of becoming juniors and seniors. They had completed multiple pedagogical courses, including "Principles and Methods of Teaching," "Mathematics Teaching and Learning Methods," "Developing Activities in Teaching Mathematics," and "Middle School Mathematics Curriculum." Throughout these courses, the students occasionally engaged in microteaching and presentations. Nevertheless, according to the findings, the PMTs had not developed a foundation for teacher identity and they turned to ChatGPT for further motivational support to establish it.

The PMTs were also aspired to utilize ChatGPT to gather information about various *career goals* including available scholarships, teaching appointments, job prospects, studying abroad, graduate education, and paths to academic careers.

> "Another question I asked to the application was: 'As a person studying elementary mathematics, is there a possibility that I can study abroad?' The answer to this question given by the application was both uplifting and informative. It told me what I should actually do in bullet points. And even though it gave detailed information, it said that I could get the best details from the embassy and consulate." (P9)

This kind of nuanced information may not be easily accessible to every PMT and they may perceive these opportunities as unreachable. Thus, this feature of ChatGPT can contribute to equality of opportunity as well.

Aspirations to use for Prospective Teaching

The PMTs indicated their aspirations for curriculum content development including creating targeted questions and activities, encompassing contextual issues, curriculum-aligned questions, concrete examples to teach abstract concepts, and consciousness-raising questions related to global issues and social injustices. Consequently, most PMTs aimed to use ChatGPT to bridge the gap between abstract mathematical concepts and real-life. They also planned to create general, extracurricular and game-based mathematics activities. One PMT expressed, "I would like to use it to get ideas about activities I can do and how to implement them in different topics to make students love math more." (P20) Similar findings demonstrate that the PMTs did not feel competent in creating real-life examples and engaging activities that motivate students to engage with mathematical problems. Furthermore, the PMTs aimed to utilize ChatGPT for various purposes in their future teaching such as creating special curriculum materials and content that i) takes individual differences into account, ii) compares curricula across multiple countries and cultures, iii) assists in teaching inclusively, and iv) provides concrete examples of abstract mathematical concepts.

The PMTs' interest in using ChatGPT for future teaching was generally based on their goal of acquiring effective teaching strategies, developing lesson planning and classroom management methods, and implementing equitable teaching strategies. The PMTs specifically sought subject-specific effective teaching methods and strategies when it comes to mathematics topics. The PMTs expressed their aspiration to benefit from ChatGPT to anticipate possible student misconceptions and adjust their teaching accordingly. They were also interested in using it for classroom management, effective communication with students, lesson planning, and time management.

Some PMTs understood the importance of equitable teaching techniques for inclusive education. This awareness might be the result of completing the "Inclusive Education in Teaching Mathematics" course or recalling the practice task. Therefore, most PMTs expressed their interest in developing inclusive teaching strategies to aid students with disabilities, meet their requirements, and enhance their learning experience with adaptive teaching methods.

> "I especially think that the strategies it will suggest will contribute to my teaching of students with special needs because I may have many students with hearing impairment, autism, attention deficit [hyperactivity disorder], etc." (P24)

Development and implementation of effective assessment is often overlooked by many in-service teachers, who tend to focus on preparing students for high-stakes exams and tailoring their assessments to those exams. The PMT's goal of utilizing ChatGPT for assessment involved creating routine homework assignments, project assignments, performance assessments, and expanding their knowledge of other effective assessment strategies. For example, a participant in the study mentioned, "I will benefit more in my teaching because it will be very useful in assigning various project assignments and preparing [their] instructions" (P25). These PMTs were informed about these assessment methods; however, their desire to learn more about the preparation of these types of assessment methods indicates a gap in their practical skills for applying theoretical assessment knowledge. The PMTs did not discuss ChatGPT's capacity to monitor student progress and request suggestions for adjusting instruction and content to meet their needs. For instance, inputting specific students' learning styles, interests, motivation, and social interactions into ChatGPT can provide recommendations on appropriate adjustments in teaching to enhance their learning of mathematics. Nevertheless, ChatGPT's responses should be viewed as timely guidance and rapid solutions that should be implemented only after being justified by the literature's findings, as the application is prone to generating erroneous outputs.

Most PMTs prioritized students' individual needs, and they intend to use ChatGPT to address students' needs, motivation, engagement and communication in the classroom. They were aspired to adjust their teaching methods to meet individual student's unique needs. To achieve this goal, they aimed to use ChatGPT to gain an understanding of student psychology, find solutions to their problems in social life, recognize their individual learning styles, determine appropriate approaches for their transition to adolescence, and provide timely and relevant personalized feedback. For example, a PMT stated that "Each student is unique and may have different learning needs. So, I think it will contribute to me by offering different alternatives." (P24)

The PMTs also highlighted the importance of enhancing student motivation through the use of ChatGPT. Numerous PMTs posed inquiries about effective methods to boost student motivation. They anticipated strategies, techniques and activities from the application to draw students' attention to lessons, and increase their curiosity by making learning joyful. They also planned to use ChatGPT for student engagement and enhancing communication in the classroom. Their strategies aimed to develop active learning, enhance student engagement, improve communication between students and teachers, communicate at the student level (including students with special needs), use ChatGPT as a virtual study friend for students, and develop solutions for student issues while collaborating with parents. One PMT asked "How can I keep my students active in the lesson with a student-centered teaching approach, how can I increase their communication with each other?" (P6). The findings and the excerpt suggest that some PMTs might not have been taught in classrooms that met their learning needs, lacked motivation to learn mathematics, and had limited or one-sided communication within the classroom. This can also be related to the extrapolation of some PMTs' low motivation to that of students. However, these aspirations can also be attributed to their awareness of the abstract nature of mathematics and their desire to motivate and engage their future students through conceptual learning with the help of ChatGPT.

Finally, in their forthcoming teaching careers, some PMTs planned to use ChatGPT for their professional development as a tool for enhancing their teaching abilities and integrating new math applications, studying the traits of effective teachers, increasing their mathematics proficiency, and utilizing ChatGPT as a mentor to offer academic assistance to students in their everyday lives.

Discussion

AI rapidly permeates educational settings; nevertheless, the potential benefits of AI have not yet been adequately investigated in pre-service teacher education (Celik et al., 2022) or the K-12 literature (Crompton & Burke, 2022) from an educational perspective (Cope et al., 2021; Zawacki-Richter et al., 2019). Moreover, the capabilities of AI have led to some paradigm-shifting ethical concerns, such as discussions about adopting preventive assessment methods to discourage the increasing exploitation of ChatGPT for academic dishonesty (e.g., Cotton et al., 2023; Cu & Hochman, 2023), misconceptions about the affordances of AI (Antonenko & Abramowitz, 2023), or the spread of misinformation among users. This study provides empirical evidence on these issues related to the PMTs' experiences and intention to use it for their college education and forthcoming teaching career as a supplemental tool. The results also provide insight into their plans for using ChatGPT for assignments at teacher education programs, which could offer opportunities for educators to develop preventive assessment methods. The findings are discussed for ChatGPT-3.5 version.

The findings showed that a fifth of participants had previously used ChatGPT. Similar frequencies were reported in the literature (Cu & Hochman, 2023; Lozano & Fontao, 2023). As student adoption of ChatGPT is growing rather rapidly, this rate might increase. The findings suggest that the PMTs have already begun utilizing ChatGPT for their assignments and education in college-level mathematics and pedagogy classes and they had some concerns about potential changes in learner dispositions because of ChatGPT affordances.

An unequivocal enthusiasm was found among PMTs about the affordances of ChatGPT. Positive perceptions for the affordances of ChatGPT were reported by pre-service teachers of primary education (Lozano & Fontao, 2023) and this perceived satisfaction of interacting with generative AI does not differ based on the level of prior knowledge (Saiz-Manzanares et al., 2023) including earlier exposure to the ChatGPT. PMTs' awareness of ChatGPT's user-friendly features that motivates and support their learning (Shoufan, 2023) through efficient access to information, along with their overall satisfaction with the diverse and comprehensive responses, as well as its multi-purpose use and the capability of providing multiple perspectives, which can reduce their effort and cognitive load in learning and completing complex tasks, were the source of their enthusiasm. This enthusiasm may arise from ChatGPT's quick retrieval of answers to their questions, which relieves their mental workload and allows them to pay more attention to understanding, interpreting, and integrating information. In the literature, multipurpose use and the capability of offering multiple perspectives of AI were either reported as a challenge (Celik et al., 2022) or failed to be included in their model (i.e., CHISM model, Belda-Medina & Kokošková, 2023). This feature of ChatGPT (i.e., multipurpose use and multiple perspectives) has the potential to inculcate critical thinking dispositions in PMTs. Moreover, even though the PMTs found ChatGPT's responses to be more informative and comprehensive than those provided by an educator, an experimental study found optimal benefits from the combination of AI and instructors (Essel et al., 2022). The implications of this finding highlight the need for more productive and sophisticated communication between PMTs and educators.

The PMTs' dissatisfactory experiences with certain technical features of ChatGPT and their perception of potential ethical concerns are significant. The imprecise accuracy of responses produced by ChatGPT, as found in other studies (e.g., Shoufan, 2023), was realized that may potentially disseminate misinformation regarding mathematical operations, pedagogical content knowledge and teaching methods. Moreover, the risk of overestimating ChatGPT's capabilities and relying heavily on it for assignments could exacerbate the issue of cheating on assignments that hinder academic integrity and creativity (Cope et al., 2021; Pavlik, 2023; Popenici & Kerr, 2017). Precautionary measures should be taken to identify AI-generated submission in coursework (For more efficient strategies to detect and prevent plagiarism with various assessment designs, see Cotton et al., 2023). Additionally, PMTs' dependency on ChatGPT can prevent higher-order learning (Farrokhnia et al., 2023) through lessened conventional research and investigative methods, leading to reduced enthusiasm for thorough examination and critical analysis, lessened inquisitiveness and emotional engagement in the learning process, and decreased self-directed learning due to the diminished independent learning behaviors (Lozano & Fontao, 2023; Shoufan, 2023). However, because of the affordances of ChatGPT to pre-service and in-service teachers and easy access to it, a completely prohibitive approach to the use of ChatGPT at higher education institutions is practically not feasible. Educators in higher education must clearly define ChatGPT's role as an assistive tool, not a replacement for traditional research and inquiry methods to ensure a balance between ChatGPT's benefits and maintaining students' skills and participation.

Research on pre-service teachers and in-service teachers' knowledge of AI-based tools in education is limited (Celik et al., 2022; Kim et al., 2021). Teachers generally benefit more from AI when they possess knowledge of its beneficial features and usage (Celik, 2023). Following their exposure to the positive affordances of generative AI, the PMTs showed increased interest in ChatGPT and other ICTs that could support their teaching and learning abilities at the university. Aside from pedagogical content knowledge, the teaching profession requires affective personality traits such as tolerance and compassion for equitable teaching, commitment and passion for teaching, resilience in the face of difficulties (Hotaman, 2010), and a sense of professionalism. Teacher identity is shaped by these non-cognitive factors. Therefore, it is imperative that teacher education programs prioritize the development of a strong teaching identity for prospective teachers as the PMTs aimed to fill this gap by using ChatGPT. However, ChatGPT provides no evidence for its outputs (Cooper, 2023), and most of the time it fabricates false links for ghost bibliographic references in its output (Orduña-Malea & Cabezas-Clavijo, 2023). Its outputs are based on argumentum ad populum, meaning that instead of justifying its responses with evidence, it constructs arguments based on what is most argued or repeated in its trained data. As pre-service and in-service teachers are more susceptible to misinformation through AI due to lack of knowledge (Antonenko & Abramovitz, 2023), to protect PMTs and in-service teachers from potential misinformation, interventions and professional development trainings that include critical comparison of ChatGPT output with scientifically based counter-examples can be implemented.

The PMTs intend to utilize ChatGPT for adapting and organizing math curriculum in their prospective teaching. This involves creating content like real-world examples, activities, and assignments for abstract mathematical concepts. It also includes inclusive teaching methods for special needs students, instructional strategies, and assessment techniques such as project proposals and performance-based assessments. Some of these recommendations are consistent with systematic reviews (i.e., Celik et al., 2022; Crompton & Burke, 2022); however, the studies in these reviews did not incorporate AI tools to assist in the creation of inclusive instructional designs that could help address individual student needs. Similarly, ChatGPT can generate ideas, classroom examples, and activities to equip pre-service teachers to effectively enact social justice pedagogy (DeMink-Carthew, 2018) for underrepresented students. The PMTs aimed to use ChatGPT to assist students with unique learning needs due to their lack of experience. The recognition of the importance of inclusive instructional strategies by PMTs may have stemmed from practice tasks activities. However, because the sample activities did not include questions about collaborative learning or data-driven decision making, which were highlighted in the previous systematic reviews (i.e., Celik et al., 2022; Crompton & Burke, 2022), the PMTs did not express their intention to use ChatGPT to incorporate these aspects into their prospective teaching. This realization highlights the need for careful planning when training PMTs on AI tools, such as ChatGPT.

The PMTs emphasized using ChatGPT for student motivation strategies. They anticipated the application to enhance engagement, communication, and understanding of student psychology. The PMTs also expected it to help solve real-life math problems, identify learning styles, and provide timely feedback for students transitioning to adolescence. By generating immediate feedback, AI can facilitate student learning progression by reducing delays in teacher feedback (Chen et al., 2023; Goel & Joyner, 2017). It should be noted that the study sample experienced COVID-19 pandemic restrictions and they are survivors of Mw 7.7 and 7.6 earthquakes that hit the southeastern regions of Türkiye in February 2023. It is possible that they might prioritized their need for motivation and self-regulation because of their conditions.

Further research is needed to uncover i) pre-service teachers' ICT literacy to responsibly use AI tools in their learning and teaching by considering their potential positive and negative outcomes, ii) effective strategies to prevent cheating through AI tools, iii) development of specific ethical guidelines for integrating AI tools in teacher education programs, iv) long-term impact of AI tools on pre-service teachers' learning dispositions using longitudinal data that focuses on PMTs' performance and behaviors, v) the best practices for integrating AI tools such as ChatGPT in teacher education programs that can enhance PMTs' essential thinking and learning (e.g., creativity, analytical and critical thinking, and data-driven decision-making), teaching (e.g., inclusive and culturally relevant instruction), and assessment skills.

Conclusion

The rapid evolution of AI technologies and their planned and unplanned penetration into educational settings requires careful examination, preparation, and action to prepare teachers for this changing educational landscape. The PMCA generated by this study contribute to the literature and teacher education programs, which can serve as a tentative theoretical template, by providing a more comprehensive and unexplored intentions of PMTs to use ChatGPT for their education and future teaching. As a free and easily accessible alternative to contract cheating, ChatGPT is a difficult challenge for educators in teacher education programs and in-service teachers. Although some available software can detect AI-generated content to some extent (e.g., Scribbr's AI detector, Turnitin, ChatZero and Isgen), PMTs and students can discover loopholes to avoid the detection. Further research, data-driven discussions and preventive policy measures regarding the spread of misinformation through ChatGPT in teacher preparation programs are also urgently needed. Nevertheless, in our ever-evolving dynamic environment, where finding plausible answers, sometimes under the pressure of deadlines or the need for quick decision-making, and finding effective ways to communicate with students as well as providing culturally appropriate communication via AI can benefit teachers and pre-service teachers (Blanchard, 2015; Farrokhina et al., 2023; Lozano & Fontao, 2023). PMTs can consult ChatGPT and other resourceful AI applications for assistance, while being informed of their limitations.

APPENDIX 1

Introductory Practice Task for ChatGPT

Preparation of Course Content/Assignments:

- Prepare a 7th grade performance homework question about solving equations that can be related to real life.
- I will take my 6th grade students to the Archaeology Museum for an out-of-school field trip. The topics we have covered this semester are: factors and multiples, sets, whole numbers and operations with fractions. Which questions can I ask during the museum visit to help students reinforce these topics?
- I am going to teach probability to 8th graders in math class. I want to give a project-based assignment. Write a project idea that can be solved in several steps and write [homework] instructions that I can give to the students.

- I will teach my 6th grade students to gain the objective 'Construct the area relation of a triangle and solve related problems.' Create a question [related to this objective] that will raise awareness in students about global problems and social justice concepts.

Approaches to Inclusion Students:

- In my 7th grade class, there is a student with Attention Deficit Hyperactivity Disorder (or hearing impaired, autistic, exposed to domestic violence, etc.). How should I orient my teaching for this student?
- I have students in my class who do not speak Turkish well. What can I do to increase their participation in math class?

Helping Students:

- How do I solve the equation 3x - 15 = 4x + 20?
- In 8th grade math class, I didn't understand the difference between the concepts of statistics and parameter. what is it?
- (Follow-up question) I don't understand the parameter. Can you explain it in a simpler way?
- Solve the equation ((2^3)^5)/16

APPENDIX 2

Online Interview Questions:

1. Have you used ChatGPT before? If yes, for what purpose?
2. What do you think about the application?
3. Did you encounter any technical problems while using ChatGPT? Do you think the answers given to the questions are correct and sufficient?
4. Answers to which questions do you think would contribute more to your academic knowledge or future teaching?
5. In which areas do you intend to use ChatGPT in your university life or in your teaching?
6. Asking which questions other than the ones mentioned here (in Introductory Task) can contribute to your learning, your professional development as a teacher and to improve your teaching approach?
7. Write down 5 questions about your academic life that you are curious about.

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