Ed Process Int J

www.edupij.com

ISSN 2147-0901 (Print), 2564-8020 (Online)

EDUCATIONAL PROCESS
INTERNATIONAL JOURNAL

Students' Perceptions and Applications of Metacognitive Awareness Levels in Problem Solving with ChatGPT

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Research Article

Cite this article: Filiz, A., & Gür, H. (2025). Students' Perceptions and Applications of Metacognitive Awareness Levels in Problem Solving with ChatGPT. *Educational Process: International Journal, 14*, e2025063. https://doi.org/10.22521/edupij.2025.14.63

Received January 2, 2025
Accepted February 20, 2025
Published Online February 23, 2025

Keywords:
Metacognitive awareness, ChatGPT usage, problem-solving, AI tools, pedagogical strategies

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Abstract

Background/purpose. Background/purpose. This study aims to examine the impact of prospective mathematics teachers' metacognitive awareness on their perceptions and applications of ChatGPT in problem-solving processes. The research investigates how these prospective mathematics teachers perceive and utilize ChatGPT, focusing on the relationship between their metacognitive awareness levels and the use of artificial intelligence tools.

Materials/methods. The study utilizes both qualitative and quantitative research methods. In the quantitative phase, data was collected from 42 prospective mathematics teachers through a survey, exploring how their metacognitive awareness levels impacted their use of ChatGPT in solving mathematical problems. The qualitative phase involved in-depth interviews with four prospective teachers to gain detailed insights into their perceptions and practical applications of ChatGPT in problem-solving.

Results. The findings of this study give valuable results on the intersection of metacognitive awareness and artificial intelligence in education. By understanding how prospective mathematics teachers use ChatGPT, the research provides to the development of more effective pedagogical strategies for leveraging AI tools in teacher education. The study emphasizes the importance of professional development to help educators navigate the complexities of AI tool implementation in teaching and learning, ultimately enhancing problem-solving skills among future mathematics teachers.

Conclusion. The study demonstrates that ChatGPT can significantly enhance prospective mathematics teachers' metacognitive awareness and problem-solving strategies. ChatGPT can improve teaching practices and foster more effective problem-solving approaches in mathematics education by providing rapid feedback and supporting strategic thinking.

1. Introduction

In the past decade, technological advancements in education have significantly transformed various aspects of learning, particularly due to developments in artificial intelligence (AI). These advancements have facilitated greater access to educational resources and expanded the scope of higher education beyond traditional classroom settings, thereby creating new opportunities for both educators and prospective teachers (Rawas, 2023). AI-supported applications have led to the development of intelligent tutoring systems designed to deliver personalized learning materials, guidance, and feedback to prospective teachers (Zhu et al., 2023). Among these innovations, one that holds the potential to radically reshape the education system, particularly in higher education, is ChatGPT. Initially developed in 2018 and launched in November 2022 (Leng, 2024), ChatGPT reached 100 million users within just two months of its release (The Guardian, 2023). The tool has demonstrated considerable success in comprehending complex queries and providing accurate responses. With its ability to deliver timely and coherent information, ChatGPT is capable of offering effective solutions to intricate problems. As a result, its potential applications extend across various sectors, including business and everyday life (Zhu et al., 2023).

ChatGPT can also assist prospective mathematics teachers in enhancing their research skills by providing relevant information, suggesting unexplored research avenues, and introducing them to new fields of study. This, in turn, enables prospective mathematics teacher to deepen their understanding of educational topics and refine their evaluative skills (Kasneci et al., 2023). Metacognitive awareness refers to an individual's recognition and understanding of their own cognitive processes and strategies. Such awareness plays a crucial role in improving information processing and problem-solving abilities. When interacting with AI tools like ChatGPT, users with metacognitive awareness are better equipped to identify and apply effective strategies for problem-solving. Therefore, it can be argued that metacognitive awareness is an essential skill for effectively engaging with ChatGPT and similar AI technologies, particularly in complex problem-solving contexts. The present study aims to investigate the potential impact of prospective mathematics teachers' metacognitive awareness on their use of ChatGPT in problem-solving processes.

2. Literature Review

Prospective mathematics teachers engaging in ill-defined problem-solving tasks within educational contexts show advanced competencies in transferring knowledge across various domains, extending academic insights beyond traditional boundaries, and generating innovative ideas (Walker & Leary, 2009; Hamarat, 2019; Cunningham, 2020). These undefined problem-solving tasks not only enhance critical thinking skills (Liu & Pasztor, 2022) but also play a significant role in increasing prospective mathematics teachers motivation to learn by providing them with novel and engaging challenges (Demirel & Dagyar, 2016). Given the inherent uncertainty and complexity of ill-defined problems, pre-service teachers are expected to employ a range of cognitive and metacognitive skills. Ultimately, they must engage in a convergence process to identify the most innovative and effective solution (Treffinger et al., 2008). In other words, solving ill-defined problems involves both cognitive and metacognitive skills, as well as divergent (creative) thinking (Mumford et al., 1991, 2019).

Artificial intelligence (AI) technologies hold the potential to radically alter the roles of educators, making them an important area of research and application in the field of education (Felix, 2020; Şekeroğlu et al., 2019; Nayıroğlu & Tutak, 2024). Mathematics plays a pivotal role in the development of fundamental skills such as analytical thinking, problem-solving, and logical reasoning (Van Vaerenbergh & Pérez-Suay, 2021). AI applications operate by integrating algorithms designed to solve specific problems or achieve set objectives intelligently and iteratively. The binary system of 1s and 0s, the core of mathematical logic, forms the foundation of programming languages, thus linking AI

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applications closely with mathematical principles (Dengiz, 2023). Generative artificial intelligence technologies, such as ChatGPT, have the potential to significantly alter the processes involved in solving well-defined problems (Zhai, 2022; Terwiesch, 2023; Dwivedi et al., 2023; Lim et al., 2023; Noy & Zhang, 2023).

In this context, the present study aims to address this gap by exploring how prospective mathematics teachers' perceive and utilize ChatGPT in their problem-solving processes. On the other hand, ChatGPT's ability to solve mathematical problems has garnered significant attention. ChatGPT is capable of addressing a broad spectrum of topics, from basic arithmetic to more complex mathematical equations. Designed specifically to understand mathematical equations and formulas, ChatGPT initiates the problem-solving process by analyzing the question it receives. Moreover, as a software developed for both corporate and individual use globally, it is capable of providing answers with impressive speed (Plevris et al., 2023; Kashefi & Mukerji, 2023; Remoto, 2023; Dao & Le, 2023; Karabıyık, 2024; Plevris et al., 2023; Kashefi & Mukerji, 2023; Karabıyık, 2024; Plevris et al., 2023; Kashefi & Mukerji, 2023). At present, ChatGPT is effective for addressing basic and straightforward mathematical questions. However, with the rapid evolution of AI technologies, it is anticipated that its capacity to handle more complex mathematical problems will improve over time (Karabıyık, 2024). This improvement could prove to be a significant advantage for professionals working with intricate equations and advanced mathematical tasks.

Metacognition is a multifaceted concept that researchers have explored for over three decades and has been defined in various ways (Ünsever & Kutluca, 2024). Rhodes (2019) characterizes metacognition as the collection of mechanisms that individuals use to continuously monitor and regulate their cognitive processes. Vo et al. (2014) defines metacognition as an individual's ability to evaluate their own knowledge and recognize it as a critical tool in learning, particularly in mathematics. The metacognitive approach allows prospective mathematics teachers to more effectively manage their thought processes, evaluate their own participation and actions during learning, and foster creativity (De Ocampo-Acero et al., 2015; Puryear, 2016). This approach also supports prospective mathematics teachers in maximizing their potential, pushing their cognitive limits, and focusing on tasks while adapting to new learning environments (De Ocampo Acero et al., 2015; Tabuyo, 2024; Hacker, 1998).

Metacognition provides a framework for understanding how cognitive processes are managed and organized. Flavell (1979) defines metacognition as the conscious structuring and transfer of information to memory, the scanning of memory to identify and retrieve relevant information, and the awareness of stored knowledge. Reeve and Brown (1985) describe metacognition as the ability to manage and direct cognitive processes. Shanahan (1992) defines it as the understanding and regulation of cognitive activities, while Butterfield et al. (1995) and Binkley et al., (2010) emphasize metacognition as the comprehension of the factors influencing cognitive processes and the monitoring and regulation of these processes. Flavell (1976) further distinguished two components of metacognitive processes. The first, **metacognitive knowledge,** refers to a person's general awareness about their own cognitive processes, which can be assessed independently of any specific task. The second component, **metacognitive awareness,** refers to the ability to monitor and control cognitive processes and strategies in real time. This awareness is typically assessed during the execution of tasks, especially in neuropsychological contexts (Koriat, 2007). Metacognitive awareness in the learning process is widely accepted, there remains a limited body of research on the subject (Wenden, 1991, 1999; Wilkins, 1997; Balçıkanlı, 2011), highlighting the need for further exploration.

Prospective mathematics teachers who lack metacognitive awareness often struggle to navigate their learning processes effectively and are unable to assess their progress, success, or future learning needs (Q'Malley et al., 1985). Without metacognitive skills, these individuals may find it difficult to identify appropriate learning strategies, monitor their understanding, or adjust their approach when

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facing challenges. Since the early 1980s, researchers in the field of mathematical problem-solving have increasingly turned their attention to the role of metacognition. Scholars have raised important questions such as: "Can problem-solving skills be taught?", "What is the role of understanding in problem-solving?", and "How does metacognition influence problem-solving?" (Lester, 1982; Silver, 1982). International studies have highlighted that students often struggle with solving complex mathematical problems that require multiple operations, and that mathematics teachers face difficulties in planning and implementing lessons designed to develop problem-solving skills (Kramarski, 2008). Metacognition has been recognized as a valuable tool for addressing these challenges.

Garofalo and Lester (1985) identified metacognition as fundamental to the analysis and understanding of mathematical performance. Cardella-Elawar (1995) emphasized that prospective mathematics teachers who fail to carefully analyze the problem, who do not explore all possible solutions, and who do not monitor their steps are typically unsuccessful in solving mathematical problems. A large body of research has explored the relationship between metacognition, mathematics, and problem-solving (Culaste, 2011; Desoete, 2008; Goldberg & Bush, 2003; Ifenthaler, 2012; Kapa, 2001; Panaoura & Philippou, 2007; Van der Stel & Veenman, 2008; Zan, 2000; William & Maat, 2020; Anggo et al., 2021; Defi et al., 2022; Shodikin et al., 2022; Tabuyo, 2024). These studies consistently demonstrate a significant relationship between metacognitive skills and problem-solving abilities. Specifically, the development of metacognitive skills and progress in problem-solving ability are shown to be closely aligned, with individuals who excel in problem-solving typically exhibiting higher levels of metacognitive awareness.

The importance of problem-solving in mathematics education has been widely emphasized by researchers (Lesh & Zawojewski, 2007; Lester & Kehle, 2003; National Council of Teachers of Mathematics, 2000; Polya, 1957; Schoenfeld, 1985, 1992; Campione, Brown, & Connell, 1989; Cummins, 1992; Hegarty, Mayer, & Monk, 1995). One of the key characteristics that distinguishes successful problem-solvers, especially among prospective teachers, is the presence of metacognitive awareness (Mayer, 1998; Schoenfeld, 1985). Metacognition plays a vital role in the problem-solving process by facilitating the generation of appropriate representations of the problem at hand and ensuring the accessibility of the solution (Schoenfeld, 1983; Verschaffel, 1999). Additionally, metacognitive skills help prospective teachers to understand the problems more deeply, make accurate solutions, and effectively utilize the given information (Davidson & Sternberg, 1998; Lucangeli, Tressoldi, & Cendron, 1998). In this sense, metacognition serves as a crucial cognitive tool that guides the learner through the problem-solving process, enhancing both the efficiency and effectiveness of their approach. Metacognitive experiences, often referred to as metaphysical experiences, involve the emotional and cognitive responses individuals have during the execution of a task (Efklides, 2001; Flavell, 1979; Efklides, 2001, 2006). They enable the learner to make informed decisions about how to proceed with problem-solving tasks and contribute to the transfer of learned content into meaningful, actionable strategies (Desoete & Veenman, 2006).

Up to date, there are no studies specifically investigating how prospective mathematics teachers perceive ChatGPT in their problem-solving processes and the relationship between their metacognitive awareness and this interaction. Existing research has primarily focused on the connection between metacognition and problem-solving, as well as the impact of ChatGPT on problem-solving activities. For instance, Daher and Gierdien (2024) explored the text responses generated by ChatGPT as prospective mathematics teachers solved mathematical problems related to quadratic equations. They found that ChatGPT's responses could support prospective mathematics teachers' understanding of different solution strategies for quadratic equations. Similarly, Anggo et al. (2021) examined the metacognitive strategies used by prospective mathematics teachers when solving mathematical problems, noting that such strategies are critical for developing strong

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problem-solving foundations, particularly for solving complex problems in varied contexts. Another study by Tabuyo (2024) investigated the role of metacognition in prospective mathematics teachers' problem-solving performance, concluding that effective metacognitive strategies were key to achieving success in mathematics problem-solving. Urban et al. (2024) explored the impact of ChatGPT on creative problem-solving in university prospective mathematics teachers, finding that the perceived usefulness of ChatGPT influenced their self-assessment judgments, which, in turn, led to higher error rates in their evaluations. These studies indicate the significant potential of ChatGPT in supporting problem-solving tasks but also highlight the need for further research on how prospective mathematics teachers' metacognitive awareness might influence their interactions with such AI tools.

2.1. The Present Study

The advent of generative artificial intelligence tools, particularly language models like ChatGPT, has led to a paradigm shift in educational technologies. These advancements have significantly contributed to supporting the learning processes of prospective mathematics teachers, especially in fields like mathematics. While research has explored the use of chatbots in specific domains such as reading, mathematics, and argumentation (Guo et al., 2023; Lee & Yeo, 2022; Li et al., 2023), there remains a notable gap in understanding how ChatGPT influences ambiguous or ill-defined problem-solving tasks in educational settings. The central focus of this study is the gap in the literature regarding how prospective mathematics teachers perceive ChatGPT and how their metacognitive awareness affects their problem-solving processes with this tool. The primary aim of this research is to investigate the potential effects of prospective mathematics teachers' metacognitive awareness levels on their use of ChatGPT, particularly in the context of problem-solving tasks. This study also examines the relationship between how prospective mathematics teachers perceive and utilize ChatGPT in their problem-solving processes and their metacognitive awareness levels. By addressing this gap, the study aims to provide valuable insights for both educators and researchers. Understanding the interplay between metacognitive awareness and the use of AI tools like ChatGPT could inform the design of more effective pedagogical strategies and support the development of essential problem-solving skills among prospective mathematics teachers. To guide the investigation, the study will address the following research questions:

1. Do prospective mathematics teachers' perceptions and use of ChatGPT in their problem-solving processes differ based on their metacognitive awareness levels?

2. What are the potential effects of prospective mathematics teachers' metacognitive awareness levels on their use of ChatGPT in problem-solving tasks?

3. Methodology

3.1. Research Design

This study employs mixed-methods research design (both qualitative and quantitative approaches) (Battista & Torre, 2023). Integrating qualitative and quantitative data facilitates data triangulation, leading to a deeper, more reliable understanding of the research topic (Yin, 2018). The methodology of the study is given in Figure 1.

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Figure 1. Methodology

3.2. Sample

The study sample was selected using a convenience sampling method that focuses on selecting participants who are easily accessible and representative of the target audience (Patton, 2002). The quantitative part of the study included 42 fourth-grade pre-service mathematics teachers enrolled in the Elementary Mathematics Teaching program at a foundation university in Istanbul. Four pre-service mathematics teachers were selected from the sample for the qualitative study. Data was collected during the fall semester of the 2024-2025 academic year. The sample was selected to include participants who were in the final stages of their teacher education, making them suitable for providing insight into how metacognitive awareness may affect the use of ChatGPT in problem-solving contexts. This study aims to contribute to the growing literature on the role of artificial intelligence in education and metacognitive processes in teacher education by analyzing the relationship between metacognitive awareness and ChatGPT use among these potential mathematics teachers.

3.3. Metacognitive Awareness Scale

In this study, the Metacognitive Awareness Scale developed by Schraw and Dennison (1994) and adapted into Turkish by Akın et al. (2007) was used to determine the metacognitive awareness levels of prospective mathematics teachers. The scale employs a 5-point Likert-type rating system ranging

from strongly disagree (1) to strongly agree (5). It consists of two main dimensions and 52 items. The first main dimension is knowledge of cognition, which includes three subdimensions: declarative knowledge, procedural knowledge, and conditional knowledge. The second main dimension is regulation of cognition, which consists of five subdimensions: planning, monitoring, evaluating, debugging, and information management (Schraw & Dennison, 1994). The reliability coefficients for the subdimensions of the knowledge of cognition dimension are as follows: declarative knowledge (.95), procedural knowledge (.94), and conditional knowledge (.96). The reliability coefficients for the subdimensions of the regulation of cognition dimension are planning (.98), monitoring (.94), evaluating (.95), debugging (.93), and information management (.98). In this study, the whole scale was analyses and its dimensions were not used. The overall reliability coefficient for the scale, as reported by Akın et al. (2007), was 95, and in the present study, it was found to be 94.

3.4. Self-Report Questionnaire

The Self-Report Questionnaire was developed by Abdelhalim (2024) based on the research topics and tasks covered in a research methodology course. This questionnaire assesses prospective mathematics teachers' perceptions, usage, and overall satisfaction with ChatGPT. The self-report questionnaire was adapted by the researchers to align with the research questions of the current study. The first 12 items of the questionnaire evaluate the perceptions of ChatGPT, items 13-25 evaluate implementation, and items 26-31 evaluate general satisfaction. The questionnaire contains a total of 31 items. Reliability coefficients for each sub-dimension of the self-report questionnaire were calculated as the perception of ChatGPT .79, implementation of ChatGPT .89, and general satisfaction with ChatGPT .89. It has shown high internal consistency with a Cronbach's alpha coefficient for the whole scale 0.80, indicating reliability (Abdelhalim, 2024).

3.5. Semi-Structured Interview Form

To explore the prospective mathematics teachers' perceptions and usage of ChatGPT, semi-structured individual interviews were conducted. The interview questions consisted of open-ended items. The first two questions were general questions, four questions focused on ChatGPT, three on metacognitive awareness, two on perceptions of ChatGPT, and two on results and feedback. Other questions addressed the problem-solving process, ChatGPT usage, metacognitive awareness, and feedback for each of the problems provided. The interviews lasted between 45 and 60 minutes.

3.6. Data Collection Process and Data Analysis

The data collection process for the study was conducted in three main stages. In the first stage, the Metacognitive Awareness Scale was administered to evaluate the prospective mathematics teachers' metacognitive awareness levels. In the second stage, to address the potential lack of prior knowledge about ChatGPT among the participants, the prospective mathematics teachers were provided with information about ChatGPT and how it could be used. Subsequently, the participants solved mathematical problems using ChatGPT and navigated through the problem-solving process with the assistance of the AI tool. In the final stage, the Self-Report Questionnaire was administered to assess the forty-two prospective mathematics teachers' perceptions of ChatGPT. The responses of four prospective mathematics teachers were then analyzed in conjunction with the semi-structured interviews.

In this study, methodological and data triangulation were employed to ensure comprehensive analysis. The quantitative data from the Metacognitive Awareness Scale and the Self-Report Questionnaire were analyzed using quantitative methods via SPSS 20.0.

Firstly, the participants' scores on the Metacognitive Awareness Scale were divided into two groups: low and high metacognitive awareness, based on their total scores. The lowest score obtained was 150, and the highest score was 249. these scores were divided into low and high

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categories. T-tests were conducted to compare the perceptions of ChatGPT between the low and high metacognitive awareness groups. A regression analysis was also performed to examine the relationship between metacognitive awareness levels and prospective mathematics teachers' perceptions of ChatGPT.

For the qualitative data, responses obtained from the semi-structured interviews were analyzed and categorized under the themes of "Problem-Solving Process," "ChatGPT Usage," "Metacognitive Awareness," and "Results and Feedback." The analysis examined how prospective mathematics teachers approached mathematical problem-solving with the use of technology, as well as how ChatGPT influenced this process. Additionally, the study explored the development of metacognitive awareness, and the strategies employed during problem-solving through the responses given for two different mathematical problems.

The Shapiro-Wilks normality test was first applied to determine whether the variables followed a normal distribution (Table 1).

Table 1. Results of the Normality Test

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	p	Statistic	df	p
Total	.351	42	.000	.636	42	.000

Table 2. Skewness and Kurtosis values

	Skewness	Std. Error of Skewness	Kurtosis	Std. Error of Kurtosis
Total	-.099	.365	-2.092	.717

Note: Table 1. “Results of Normality Test" would follow here with the actual data results, but since this section is focused on methodology and data analysis, specific data results are not included in the text above. In addition, according to Table 2, the fact that Skewness and Kurtosis values are not between -2 and +2 indicates that the distribution is not normal (Lomax & Hahs-Vaughn, 2012).

By conducting both qualitative and quantitative analyses, this study aims to provide a deeper understanding of how prospective mathematics teachers’ metacognitive awareness influences their perceptions and usage of ChatGPT in the problem-solving process. The combination of these analytical approaches contributes to triangulating the findings and offering a comprehensive picture of the educational impact of generative AI tools like ChatGPT in teacher education. According to the Kolmogorov-Smirnov test results presented in Table 1, the p-value was found to be smaller than 0.05, indicating that the data do not follow a normal distribution. Therefore, non-parametric tests were applied to analyze the data.

In the first research question, the perceptions of prospective mathematics teachers with low and high levels of metacognitive awareness regarding their use of ChatGPT were compared using the Mann-Whitney U test. The results revealed the following: The mean rank for prospective mathematics teachers with low metacognitive awareness regarding their perceptions of ChatGPT, its suitability, satisfaction, interest level, and overall average score from the self-report questionnaire was 17.47. The mean rank for prospective mathematics teachers with high metacognitive awareness

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regarding the same factors was 25.16. The Mann-Whitney U test results indicate a significant difference between the perceptions of ChatGPT between the two groups, based on their metacognitive awareness levels. The Mann-Whitney U test results showing the difference in mean ranks of prospective mathematics teachers with low and high metacognitive awareness levels regarding their ChatGPT usage experiences are presented in Table 3.

Table 3. Mann-Whitney U Test Results for the Experiences of Prospective mathematics teachers with Low and High Metacognitive Awareness Regarding ChatGPT

ChatGPT experience	Group	N	Ranks M	Ranks sum	U	Z	p
Application	Low	20	18.35	367.00	157.00	1.59	.11
	High	22	24.36	536.00			
Perceived effectiveness	Low	20	16.93	338.50	128.50	2.31	.02
	High	22	25.66	564.50			
Satisfaction&interast	Low	20	17.13	342.50	132.50	2.21	.02
	High	22	25.48	560.50			

According to Table 3, the perceived effectiveness and satisfaction/interest of ChatGPT in the experiences of prospective mathematics teachers with low and high metacognitive awareness levels were found to be statistically significant ($p<.05$). Specifically, perceptions of effectiveness and satisfaction/interest levels differed between the groups based on their metacognitive awareness. However, no significant difference was found in the application of ChatGPT in problem-solving between the low and high metacognitive awareness groups ($p >.05$).

3.7. Regression Analysis

In the second research question, regression analysis was conducted to explore the relationship between prospective mathematics teachers' metacognitive awareness levels and their perceptions of ChatGPT experiences. The results of the simple linear regression analysis are provided in Table 4.

Table 4. Simple Linear Regression Analysis Results

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
(constant)	3.55	.10		33.52	.00
Metacognition	.37	.14	.375	2.56	.01
F=6.55, p=0.01 (Anova)					

The regression analysis indicates a positive significant effect of metacognitive awareness on ChatGPT usage experiences ($\beta = 0.375$, $p = 0.01$). This result shows that higher metacognitive awareness in prospective mathematics teachers leads to better ChatGPT experiences. The R^2 value is 0.14, indicating that metacognitive awareness explains 14% of the variance in ChatGPT usage experiences.

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3.8. Qualitative Data from Semi-Structured Interviews

The qualitative findings from the semi-structured interviews with four prospective mathematics teachers, all with similar levels of metacognitive awareness, are presented in the second part of the study. The data were analyzed by adding new themes that were created after an in-depth analysis of themes and categories identified through a review of relevant literature, and the results were interpreted in an understandable manner, including direct quotes as a way of reflecting the themes (Görgülü Arı & Hayır Kanat, 2020). They were coded with numbers in parentheses (S1, S2, ...). To ensure the ethical standards, participants were assigned pseudonyms (e.g., S1, S2, etc.) to ensure their anonymity. To ensure inter-rater reliability, regular weekly meetings were conducted with the researchers to discuss any differences in interpretation and reach a consensus (Braun & Clarke, 2006). In this process, disagreements between researchers were discussed and consensus was reached (Campbell, Quincy, Osserman & Pedersen, 2013). Moreover, the validity and reliability of the study were enhanced through content validity assessments by four field experts and members checking, where participants were asked to verify that the data were accurately represented and if they wanted to add any further information. Each participant was contacted and asked whether the information in the interview form was reflected accurately. The necessary arrangements were made by learning about the differences and whether there was any other information they wanted to add. All participants were assigned a code, and the data were analyzed based on these codes. Apart from this, the inter-rater reliability was calculated using Miles & Huberman's (1994, p.100) formula for Inter-coder Agreement:

$$\text{Reliability}=\frac{\text{Agreement}}{\text{Agreement + Disagreement}}\text{x}100$$

Interview responses were analyzed thematically under categories such as Problem-solving process; ChatGPT usage; Metacognitive awareness and Results and feedback.

The discussion section was created by matching the quantitative and qualitative findings of the study. The factors in the "Metacognitive Awareness scale", which is the questionnaire used in the study, were also matched with the interview categories. The "Cognitive knowledge factor" (sub-factors; declarative knowledge, procedural knowledge and conditional knowledge) in the questionnaire was matched with the "metacognitive awareness" and "ChatGPT usage" categories in the interview category. The "situation organization" factor in the Metacognitive Awareness scale was matched with the "problem solving" and "results and feedback" categories obtained because of the interview analysis.

4. Findings of Qualitative Results

While investigating the effects of prospective mathematics teachers' metacognitive awareness levels on ChatGPT usage, the obtained data will be analyzed under the subthemes of "problem-solving," "ChatGPT usage," and "metacognitive awareness." The prominent points regarding these themes, based on the responses of prospective mathematics teachers , are as follows: 1. Problem-solving (cognitive strategies, self-regulation in problem-solving, problem solving support); 2. Chatgpt usage (tool perception, satisfaction and engagement, critical evaluation); 3. Metacognitive awarness (self-reflection and strategy monitoring, awarness of cognitive processes, limitation of AI, lack of reflection in low metacognitive awarness groups).

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1. The responses of prospective mathematics teachers to each open-ended question are presented below.

	You want to buy glass for a photo frame with dimensions of 83 cm and 55 cm. If the square meter of glasses is 30 liras (1m2=30TL), would it be enough to take 15 liras with you to buy the glass for this frame? Calculate

In this section, the responses provided by four prospective mathematics teachers will be analyzed according to the identified themes: "Problem Solving," "ChatGPT Usage," and "Metacognitive Awareness." Each teacher's responses to the two problem-solving questions will be grouped and examined under these themes. The following subsections provide the breakdown of each theme based on the individual responses of the prospective mathematics teachers.

4.1. Problem Solving Process

The first step in problem-solving involves analyzing the problem, which refers to understanding the problem's structure, the given information, and identifying the goals and constraints. Below are the responses of the four prospective mathematics teachers to the problem analysis phase.

S1(prospective mathematics teacher1) stated that he used ChatGPT as a support tool in the problem-solving process.

> *"I use ChatGPT to make sure I'm doing it right. The ChatGPT is useful in multi-step complex problems and verifies the solution" S1*

This emphasis illustrates that ChatGPT plays a significant role in verification and troubleshooting. In addition to this, the prospective mathematics teacher also noted that ChatGPT is useful in multi-step problems, emphasizing the need to follow and verify complex steps.

> *"ChatGPT has been extremely useful in multi-step problems. However, sometimes when I provide incomplete information, ChatGPT's responses can be incorrect. In such cases, I manage to obtain the correct answers by attempting to phrase the question more clearly. Additionally, I always verify the answers I receive from ChatGPT myself." (S1)*

S1's practice of cross-checking the answers provided by ChatGPT with their own knowledge indicates a critical approach and suggests that they view artificial intelligence as a supportive tool rather than becoming entirely dependent on it.

> *"ChatGPT has been quite helpful in finding different solutions. It allows me to approach solutions from an unfamiliar perspective. I find it particularly useful for non-routine problems." (S2)*

S2 expressed that ChatGPT brings alternative perspectives to problem-solving and is particularly beneficial for non-routine types of problems. They also mentioned that in some cases, ChatGPT provides suggestions related to the solution rather than solving the problem directly, but by asking the question in a clearer manner, the problem is eventually resolved.

4.2. ChatGPT Usage

As mentioned by S1, S2, S3, and S4, ChatGPT is seen as a resource they turn to when solving mathematics problems.

> *'ChatGPT even solves complex problems, and I can get good responses.' (S2, S3)*

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Prospective mathematics teachers S2 and S3 expressed that they were impressed by ChatGPT's problem-solving ability when they first encountered it.

'ChatGPT is very useful because it provides quick feedback and offers alternative solutions.' (S1)

According to the prospective mathematics teachers' evaluations, the quick feedback and alternative solution suggestions provided by ChatGPT contributed to the problem-solving process.

'It offers different perspectives on the question and facilitates operations in many ways. However, it cannot perform advanced mathematical operations.' (S2)

S2 noted that while ChatGPT offers different perspectives and facilitates operations in many ways, it has some limitations, particularly in performing advanced mathematical operations.

4.3. Metacognitive Awareness

Metacognitive awareness significantly influences perceptions of ChatGPT use among prospective mathematics teachers.

"As my metacognitive awareness level increases, I can use ChatGPT more effectively." (S1)

S1's metacognitive awareness level improved during the problem-solving process with ChatGPT. In his answers to the questions, he emphasizes that he is aware of his thinking processes while solving problems and that these processes need to be analyzed.

The statement "Before asking a problem to ChatGPT, I need to realize how I think and which part of the question I am stuck on" points to an element that increases the prospective teacher's metacognitive awareness. He also stated that this increase in awareness enables ChatGPT to ask more accurate questions.

"It is important to provide correct guidance when using ChatGPT. This situation is directly proportional to the level of metacognitive awareness." (S2)

S2's level of metacognitive awareness has enabled her to gain different perspectives when solving questions with ChatGPT and has led her to realize that this skill can be applied to other types of questions. In this way, S2 can better analyze its own thinking processes and develop effective solutions to different types of problems.

4.4. Conclusion and Feedback

S1 stated that ChatGPT had positive contributions to the education process and improved problem-solving and thinking processes. The feedback and solutions provided by ChatGPT allowed the pre-service teacher to evaluate his/her own thinking processes.

"I experienced an improvement in my problem-solving skills. I became more conscious, especially in terms of metacognitive awareness." (S1)

"I definitely felt an improvement; it allowed me to look at questions from different perspectives." (S2)

The pre-service teacher's analysis of problem-solving processes with ChatGPT seems to have contributed to the development of his/her metacognitive awareness.

S2 stated that interaction with ChatGPT contributed to his/her thinking processes and increased his/her metacognitive awareness. While emphasizing that he/she experienced a visible improvement in his/her own learning and thinking skills with the statement "I definitely felt an improvement", he/she expressed that this experience increased his/her flexibility of thought and enabled him/her to develop alternative solutions with the statement "it allowed me to look at questions from different perspectives". This shows that ChatGPT can play a guiding role in problem-solving processes and

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contribute to personal development. This data showed that we can conclude that the way pre-service teachers use ChatGPT is related to their metacognitive awareness levels and that this awareness makes the problem-solving process more effective.

> *"I began by carefully identifying the key elements of the problem." S3*

> *"I focused more on the mathematical operations involved in the problem and initially struggled to identify the relationship between the given data. After using ChatGPT for assistance, they quickly understood how to manipulate the information and begin the calculation process." S2*

> *"I emphasized the importance of a conceptual approach. They noted the significance of identifying patterns in the problem, linking it to previous knowledge, and recognizing similarities with problems encountered in the past. They appeared more confident in understanding the problem's structure and started by rewriting the problem in simpler terms before proceeding to the solution." S3*

> *"I began by analyzing the problem step by step, focusing on understanding the underlying question. They mentioned that their first step was to clarify the goal and assess whether all necessary information was provided. They also noted the potential pitfalls of misinterpreting the problem's objectives." S4*

They highlighted the need to first organize the given data and recognized the importance of understanding the problem's requirements. According to their response, they preferred to break down the problem into smaller steps, starting with identifying what was already known and what needed to be found.

4.5. ChatGPT Usage

After analyzing the problem, each prospective mathematics teacher used ChatGPT to assist in solving the problem. Their usage of the AI tool was categorized as follows:

> *"I used ChatGPT primarily for confirming their initial approach to solving the problem. They entered their preliminary understanding of the problem and used ChatGPT's suggestions to refine their strategy. They reported that ChatGPT was helpful in suggesting alternative methods for solving the problem." S1*

One prospective mathematics teacher primarily used ChatGPT to confirm their initial approach to solving the problem. This approach highlights how ChatGPT can serve as a tool for validation and alternative exploration, helping teachers improve their initial solution framework.

> *"I heavily relied on ChatGPT to guide them through the problem-solving process. Initially unsure of how to proceed, they used ChatGPT to break the problem into manageable parts. ChatGPT provided step-by-step instructions, which allowed teacher to follow along and gain clarity on the necessary steps for solving the problem." S2*

Another prospective mathematics teacher relied heavily on ChatGPT to guide them through the problem-solving process. By providing step-by-step instructions, ChatGPT helped the teacher gain clarity and structure their approach, demonstrating how the AI tool can be a supportive guide when the user is unsure about the process.

> *"I used ChatGPT more as a tool for verification rather than guidance. I felt confident in their approach but wanted to double-check their solution. ChatGPT's suggestions were used to confirm the calculations and ensure that they had not overlooked any key details." S3*

A third prospective mathematics teacher used ChatGPT as a verification tool, not for guidance but for double-checking their solution. S4 teacher felt confident in their approach but used ChatGPT's suggestions to confirm their calculations and ensure that no critical details were missed. This reflects

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a more critical, self-assured use of ChatGPT, where it serves as a means of validation rather than an active guide.

> *"I used ChatGPT to explore different solution strategies. They evaluated multiple approaches, relying on ChatGPT for feedback on their solutions. This process helped Teacher 4 evaluate various methods, which led to a deeper understanding of the problem." S4*

The S4 prospective mathematics teacher used ChatGPT to explore different solution strategies. By testing multiple approaches and relying on ChatGPT's feedback, the teacher evaluated various methods and deepened their understanding of the problem. ChatGPT as a tool for experimentation and exploration, helping the teacher refine their problem-solving techniques and broaden their understanding. Each prospective mathematics teacher utilized ChatGPT in unusual ways, depending on their needs at each stage of the problem-solving process.

4.6. Metacognitive Awareness

Metacognitive awareness refers to the ability to reflect on one's own thinking process, monitoring and regulating it as needed. Each prospective mathematics teacher's responses were analyzed for signs of metacognitive awareness during their problem-solving process:

> *"I demonstrated a powerful sense of metacognitive awareness. They were constantly reflecting on their understanding of the problem and their approach to solving it. They also noted how using ChatGPT helped them become more aware of alternative strategies, leading to a deeper understanding of the problem-solving process." S1*

The first prospective mathematics teacher demonstrated a powerful sense of metacognitive awareness throughout the problem-solving process. This indicates an active engagement in self-reflection and a conscious effort to refine their problem-solving methods.

> *"I displayed less metacognitive awareness initially, as they seemed uncertain about how to proceed with the problem. However, once they began interacting with ChatGPT, they began to reflect on their thought process, which helped them gain a better understanding of the problem. They mentioned that ChatGPT prompted them to think more critically about the problem." S2*

The first prospective mathematics teacher demonstrated an intense sense of metacognitive awareness throughout the problem-solving process. They consistently reflected on both their understanding of the problem and their approach to solving it. This indicates an active engagement in self-reflection and a conscious effort to refine their problem-solving methods.

> *"I exhibited an important level of metacognitive awareness throughout the process. They continually assessed their own understanding of the problem and adjusted their approach as necessary. Their confidence in problem-solving seemed to be guided by both self-reflection and validation through ChatGPT, which allowed them to refine their thinking." S3*

The third prospective mathematics teacher exhibited a high level of metacognitive awareness throughout the entire process. This shows that the teacher was actively involved in both introspection and using external feedback to refine their thinking, enhancing their problem-solving process.

> *"I demonstrated moderate metacognitive awareness. They were aware of their own thought process but relied more on the AI tool for guidance. Despite this reliance, they noted that they often reflected on whether ChatGPT's suggestions aligned with their own reasoning, which allowed them to adjust their strategies as needed."S4*

The fourth prospective mathematics teacher demonstrated a moderate level of metacognitive awareness. While they were aware of their own thought process, they relied more heavily on ChatGPT for guidance. Despite this, they reflected on whether ChatGPT's suggestions aligned with their reasoning, which allowed them to adjust their strategies as needed. This suggests that while

they were more dependent on the AI tool, they still engaged in some reflective thinking to ensure the coherence of the solution with their own understanding.

4.7. Integration of Metacognitive Awareness and ChatGPT Usage

The relationship between metacognitive awareness and ChatGPT usage became particularly evident in the way each prospective mathematics teacher interacted with the AI tool. Those with higher levels of metacognitive awareness seemed to use ChatGPT more strategically, integrating it into their problem-solving process as a tool for verification or exploring alternative strategies. The prospective mathematics teachers with lower levels of metacognitive awareness, however, appeared to use ChatGPT more as a primary tool for guidance, relying on it to structure their thinking and lead them through the solution process.

These findings highlight the importance of developing metacognitive awareness in prospective mathematics teachers, as it appears to influence how effectively they use AI tools like ChatGPT in problem-solving contexts. Enhancing metacognitive skills can help teachers make more intentional and strategic use of technology, leading to more effective learning outcomes.

2. The qualitative analysis of the second open-ended question is given in the following section.

	A blind man stranded in the desert has two red and two blue pills in his box. The man must take one blue and one red pill to survive. Any other combination will cause the man's death. How does a blind man manage to take one blue and one red pill without seeing?

4.8. Problem-Solving Process

S3 stated that during the problem-solving process, ChatGPT provided extremely fast and near-accurate information, saving time, and enhanced their reasoning skills by pointing out aspects of the problem that might otherwise have been overlooked.

> *"Since ChatGPT provides us with very fast and near-accurate real information, it contributes to saving time. On the other hand, in some problem situations where we need to use reasoning to find the solution, it shows us how to approach it." (S3)*

ChatGPT contributes significantly to time efficiency by providing fast and accurate information. It helps users quickly access relevant data, which speeds up the problem-solving process. On the other hand, alternative solutions and problem-solving flexibility are given. ChatGPT also aids in exploring alternative solutions, allowing users to consider different approaches to solving a problem. This indicates that ChatGPT not only speeds up access to information but also supports the user in their thinking and analysis processes.

S4 mentioned that during the problem-solving process, ChatGPT helped save time by increasing speed, especially in problems that required procedural skills, and supported problem-solving by offering alternative solutions.

> *"If the solutions to problems only require processing steps, using ChatGPT speeds up. Additionally, using ChatGPT helps us see different solution paths. However, it does not solve numerical logic problems correctly, like the one here... But I've noticed it gives successful results in problems that require processing steps." (S4)*

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For problems that require processing steps, ChatGPT helps users by accelerating the solution process. The AI tool is particularly effective in step-by-step procedural tasks, where users can follow the instructions or calculations provided by ChatGPT, leading to quicker and more efficient solutions. ChatGPT has limitations in solving numerical logic problems. As noted, it struggles with abstract or more complex problems that require logical reasoning or numerical manipulation beyond basic operations.

With the statement, "I noticed it gives more accurate results in procedural problems than in numerical logic problems," they highlighted that ChatGPT performs well in process-focused problems but provides more limited assistance in abstract thinking and logic problems. However, its utility is more limited in numerical logic problems and tasks that require complex abstract reasoning. Therefore, while ChatGPT is a valuable tool for improving efficiency and exploring different strategies, its support is most beneficial for problems that rely on clear, procedural steps rather than abstract logic or deep reasoning.

4.9. ChatGPT Usage

Initially, S3 faced challenges in using mathematical expressions with ChatGPT, particularly in the realm of pure mathematics. S3 reported that the feature allowing the upload of pictures of mathematical problems (such as photos of written questions) significantly improved their experience, making it easier to work with complex problems. This indicates that visual inputs (e.g., images of problems) facilitated a more efficient interaction with ChatGPT, offering a solution to the limitations they initially encountered.

S3 stated that they initially struggled with using mathematical expressions in ChatGPT, but over time, they learned to use the system more efficiently.

> *"At first, I had difficulty using mathematical expressions in ChatGPT. Honestly, I did not use it much for pure mathematics. However, later, the ability to upload pictures of questions from files made my work much easier." (S3)*

S3 specifically mentioned that the ability to upload photos of questions helped simplify the process of solving complex mathematical problems and positively contributed positive usability of the tool.

ChatGPT's ability to accept images of problems provided a valuable tool for overcoming initial difficulties with mathematical expressions, making the tool more accessible and useful for mathematical problem-solving.

S4 reported that they initially tried to solve problems independently, but when they encountered difficulties or got stuck, they turned to ChatGPT for assistance. This suggests that S4 relied on ChatGPT as a support tool rather than a primary solution source, indicating a more strategic use of the AI tool—when needed, to help overcome obstacles or gain alternative perspectives. Moreover, S4 used ChatGPT to explore different solution methods, showing that they used the tool not only for troubleshooting but also to broaden their problem-solving approach.

> *"At first, I tried to solve the problems on my own. When I could not solve them or got stuck, I used the ChatGPT application. Sometimes, I also used it to see different solution methods." (S4)*

S4's active participation in the problem-solving process allowed them to develop their thinking and analysis skills while also discovering new methods with ChatGPT's assistance. Thus, it can be concluded that ChatGPT provided an opportunity for users to maintain their independent thinking abilities while also enhancing their problem-solving competence by utilizing alternative solutions. Both S3 and S4's experiences highlight the supportive role of ChatGPT in problem-solving.

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4.10. Metacognitive Awareness

The use of ChatGPT by prospective mathematics teachers leads to positive outcomes in terms of metacognitive awareness. On the other hand, it could also potentially lead to psychological distress for the prospective mathematics teachers.

> *"ChatGPT is on a much higher level than I am. Naturally, if I compare every piece of information, I search for with the answers it provides, it could lead me to psychological collapse. From a metacognitive awareness perspective, of course, it has an effect. At times, I find my level of metacognitive awareness sufficient, while at other times, I think it needs improvement." (S3)*

S3 pointed out that encountering ChatGPT's high-level knowledge capacity led them to reassess their own knowledge level, which at times caused them to question their personal competence and experience psychological discomfort. However, they also acknowledged that this process offered an important opportunity for development in terms of metacognitive awareness. This suggests that, while ChatGPT could be a source of comparison, it could more effectively be viewed as a learning tool rather than a benchmark for self-assessment, thus deepening the user's metacognitive awareness. Prospective mathematics teachers are able to interpret ChatGPT's responses based on their own awareness and knowledge level.

> *"The way we interpret the solutions to questions in ChatGPT can change depending on our level of awareness." (S4)*

S4 emphasized that the solutions to questions in ChatGPT evaluated in unusual ways, depending on the individual's awareness level. It means that a person with higher metacognitive awareness is more likely to analyze the solutions provided by ChatGPT in greater depth and compare them with their own thinking processes.

5. Conclusion and Feedback

Prospective mathematics teachers reported that when they relied on ChatGPT to evaluate problem solutions, they did not engage in interpreting the results themselves, which they believed could dull their thinking skills.

> *"ChatGPT saves time, and it is quite useful for gaining ideas for assignments or studies, but this depends on the purpose of use. As humans, instead of thinking about the result of the information or the problem, we take the easy route by asking for artificial intelligence, which dulls our thinking skills. I think ChatGPT gives more detailed answers when questions are asked in English, because its primary language is English, and I have particularly noticed this with the way the questions are phrased." (S3)*

S3 noted that ChatGPT saves time and is useful for gaining ideas for assignments or studies, but its effectiveness can vary depending on the purpose of use. They also highlighted the importance of balancing the efficient use of artificial intelligence as a learning tool with the risk of dulling one's thinking abilities. Furthermore, S3 observed that when questions asked in English, ChatGPT tended to provide more detailed answers, suggesting that the AI's performance can be influenced by the language in which questions are asked.

Prospective teachers also mentioned that ChatGPT serves as a guiding tool during problem-solving processes but emphasized the importance of using the tool correctly.

> *"It can help us determine the approach to take in problem-solving. However, sometimes it provides incorrect solutions, or at times, I use it to find the quick answer without giving enough thought to the problem. This can hinder our development." (S4)*

S4 stated that ChatGPT sometimes provided incorrect solutions. Based on this data, we can conclude that when using ChatGPT as a guide, it is essential to keep the thinking process active and

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not to abandon the effort of solving problems. In the long run, this approach will be more beneficial for development.

In summary of these qualitative data, the analysis reveals that prospective mathematics teachers with higher metacognitive awareness tend to use ChatGPT more effectively and engage in deeper reflection during problem-solving tasks. These findings suggest that fostering higher levels of metacognitive awareness can improve the way prospective mathematics teachers utilize AI tools like ChatGPT, enhancing both their problem-solving abilities and their overall learning experience.

6. Discussion

ChatGPT provided various forms of support during the problem-solving process for different prospective mathematics teachers. S1 used ChatGPT primarily as a tool for verification and error correction, noting that it provided reassurance during complex, multi-step problems by meeting the need for validation. S2 highlighted the tool's usefulness in offering alternative perspectives, particularly in non-routine problems, and concluded that the quality of solutions varied based on the way the questions framed. This result shows that ChatGPT is not only a solution-providing tool but also an assistant that facilitates the development of solution paths for the user. According to S3's evaluation, ChatGPT saved time by providing fast and near-accurate information, while also supporting reasoning skills by highlighting aspects of problems that might otherwise overlooked. This demonstrates that ChatGPT contributes to both quick access to information and the thinking process. S4 emphasized ChatGPT's effectiveness in processing heavy problems, noting that it accelerated problem-solving, but its contributions were more limited for abstract logic problems. Karabıyık (2024) found that, according to teacher perspectives, ChatGPT's artificial intelligence algorithms and machine learning capabilities allowed it to analyze complex problems and generate rapid responses, helping solve questions in seconds. Similarly, Aleven et al. (2002) focused on how AI-based educational systems provided personalized feedback and practice opportunities and tracked student progress. In ElSayary's (2023) study, educators used ChatGPT as a supportive tool in teaching rather than as a direct learning tool. The findings of the present study align with these studies. The results indicate that ChatGPT's effectiveness varies depending on the type of problem.

Prospective teachers viewed ChatGPT as a supportive tool that facilitates the learning process in mathematics. S1 mentioned that ChatGPT was effective in solving complex problems and provided valuable feedback and alternative solutions, contributing to the process. S2 acknowledged that ChatGPT provided different perspectives, making processes easier, but also pointed out its limitations in high-level mathematics. S3, although initially struggling with mathematical expressions, had a positive experience due to the tool's photo upload feature, which helped them with mathematical problems. This feature supports those who struggle in pure mathematics. S4 used ChatGPT not only when stuck but also to explore different solution paths, which they found helpful in improving their thinking and analytical skills. Kojo et al.'s (2018) study found that factual and guiding questions promoted less student independence and active participation compared to exploratory questions. Dertli et al. (2024) concluded that while ChatGPT was capable of successfully guiding students through mathematical problem-solving processes, it fell short in encouraging deeper, higher-level thinking on a single problem. Despite its ability to generate reasonable answers, ChatGPT has shortcomings (Farrokhnia et al., 2024; Tabone & De Winter, 2023). However, it is also evident that ChatGPT has limitations in prompting higher-level thinking for both students and prospective mathematics teachers.

The analysis of the prospective mathematics teachers' responses to mathematical problems indicates that ChatGPT played a significant role in enhancing metacognitive awareness. S1, during the problem-solving process with ChatGPT, became more aware of their thinking processes, which led to a more strategic approach to questions, increasing their metacognitive awareness. S2 gained

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different perspectives through ChatGPT and was able to apply this skill to other types of problems. The emphasis on correct guidance enhancing metacognitive awareness highlights the importance of using the tool effectively. S3 used ChatGPT's information capacity to assess their own knowledge level, finding that while this process was sometimes challenging, it provided an opportunity for metacognitive growth. This can be seen as an opportunity for self-awareness and identifying areas for improvement. S4 pointed out that the level of awareness directly affected how ChatGPT's solutions interpreted, with individuals having higher levels of metacognitive awareness being able to analyze solutions more deeply. Overall, ChatGPT not only provided information but also helped deepen thinking processes and improve analysis skills, with metacognitive awareness playing a crucial role in determining the quality of the benefits gained from ChatGPT.

In line with these analyses, it found that prospective mathematics teachers with important levels of metacognitive awareness were able to effectively plan their cognitive and learning processes while using ChatGPT. They were able to develop their analytical skills and deepen their thinking. Furthermore, these prospective mathematics teachers expressed satisfaction and interest in ChatGPT, as it quickly solved problems and provided ease in different areas. These results align with the findings of the quantitative analysis. Prospective mathematics teachers with lower levels of metacognitive awareness, on the other hand, used ChatGPT primarily for verifying the accuracy of operations, error correction, and seeking answers to abstract or higher-level questions. They also evaluated ChatGPT's information capacity as a tool for reviewing their knowledge level, acknowledging that this process could sometimes be challenging. Based on these findings, it concluded that prospective mathematics teachers with high metacognitive awareness used ChatGPT as an effective tool in solving mathematics problems, developing more conscious strategies by enhancing their metacognitive awareness, and benefiting significantly from ChatGPT's rapid feedback in the problem-solving process. Their teaching practices may also reflect these experiences, allowing them to engage in problem-solving activities with more conscious and strategic approaches. On the other hand, prospective mathematics teachers with lower levels of metacognitive awareness tended to use ChatGPT more for evaluation and control purposes. This highlights how their metacognitive awareness levels shaped their attitudes and strategies toward using ChatGPT.

The prominent points regarding these themes, based on the responses of prospective mathematics teachers, are as follows:

Mathematics preservice teachers with higher metacognitive awareness levels demonstrated more systematic and reflective problem-solving approaches. These mathematics preservice teachers used ChatGPT not only as a tool for generating solutions, but also to validate the accuracy of their approaches. Mathematics preservice teachers with lower levels of metacognitive awareness, on the other hand, tended to take a more linear approach, often relying on ChatGPT to provide direct answers rather than engaging in deeper thought about the problem-solving process. When using ChatGPT to complete tasks, they were less likely to critically evaluate the logic behind the solutions generated by the AI. Mathematics preservice teachers with higher levels of metacognitive awareness also reported using ChatGPT as a way to explore alternative methods for solving problems. They viewed the AI as a collaborator who could suggest different solution strategies and foster a broader understanding of mathematical concepts. They appreciated the AI's ability to provide step-by-step solutions and explain concepts in a variety of ways. Those with higher metacognitive awareness also expressed greater satisfaction with the tool, particularly appreciating its ability to provide immediate feedback and clarify doubts. Teachers with lower metacognitive awareness, on the other hand, tended to use ChatGPT more passively. They were less likely to follow the steps of problem solving and often relied on ChatGPT without questioning their answers. In summary, the analysis suggests that potential mathematics preservice teachers with higher metacognitive awareness tend to use ChatGPT more effectively and engage in deeper reflection during problem solving tasks. They adopt

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a more critical, self-regulated approach when using the tool and often exploit its potential to enhance understanding and explore alternative solution strategies. This resulted in a high inter-rater reliability score of 90%. To summarize the findings, metacognitive awareness significantly influences perceptions of ChatGPT use among potential mathematics preservice teachers, particularly in terms of perceived effectiveness and satisfaction. Regression analysis showed a positive relationship between metacognition, an opportunity for self-awareness, and identifying areas for improvement. Overall, ChatGPT not only provided information but also helped deepen thinking processes and improve analysis skills, with metacognitive awareness playing a crucial role in determining the quality of the benefits gained from ChatGPT.

In line with these analyses, it was found that prospective mathematics teachers with high levels of metacognitive awareness were able to effectively plan their cognitive and learning processes while using ChatGPT. They were able to develop their analytical skills and deepen their thinking. Furthermore, these prospective mathematics teachers expressed satisfaction and interest in ChatGPT, as it quickly solved problems and provided ease in many areas. These results align with the findings of the quantitative analysis. Prospective mathematics teachers with lower levels of metacognitive awareness used ChatGPT primarily to verify the accuracy of operations, correct errors, and seek answers to abstract or higher-level questions. Based on these findings, it can be concluded that prospective mathematics teachers with high metacognitive awareness used ChatGPT as an effective tool in solving mathematics problems, developing more conscious strategies by enhancing their metacognitive awareness, and benefiting significantly from ChatGPT's rapid feedback in the problem-solving process. It is predicted that these experiences may also be reflected in their teaching practices, allowing them to engage in problem-solving activities with more conscious and strategic approaches. On the other hand, prospective mathematics teachers with lower levels of metacognitive awareness tended to use ChatGPT more for evaluation and control purposes. This highlights how their metacognitive awareness levels shaped their attitudes and strategies toward using ChatGPT. Artificial intelligence can present information from various sources (Rudolph et al., 2023). This allows prospective mathematics teachers to view AI as a valuable information source to support their learning processes and quickly adapt to scientific innovations. However, it should not be overlooked that while AI tools can provide accurate and up-to-date information, they may also give incorrect or incomplete information. Seden and Broutin's study emphasizes the importance of this approach.

7. Recommendations

The findings of this study highlight the critical role of metacognitive awareness in learning processes supported by AI tools. Based on these results, recommendations are made for educators and policymakers: The role of AI tools such as ChatGPT in education should investigated on a broader scale. More research is needed to investigate how these tools are effectively integrated into teaching and learning processes across disciplines and educational levels. This research should aim to understand not only the potential benefits of AI tools, but also the challenges that may arise in their implementation and use. Professional development opportunities should provide teachers with a better understanding of how AI tools such as ChatGPT are used to support and enhance teaching and learning. Based on the findings of this study, it is important to develop strategies for effectively integrating AI-enhanced learning tools into educational environments. These strategies should address how to use AI to support metacognitive development and how to balance AI use with traditional teaching methods. AI tools should not replace the teacher but rather complement the learning process by providing personalized support and encouraging a deeper understanding of the content. Educators and policymakers should implement programs and develop educational materials that help students and potential mathematics teachers develop metacognitive strategies. This may include integrating activities that encourage self-regulation, reflection, and critical thinking into the

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curriculum. Teaching practices that encourage students to monitor their thought processes, evaluate their strategies, and adjust their approaches can promote metacognitive awareness. Educators should encourage students and potential mathematics teachers to engage critically with AI tools. Students should teach questions and validate information provided by AI systems rather than simply accepting AI-generated solutions. Future research should investigate how AI tools such as ChatGPT affect the development of metacognitive skills over time. In conclusion, this study contributes to understanding the potential of AI tools such as ChatGPT in education. It highlights the role of metacognitive awareness in facilitating effective learning with these tools.

8. Conclusion

ChatGPT provided various forms of support during the problem-solving process for different prospective mathematics teachers. S1 used ChatGPT primarily as a tool for verification and error correction, noting that it provided reassurance during complex, multi-step problems by meeting the need for validation.

This study examined the impact of prospective mathematics teachers' metacognitive awareness levels on their use of ChatGPT during problem-solving processes. The results of the quantitative analysis revealed that the teachers' metacognitive awareness levels influenced their perceptions of the effectiveness of ChatGPT, as well as their satisfaction and engagement with the tool. Qualitative data supported these findings.

This study finds that; ChatGPT is not only a solution-providing tool but also an assistant that facilitates the development of solution paths for the user; ChatGPT's effectiveness in processing-heavy problems, noting that it accelerated problem-solving, but its contributions were more limited for abstract logic problems; ChatGPT, when used with appropriate strategies in educational contexts, can support prospective mathematics teachers by enhancing their metacognitive awareness and problem-solving skills; Prospective teachers viewed ChatGPT as a supportive tool that facilitates the learning process in mathematics; ChatGPT has limitations in prompting higher-level thinking for both students and prospective mathematics teachers.

In conclusion, the findings of this study suggest that prospective mathematics teachers effectively used ChatGPT in their problem-solving processes, enhancing their metacognitive awareness and developing more conscious strategies. The rapid feedback provided by ChatGPT contributed significantly to the problem-solving process. These experiences are expected to influence prospective mathematics teachers' teaching practices, potentially leading to more strategic and conscious approaches to problem-solving activities.

Declarations

Conflicts of Interest. The authors declare no conflict of interest.

References

Abdelhalim, S. M. (2024). Using ChatGPT to promote research competency: English as a Foreign Language undergraduates' perceptions and practices across varied metacognitive awareness levels. *Journal of Computer Assisted Learning*, 40(31), 31261-1275. https://doi.org/10.111/jcal.12948

Akın, A., Abacı, R. And Çetin, B. (2007). The validity and reliability of the Turkish version of the Metacognitive Awareness Inventory, *Educational Sciences Theory & Practice*,7(2), 671-678. https://doi.org/10.17359/aced.2015611167

Aleven, V., & Koedinger, K. R. (2002). An effective metacognitive strategy: learning by doing and explaining with a computer-based cognitive tutor. Cognitive Science, 26(2), 147-179. https://doi.org/10.1207/s15516709cog2602_1

Anggo, M., Masi, L., & Haryani, M. (2021). The Use of Metacognitive Strategies in Solving Mathematical Problems. Journal of Physics: Conference Series, 1752. https://doi.org/10.1088/1742-6596/1752/1/012078.

Anggo, M., Masi, L., & Haryani, M. (2021). The use of metacognitive strategies in solving mathematical problems. Journal of Physics: Conference Series. https://doi.org/10.1088/1742-6596/1752/1/012078

Asy'ari, M., Ikhsan, M. ve Muhali. (2019). The effectiveness of inquiry learning model in improving prospective teachers' metacognition knowledge and metacognition awareness. *International Journal of Instruction.* 12 (2).455-470. https://doi.org/10.29333/iji.2019.12229a

Balçıkanlı, C. (2011). Metacognitive awareness inventory for teachers (MAIT). Electronic Journal of Research in Educational Psychology, 9(3), 1309-1332. DOI:10.25115/ejrep.v9i25.1620

Battista, A., & Torre, D. (2023). Mixed methods research designs. Medical Teacher, 45, 585 - 587. https://doi.org/10.1080/0142159X.2023.2200118

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M. ve Rumble, M. (2010). Defining 21st century skills. Assessment and teaching of 21st century skills draft white paper. The University of Melbourne. https://doi.org/10.1007/978-94-007-2324-5_2

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brophy, J. (1986). Teaching and learning mathematics: Where research should be going. Journal for Research in Mathematics Education, 17, 323–346. https://www.jstor.org/stable/i230297

Butterfield, E. C., Albertson, L. R., & Johnston, J. C. (1995). On making cognitive theory more general and developmentally pertinent. *Memory performance and competencies: Issues in growth and development*, 181-206.

Campbell, J. L., Quincy, C., Osserman, J. & Pedersen, O. K. (2013). Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement. *Sociological methods & research* 42(3), 294-320. https://doi.org/10.1177/0049124113500

Campione, J. C., Brown, A. L., & Connell, M. L. (1989). Metacognition: On the importance of understanding what you are doing. In R. I. Charles & E. A. Silver (Eds.), The teaching and assessing of mathematical problem solving (pp. 93-114). Reston, VA: Lawrence Erlbaum Associates.

Cardella-Elewar, M. (1995). Effects of Metacognitive Instruction on Low Achievers in Mathematical Problems. *Teaching and Teacher Education, 11(1),* 81-95. https://doi.org/10.1016/0742-051X(94)00019-3

Culaste, I. C. (2011). Cognitive skills of mathematical problem solving of grade 6 children. *International Journal of Innovative Interdisciplinary Research, 1*(1), 120-125. Cognitive Skills of Mathematical Problem Solving of Grade 6 Children

Cummins, D. D. (1992). Role of analogical reasoning in the induction of problem categories. *Journal of Experimental Psychology: Learning, Memory and Cognition, 18*(5), 1103-1124. DOI: 10.1037/0278-7393.18.5.1103

Cunningham, I. (2020). A new educational paradigm for the 21st century. *Development and Learning in Organizations, 34*(2), 5-7. https://doi.org/10.1108/DLO-10-2019-0253

Daher, W, Gierdien, F (2024).Use of Language By generative AI Tools in Mathematical Problem Solving: The Case of ChatGPT. African Journal Of Research in Mathematics Science and Technology Education, 10.1080/18117295.2024.2384676

Dao, X.-Q., Le, N.-B., Phan, X.-D., & Ngo, B.-B. (2023). Can ChatGPT pass the Vietnamese National High School graduation examination? https:// doi. org/ 10. 48550/ ARXIV. 2306. 09170

Davidson, J. E., & Sternberg, R. J. (1998). Smart problem solving: How metacognition helps. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 47–68). Lawrence Erlbaum Associates Publishers.

Defi, S., Haryono, Y., & Jufri, L. (2022). Metacognitive Analysis of Students in Solving Mathematics Problem. Al Khawarizmi: Jurnal Pendidikan dan Pembelajaran Matematika. https://doi.org/10.22373/jppm.v6i2.15420.

Demirel, M., & Dagyar, M. (2016). Effects of problem-based learning on attitude: A meta-analysis study. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(8), 2115–2137. https://doi.org/10.12973/eurasia.2016.1293a

Dengiz, Y. (2023). Yapay zekanın öğretmen eğitimi üzerindeki yenilikçi etkileri [Yüksek lisans tezi]. Muğla Sıtkı Koçman Üniversitesi, Muğla.

Dertli, G. Z., Korkmaz Güler, N. & Yıldız, B. (2024). Chatgpt'nin bir informal öğrenme asistanı olarak problem çözme sürecinde öğrencilere rehberlik etmesinin incelenmesi. *İnformal Ortamlarda Araştırma Dergisi, 9*(1), 33-61. https://dergipark.org.tr/tr/pub/jrinen/issue/85781/1415967

Desoete, A., & Veenman, M. (2006). Metacognition in mathematics: Critical issues on nature, theory, assessment and treatment. In A. Desoete & M. Veenman (Eds.), *Metacognition in mathematics education* (pp. 1–10). New York: Nova Science Publishers.

Desoete A. (2008). Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get. *Metacognition Learning, (3)3,* 189-206. DOI: 10.1007/s11409-008-9026-0

De Ocampo-Acero, V. C., Sanchez-Javier, E. J., & Ocampo-Castro, H. C. (2015). Principles of Teaching I. *Metro Manila, Philippines: Rex Book Store Inc.*

Dwivedi, Y. K., Kshetri, N., Hughes, L., Slade, E. A., Jeyaraj, A., Kar, A. K., Baabdullah, A. M., Koohang, A., & Wright, R. (2023). "So what if ChatGPT wrote it?" Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy. *International Journal of Information Management, 71*, Article 102642. https://doi.org/10.1016/j.ijinfomgt.2023.102642

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process? *Educational Research Review, 1*, 3–14. https://doi.org/10.1016/j.edurev.2005.11.001

Efklides, A. (2001). Metacognitive experiences in problem solving: Metacognition, motivation, and self-regulation. In A. Efklides, J. Kuhl, & R. M. Sorrentino (Eds.), Trends and prospects in motivation research (pp. 297-323). Dordrecht, The Netherlands: Kluwer.

Efklides, A. (2009). The new look in metacognition: From individual to social, from cognitive to affective. In C. B. Larson (Ed.), *Metacognition: New Research Developments* (pp 137-151). New York: Nova Science Publishers.

ElSayary, A. (2023). An investigation of teachers' perceptions of using ChatGPT as a supporting tool for teaching and learning in the digital era. *Journal of Computer Assisted Learning, 40*, 931- 945. https://doi.org/10.1111/jcal.12926

Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2024). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, *61*(3), 460- 474. https://doi.org/10.1080/14703297.2023.2195846

Felix, C. (2020). "The role of the teacher and AI in education" in *International perspectives on the role of Technology in Humanizing Higher Education Innovations in higher education teaching and learning*. eds. E. Sengupta, P. Blessinger and M. S. Makhanya, vol. *33* (Bingley: Emerald Publishing Limited), 33–48.

Flavell, J. H. (1976). Metacognitive aspects of problem solving. L. B. Resnick (Ed.). The nature of intelligence (s. 231-235). Hillsdale, NJ: Lawrence Erlbaum.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, *34(1),* 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Garofalo, J., & Lester, F. K. (1985). Metacognition, cognitive monitoring, and mathematical performance. Journal of Research in Mathematics Education, 16, 163–176. https://www.jstor.org/stable/748391

Goldberg, P. D., & Bush, W. S. (2003). Using Metacognitive skills to improve 3rd graders' math problem solving. *Focus on Learning Problems in Mathematics, 5(10),* 29-48. DOI: 10.46328/ijres.1594

Görgülü, Arı, A., Hayır Kanat, M. (2020). Covid-19 (koronavirüs) üzerine öğretmen adaylarının görüşleri. Van Yüzüncü Yıl Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Salgın Hastalıklar Özel Sayısı, 459492. https://dergipark.org.tr/tr/download/article-file/1210688

Guo, K., Zhong, Y., Li, D., & Chu, S. K. W. (2023). Effects of chatbot-assisted in-class debates on students' argumentation skills and task motivation. *Computers in Education, 203*, Article 104862. https://doi.org/10.1016/j.compedu.2023.104862.

Hacker, D. J. (1998). Metacognition: Definitions and empirical foundations. In Metacognition in educational theory and practice (pp. 1-23). (D. J. Hacker, J. Dunlosky & A. C. Graesser Eds.), Mahwah, NJ: Erlbaum.

Hamarat, E. (2019). *21. Yüzyıl becerileri odağında Türkiye'nin eğitim politikaları.* Ankara: SETA Siyaset, Ekonomi ve Toplum Araştırmaları Vakfı.

Hegarty, M., Mayer, R. E., & Monk, C. A. (1995). Comprehension of Arithmetic Word Problems: A Comparison of Successful and Unsuccessful Problem Solvers. Journal of Educational Psychology, 87, 18-32. https://doi.org/10.1037/0022-0663.87.1.18

Ifenthaler, D. (2012). Determining the effectiveness of prompts for self-regulated learning in problem-solving scenarios. *Educational Technology & Society*, *15(1),* 38–52. www.academia.edu/2683498/Determining_the_effectiveness_of_prompts_for_self_regulated_learning_in_problem_solving_scenarios

Kapa, E. (2001). A metacognitive support during the process of problem solving in a computerized environment. *Educational Studies in Mathematics, 47*(3), 317-336.

Karabıyık, Ü. (2024). Matematik eğitiminde yenilikçi bir yaklaşım: ChatGPT'nin rolü. Uşak Üniversitesi Eğitim Araştırmaları Dergisi, 10(1), 26-46. https://doi.org/10.29065/usakead.1393487

Kashefi, A., & Mukerji, T. (2023). ChatGPT for Programming Numerical Methods. ArXiv,abs/2303.12093. https://doi.org/10.48550/arXiv.2303.12093.

Kasneci, E., Seßler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., …, & Kasneci, G. (2023). *ChatGPT for good? On opportunities and challenges of large language models for education*. https://doi.org/10.35542/osf.io/5er8f

Kojo, A., Laine, A., & Naveri, L. (2018). How did you solve it?–Teachers' approaches to guiding mathematics problem solving. LUMAT: *International Journal on Math, Science and Technology Education, 6*(1), 22- 40. DOI:10.31129/LUMAT.6.1.294

Koriat,A. (2007). Metacognition and consciousness. In: Zelazo,P.D., Moscovitch, M.,Thompson,E. (Eds.), The Cambridge Handbook of Consciousness. Cambridge University Press, New-York, pp.289–325.

Kramarski, B. (2008). Promoting teachers' algebraic reasoning and self-regulation with metacognitive guidance. Metacognition and Learning, 3(2), 83–99. doi.org/10.1007/s11409-008-9020-6

Lee, D., & Yeo, S. (2022). Developing an AI-based chatbot for practicing responsive teaching in mathematics. *Computers in Education, 191*, Article 104646. https://doi.org/10.1016/j.compedu.2022.104646. article number.

Leng, L. (2024). Challenge, integration, and change: ChatGPT and future anatomical education. *Medical Education Online, 29*(1). https://doi.org/10.1080/10872981.2024.2304973

Lesh, R. and Zawojewski, J.S. (2007) Problem Solving and Modeling. In: Lester, F., Ed., Second Handbook of Research on Mathematics Teaching and Learning, Information Age Publishing, Greenwich, CT, 763-802.

Lester, F. J. & Kehle, P. E. (2003). From problem solving to modeling: The evolution of thinking about research on complex mathematical activity. In R. Lesh & H. M. Doerr (Eds.), Beyond constructivism: Models and modeling perspectives on mathematics teaching, learning, and problem solving. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lester, F. K. (1982). Building bridges between psychological and mathematics education research on problem solving. In F. K. Lester & J. Garofalo (Eds.), Mathematical problem solving (pp. 55–85). Philadelphia: The Franklin Institute Press.

Lim, W. M., Gunasekara, A., Leigh Pallant, J., Pallant, J. A., & Pechenkina, E. (2023). Generative AI and the future of education: Ragnar¨ok or reformation? A paradoxical perspective from management educators. *International Journal of Management in Education, 21*(2), Article 100790. https://doi.org/10.1016/j. ijme.2023.100790. article number

Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. Thinking Skills and Creativity, 45, 101069. https://doi.org/10.1016/j.tsc.2022.101069

Li, Y., Sha, L., Yan, L., Lin, J., Rakovic, M., Galbraith, K., Lyons, K., Gaˇsevi´c, D., & Chen, G. (2023). Can large language models write reflectively. *Computers & Education: Artificial Intelligence, 4*, Article 100140. https://doi.org/10.1016/j.caeai.2023.100140

Lomax, R. G. ve Hahs-Vaughn, D. L. (2012). An Introduction to Statistical Concepts Third Edition, Routledge Taylor & Francis Group, USA.

Lucangeli, D., Tressoldi, P. E., & Cendron, M. (1998). Cognitive and metacognitive abilities involved in the solution of mathematical word problems: Validation of a comprehensive model. *Contemporary Educational Psychology, 23*(3), 257–275. https://doi.org/10.1006/ceps.1997.0962

Mayer, R.E. (1998). Cognitive, metacognitive and motivational aspects of problem solving. *Instructional Science, 26*, 49-63. doi.org/10.1023/A:1003088013286

Miles, M. B. & Huberman, A. M. (1994). Qualitative Data Analysis. Thousand Oaks, Sage Publication.

Mumford, M. D., Martin, R., & Elliott, S. N. (2019). Creative thinking processes: Managing innovative efforts. In *Oxford research Encyclopedias*. Oxford University Press. https://doi.org/10.1093/acrefore/9780190224851.013.172

Mumford, M. D., Mobley, M. I., Reiter-Palmon, R., Uhlman, C. E., & Doares, L. M. (1991). Process analytic models of creative capacities. *Creativity Research Journal, 4* (2), 91–122. https://doi.org/10.1080/10400419109534380

National Council of Teachers of Mathematics [NCTM], (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM. https://doi.org/10.1109/ISCMI47871.2019.9004411

Nayıroğlu, B. & Tutak, T. (2024). Matematik öğretiminde yapay zekanın rolü: Öğretimde kullanılan araçların incelenmesi. *Turkish Journal of Education Studies, 11*(1). doi.org/10.33907/turkjes.1415591

Noy, S., & Zhang, W. (2023). Experimental evidence on the productivity effects of generative artificial intelligence. *Science, 381*(6654), 187–192. https://doi.org/10. 1126/science.adh2586.

Panaoura, A., & Philippou, G. (2007). The developmental change of young pupils' metacognitive ability in mathematics in relation to their cognitive abilities. *Cognitive Development*, *22*(2), 149-164. https://doi.org/10.1016/j.cogdev.2006.08.004

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (4th ed.). Sage.

Plevris, V., Papazafeiropoulos, G., & Ríos, A. (2023). Chatbots put to the test in math and logic problems: A preliminary comparison and assessment of ChatGPT-3.5, ChatGPT-4, and Google Bard. ArXiv, abs/2305.18618. https://doi.org/10.48550/arXiv.2305.18618

Polya, G. (1957). *How to solve it: A new aspect of mathematical method* (2nd ed.), Princeton, NJ: Princeton University Press.

Puryear, J. S. (2016). Inside the creative sifter: Recognizing metacognition in creativity development. *The Journal of Creative Behavior*, *50*(4), 321-332. DOI: 10.1002/jocb.80

O'Malley, J. M., & Chamot, A. U. (1990). Learning strategies in second language acquisition. Cambridge University Press.

Rawas, S. (2023). ChatGPT: Empowering lifelong learning in the digital age of higher education. *Education and Information Technologies, 29*, 6895-6908. https://doi.org/10.1007/s10639-023-12114-8

Reeve, R. A., & Brown, A. L. (1985). Metacognition reconsidered: Implications for intervention research. *Journal of Abnormal Child Psychology,* 13(3), 343–356. https://doi.org/10.1007/BF00912721

Remoto, J. (2023). ChatGPT and other AIs: Personal relief and limitations among mathematics-oriented learners. Environment and Social Psychology. https://doi.org/10.54517/esp.v9i1.1911.

Rhodes, M. G. (2019). Metacognition. *Teaching of Psychology, 46*(2), 168–175. https://doi.org/10.1177/0098628319834381

Rudolph, J., Tan, S., & Tan, S. (2023). *ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?* Journal of Applied Learning and Teaching, 6(1). https://doi.org/10.37074/jalt.2023.6.1.9

Schoenfeld, A. H. (1983). Episodes and executive decisions in mathematical problem solving. In R. Lesh & M. Landau (Eds.), Acquisition of mathematics concepts and processes (pp. 345– 395). New York: Academic Press.

Schoenfeld, A. (1985). Mathematical Problem Solving. San Diego, CA: Academic Press

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.), Handbook of research on mathematics teaching and learning (pp. 334–370). New York: Macmillan.

Schraw, G. & Dennison, R. S. (1994). "Assesing metacognitive awareneess". *Contemporary Educational Psychology*,19,460-475. https://doi.org/10.1006/ceps.1994.1033

Shanahan, T. (1992). Reading comprehension as a conversation with an author. In: M. Presley, K. R. Harris & J. T. Guthrie (Eds.), Promotion Academic Competence and Literacy in School. San Diego, CA: Academic Press.

Shodikin, A., Nurkumala, S., & Sumarno, W. (2022). Student Metacognition in Mathematics Problem Solving on Set Materials. Mathline: Jurnal Matematika dan Pendidikan Matematika. https://doi.org/10.31943/mathline.v7i2.297.

Silver, E. A. (1982). Knowledge organization and mathematical problem solving. In F. K. Lester & J. Garofalo (Eds.), Mathematical problem solving (pp. 15–25). Philadelphia: Franklin Institute Press.

Şekeroğlu, B., Dimililer, K., & Tuncal, K. (2019). Artificial intelligence in education: Application in student performance evaluation. *Dilemas Contemporáneos: Educación, Política y Valores, 7(*1), 1-21. https://doi.org/10.46377/dilemas.v28i1.1594

Tabone, W., ve De Winter, J. (2023). Using ChatGPT for human–computer interaction research: a primer. *Royal Society Open Science*, *10*(9), 231053. https://doi.org/10.1098/rsos.231053

Tabuyo, A. T. (2024). Metacognition and Mathematical Problem-Solving Performance of Pre-Service Teachers. Pegem Journal of Education and Instruction, 14(4), 474-480. doi.org/10.47750/pegegog.14.04.45

Terwiesch, C. (2023). *Would Chat GPT3 Get a Wharton MBA? A Prediction based on its performance in the Operations Management course*. Mack Institute for Innovation Management at the Wharton School. https://mackinstitute.wharton.upenn.edu/wp-content/uploads/2023/01/Christian-Terwiesch-Chat-GTP.pdf

The Guardian. (2023). ChatGPT reaches 100 million users two months after launch. *The Guardian*. https://www. theguardian.com/technology/2023/feb/02/chatgpt-100-million-users-open-ai-fastest-growing-app

Treffinger, D. J., Selby, E. C., & Isaksen, S. G. (2008). Understanding individual problem-solving style: A key to learning and applying creative problem-solving. *Learning and Individual Differences, 18*(4), 390–401. https://doi.org/10.1016/j.lindif.2007.11.007

Ünsever, Ö. & Kutluca, A. Y. (2024). Okul öncesi öğretmenlerinin düşünme becerileri eğitimine ilişkin görüşlerinin öğretmeye yönelik üstbilişsel farkındalık düzeyleri açısından incelenmesi. Trakya Eğitim Dergisi, 14(2), 609-627. doi.org/10.24315/tred.1360976

Urban, M., Dechterenko, F., Lukavsky, J., Hrabalova, V., Svacha, F., Brom, C. & Urban, K. (2024). ChatGPT improves creative problem-solving performance in university students: An experimental study. Computers & Education, 215. https://doi.org/10.1016/j.compedu.2024.105031

Van Vaerenbergh, S., & Pérez-Suay, A. (2022). A classification of artificial intelligence systems for mathematics education. In A. B. Aslan (Ed.), *Mathematics education in the age of artificial intelligence: How artificial intelligence can serve mathematical human learning* (pp. 89-106). Springer. https://doi.org/10.1007/978-3-030-94852-3_6

Van Der Stel, M., & Veenman, M. V. J. (2008). Relation between intellectual ability and metacognitive skillfulness as predictors of learning performance of young students performing tasks in different domains. *Learning and Individual Differences, 18*(1), 128–134. https://doi.org/10.1016/j.lindif.2007.08.003

Verschaffel, L. (1999). Realistic mathematical modelling and problem solving in the upper elementary school: Analysis and improvement. In J. H. M. Hamers, J. E. H. Van Luit, & B. Csapo (Eds.), Teaching and learning thinking skills. Contexts of learning (pp. 215–240). Lisse: Swets & Zeitlinger. https://core.ac.uk/download/pdf/93015312.pdf

Vo, V. A., Li, R., Kornell, N., Pouget, A., & Cantlon, J. F. (2014). Young Children Bet on Their Numerical Skills: Metacognition in the Numerical Domain. Psychological Science, 25(9), 1712-1721. https://doi.org/10.1177/0956797614538458

Walker, A., & Leary, H. (2009). A problem based learning meta analysis. *The Interdisciplinary Journal of Problem-based Learning, 3*(1), 12–43. https://doi.org/10.7771/ 1541-5015.1061

Walker, A., & Leary, H. (2009). A problem based learning meta analysis. *The Interdisciplinary Journal of Problem-based Learning, 3*(1), 12–43. https://doi.org/10.7771/ 1541-5015.1061

Wenden, A. (1991). Learner strategies for learner autonomy. London: Prentice Hall International.

Wenden, A. (1999). Special issue on metacognitive knowledge and beliefs in language learning. System, 27(4), 435-441. https://doi.org/10.1016/S0346-251X(99)00043-3

Wilkins, L.S. (1997). Fostering independence with metacognition. In L. Dickinson (Ed), Autonomy 2000 The development of learning independence in language learning, Bangkok: King Mongkut's Institute of Technology Thonburi.

William, S., & Maat, S. (2020). Understanding Students' Metacognition in Mathematics Problem Solving: A Systematic Review. International Journal of Academic Research in Progressive Education and Development, 9, 115-127. https://doi.org/10.6007/IJARPED/V9-I3/7847.

Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). Sage

Zan, R. (2000). A metacognitive ınterventıon in mathematics at university level. *International Journal of Mathematical Education in Science & Technology, 31(1),* 143-151. DOI: 10.1080/002073900287462

Zhai, X. (2022). *ChatGPT user experience: Implications for education*. SSRN. Retrieved from https://papers.ssrn. com/sol3/papers.cfm?abstract_id=4312418

Zhu, C., Jiutong Sun, M., Luo, J., Li, T. & Wang, M. (2023). How to harness the potential of ChatGPT in education? Knowledge Management & E-Learning, 15(2), 133-152. https://doi.org/10.34105/j.kmel.2023.15.008

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