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Research Article

Integrating artificial intelligence in education: How pre-service mathematics teachers use ChatGPT for 5E lesson plan design

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This study examines the utilization of ChatGPT by pre-service mathematics teachers during the 5E lesson planning process, focusing on its affordances, constraints, and potential as a supportive tool in education. Twenty-one pre-service mathematics teachers, selected through purposive sampling, participated in the study. Data collection included 5E lesson plans, ChatGPT interaction transcripts, and participant interview responses, which were analyzed using content analysis within the framework of the instrumental approach. ChatGPT was utilized for lesson planning across categories addressing instructional and pedagogical content, encompassing fourteen distinct purposes distributed across the stages of the 5E lesson plan design: five for the engagement stage, five for exploration, six for explanation, five for elaboration, and four for evaluation. Interviews revealed both the affordances and constraints of ChatGPT, noting that while it provided creative and practical ideas, it often required well-structured prompts to yield relevant results. Despite its challenges, participants expressed their intention to use ChatGPT professionally to enhance lesson planning and instructional practices. ChatGPT is a valuable yet evolving tool for fostering innovation and efficiency in mathematics education, with implications for teacher training and future research on AI integration.

Keywords: Artificial intelligence; ChatGPT; 5E learning model; Lesson plan; Mathematics education

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1. Introduction

Technology plays a key role in innovation and development across various fields, reshaping traditional practices and improving efficiency. As in other disciplines, technology has brought about significant changes, advancements, and transformations in education. Artificial Intelligence [AI], one of the latest technological innovations, has been driving significant progress in education (De Angelis et al., 2023). AI is defined as the ability of machines to exhibit behaviors similar to human actions and as technologies that imitate human-like traits such as reasoning, learning, and decision-making. By introducing new experiences in the teaching and learning process, AI customizes these experiences, promoting equal opportunities in education (Tashtoush et al., 2022).

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It is anticipated that AI's impact on education will continue to grow significantly in the coming years (MacDowell & Korchinsk, 2023).

AI models generate text in a remarkably human-like manner, simulating the output of human intelligence (Bishop, 2021). These AI technologies are called large language models or AI models capable of generating human-like language. Due to their success in producing human-like language, these models are widely used in various fields, such as content creation, translation, and text summarization (Tate et al., 2023). Pre-trained with natural language processing capabilities, AI tools equipped to generate human-like responses and engagement in conversations are commonly known as chatbots (Thorp, 2023; van Dis et al., 2023). Chatbots are designed to handle tasks such as posing mathematical questions, evaluating examples, and solving problems (van Dis et al., 2023). Users can interact with these tools by asking follow-up questions, seeking clarifications, or challenging the generated responses' validity, transforming the prompt-response interaction into a dynamic dialogue (Rospigliosi, 2023). Commonly used chatbots include natural language models such as ChatGPT and Google Gemini, with ChatGPT being the most widely used (Tate et al., 2023). ChatGPT is regarded as the most advanced chatbot due to its ability to generate natural text in real time and continuous improvement (Rudolph et al., 2023).

Integrating ChatGPT into education is deliberate and systematic (Laborde, 2002), emphasizing the importance of framing their use within responsible guidelines (Tapan-Broutin, 2024). The potential impact of AI models like ChatGPT on the teaching profession can be seen as promising. Examining how pre-service and in-service teachers utilize ChatGPT can provide deeper insights into its role in teaching and teacher education (Pişkin Tunç, 2024). Moreover, for pre-service and in-service teachers to effectively utilize technology during educational activities, they must possess sufficient knowledge and skills regarding the interaction between technology, pedagogy, and content (Angeli & Valanides, 2009). In addition to classroom activities, teachers' preparation before lessons plays a critical role in the learning and teaching process (Lim et al., 2018). Lesson plans, as the cornerstone of pre-lesson preparation, are essential components of effective teaching (Backfish et al., 2020). For effective mathematics instruction, teachers need to design and implement well-structured lesson plans (Lim et al., 2018). One widely adopted instructional design framework that supports this need is the 5E Learning Model, developed by Bybee et al. (2006). This model consists of five phases: Engagement, Exploration, Explanation, Elaboration and Evaluation, each of which has a different pedagogical function in the learning process. The Engagement phase aims to capture students' attention and activate their prior knowledge related to the topic. In the Exploration stage, learners engage in hands-on or inquiry-based activities to investigate concepts independently or collaboratively. The Explanation stage focuses on formalizing understanding, during which teachers introduce targeted content and address misconceptions. In the Elaboration phase, students apply the knowledge they have acquired to new situations, promoting deeper learning and knowledge transfer. Finally, the Evaluation stage includes both formative and summative assessments to measure student understanding and learning outcomes. In the present study, this model served as a guiding framework to examine and categorize the ways in which pre-service mathematics teachers [PMTs] utilized ChatGPT throughout the lesson planning process. In the present study, the 5E Learning Model served as a guiding framework to analyze how PMTs integrated ChatGPT into their lesson planning processes. By aligning their instructional decisions with the phases of the model, participants were able to structure their lessons in a coherent and pedagogically meaningful way. In this context, ChatGPT acted as a dynamic support tool, generating ideas in the Engagement phase, facilitating content clarification in the Explanation phase, and offering suggestions for real-world applications in the Elaboration phase. Additionally, it assisted in anticipating possible student responses and misconceptions, which teachers could address in advance. As such, AI tools like ChatGPT have the potential to enhance the quality of lesson planning by supporting teachers in designing more interactive, adaptive, and student-centered learning experiences (Lo, 2023; Trust et al., 2023).

Integrating a tool into educational practices requires its use to be well-defined and internalized by users to ensure its practical application (Trouche & Drijvers, 2008). Investigating the impact of ChatGPT usage by pre-service and in-service teachers on their professional practices can help reveal the role of ChatGPT in learning and educational environments. The use of ChatGPT in education has sparked diverse opinions and debates among educators due to its potential benefits and drawbacks (Tapan-Broutin, 2023; Wardat et al., 2023). Therefore, it is crucial to understand the advantages, disadvantages, and limitations of ChatGPT use in educational settings (Tashtoush et al., 2022). In teaching and learning, leveraging ChatGPT's strengths effectively while taking precautions against potential challenges is essential (Tashtoush et al., 2022). This study examines how PMTs' interactions with ChatGPT are reflected in their lesson plans. Building upon this background, the present study aims to examine how pre-service mathematics teachers utilize ChatGPT during the 5E lesson planning process, exploring both the purposes of use and their perceptions regarding its instructional affordances and constraints.

2. Theoretical Framework

The interaction between humans and technology is grounded in cognitive and perceptual processes. Tools' influence on human activities and human's influence on tools has led to the development of the Instrumental Genesis Theory (Rabardel, 1995; 1999). This theory is shaped by insights drawn from Vygotsky's perspectives on tool usage. Instrumental Genesis Theory is widely applied to examine technology-assisted mathematics education (Artigue, 2002; Guin, 1999; Ruthven, 2002; Trouche, 2004).

A tool is any object that supports a user in performing a task. For a tool to transform into an instrument, the individual must possess mental schemas that influence their ability to use it effectively and understand in which contexts it can be applied (Artigue, 2002). Instrumental genesis depends on the tool's limitations and potential, the user's readiness and individual characteristics. In other words, not every tool becomes an instrument for every individual. Consequently, instrumental genesis is a bidirectional, deeply interconnected, and simultaneous process that is difficult to separate into distinct components (Hoyles & Noss, 2004).

Instrumental transformation can be interpreted as how individuals turn a tool into a mathematical instrument during problem-solving (Trouche, 2004). Instrumentalization refers to perceiving a tool or object to achieve one's objectives. Specifically, the study emphasized the instrumentation process over the instrumentalization process, as the instrumental approach prioritizes examining both anticipated and unanticipated impacts of artifacts on students' mathematics learning. Through the instrumental approach, the relationship between the types of technological tool usage and users' conceptual understanding can be explored, allowing for an examination of the development of individual cognitive schemes. Additionally, when technology is integrated into their lessons, pre-service and in-service teachers' instrumental genesis can be analyzed (Trouche, 2014). This study explores the instrumental genesis of PMTs by examining their types and purposes of ChatGPT usage within a 5E lesson plan development task to uncover their utilization schemes. In addition to framing the study's focus, the Instrumental Genesis Theory also guided the analysis of participants' interactions with ChatGPT. Specifically, we operationalized instrumentalization as the process by which PMTs adapted ChatGPT to meet their instructional needs—such as modifying prompts, selecting context-appropriate content, or altering outputs. Instrumentation, on the other hand, was observed in the development of personalized strategies and internal cognitive schemes that allowed PMTs to use ChatGPT more effectively over time. These two processes informed both the coding and interpretation of the data, particularly in understanding how participants transitioned from initial trial-and-error use to more intentional and pedagogically meaningful integration of ChatGPT throughout the 5E lesson plan. The study also sought to examine the affordances and limitations of ChatGPT through the instrumental approach, as perceived by pre-service teachers [PMTs].

The integration of AI in education is expected to play an increasingly significant role in personalizing learning, designing blended learning environments, and fostering data literacy. AI tools may enhance teachers' productivity and efficiency while facilitating learning (Tapan Broutin, 2024). The impact of AI tools on individual learning and monitoring the progress of diverse students has been highlighted as providing practical benefits in educational settings (Thanasi & Mema, 2024). ChatGPT enhances students' problem-solving (Ergene & Çaylan-Ergene, 2025a) and proof skills (Yoon et al., 2024), offering them more effective learning experiences. Moreover, it plays a significant role in improving pre-service and in-service teachers' pedagogical skills through lesson planning processes (Tapan Broutin, 2023), allowing customized teaching materials, and offering a variety of assessment methods (Karaman & Göksu, 2024), promoting the effective use of digital resources, and contributing to argumentation processes (Urhan et al., 2024). In particular, using ChatGPT as an assistive tool in the teaching process for mathematics PMTs could be especially valuable. This study aims to investigate the instrumental genesis of PMTs by examining the purposes of ChatGPT usage during the 5E lesson planning process and exploring its affordances and limitations from their perspectives. In line with this purpose, the study seeks to answer the following research questions:

RQ 1) How do PMTs utilize ChatGPT throughout the stages of the 5E lesson planning process?

RQ 2) What are the purposes and ways of integrating ChatGPT responses into lesson plans?

RQ 3) How do PMTs perceive the affordances and constraints of using ChatGPT in lesson planning?

While recent studies have examined how PMTs utilize ChatGPT in lesson planning, focusing on purposes such as content development, concept explanation, assessment tool creation, and pedagogical support (Gurl et al., 2025; Pişkin Tunç, 2024; Tapan Broutin, 2024). This study extends the literature by introducing a phase-specific classification model grounded in the 5E Learning Model. By mapping distinct uses of ChatGPT to each phase (engagement, exploration, explanation, elaboration, and evaluation), it offers a more structured and pedagogically informed lens on AI integration in instructional design. The second aspect involves analyzing the lesson plans prepared by PMTs to determine how and to what extent the suggestions and responses provided by ChatGPT are incorporated into these plans. Additionally, through interviews with PMTs, their perspectives on the adequacy of ChatGPT in designing lesson content, preparing learning materials, and its affordances and limitations are explored. Therefore, it is anticipated that the findings obtained from analyzing the ChatGPT interactions of PMTs and examining how these interactions are reflected in their lesson plans will expand the body of knowledge and contribute to the relevant literature.

3. Method

This study was designed as a case study, one of the qualitative research methods, to examine how PMTs' use of ChatGPT while designing lesson plans aligned with the 5E learning model was reflected in their lesson plans, along with their perspectives on this process. Case studies aim to describe, explain, and draw conclusions or judgments about one or more cases in detail (Merriam, 2013). Participants' use of ChatGPT, their lesson plan development processes and their perspectives were considered individual cases (Yin, 1994). To clarify, the case in this study is bounded by the integration of ChatGPT within the context of lesson planning based on the 5E Learning Model, carried out by a specific group of PMTs during a defined instructional period.

3.1. Participants

This study involved 21 PMTs enrolled in a university's elementary mathematics teacher education program. They were selected using a purposive sampling method, one of the non-random sampling techniques (Patton, 2015). These participants voluntarily attended the research. Informed consent forms were provided and obtained from all participants. The PMTs had previously completed content-focused courses (Analysis, Linear Algebra, Probability, Geometry) and

teaching-oriented courses (e.g., Mathematics Learning and Teaching Approaches, Mathematics Textbook Analysis) in earlier semesters. The participants in the study were coded as PMT1, PMT2, PMT3…both during the research process and in the reporting phase.

3.2. Data Collection Process

The data collection tools of this study consist of lesson plans prepared by PMTs using the 5E Learning Model, chat transcripts generated by participants through their interactions with ChatGPT, and an interview form administered to the participants. Participants interacted with ChatGPT-4 via the free version of the OpenAI platform during the data collection period, which took place between March and May 2024. The free version of ChatGPT, chosen for its accessibility and cost-effectiveness, as well as its widespread availability for replication purposes, was used in the study. The participants selected one learning objective specific to geometric concepts from the Middle Grades Turkish mathematics curriculum (MoNe, 2024). They designed lesson plans based on the 5E Learning Model aligned with the selected concepts. Geometric concepts were intentionally selected for this study due to their visual and conceptual complexity, which often presents instructional challenges for pre-service teachers. Moreover, geometry is a core component in the middle school mathematics curriculum, and it offers diverse opportunities for activity design, conceptual explanation, and real-life contextualization, all of which align well with the 5E Learning Model. The concepts cover various topics, including polygons, triangles, circles, and three-dimensional objects such as cylinders, prisms, and pyramids, across grades 5 to 8.

Prior to the implementation, participants attended a brief orientation session designed to introduce the basic functionalities of ChatGPT. This session included an overview of how to access and use ChatGPT, key principles of effective prompt formulation, and examples of how AI could be utilized for lesson planning. Although most participants had no prior experience using ChatGPT for instructional purposes, the session ensured a baseline familiarity with the tool's features. The aim was not to train participants extensively, but to provide minimal guidance necessary for independent exploration, in line with the study's exploratory nature. They individually developed their lesson plans through interaction with ChatGPT, a process conducted individually over approximately three hours in the faculty. Although participants did not explicitly describe the 5E model to ChatGPT during their interactions, they formulated prompts in alignment with specific stages of the 5E instructional framework. For example, they requested support for designing an engaging activity or generating exploratory tasks, which correspond to defined stages of the model. During the implementation, participants' use of ChatGPT and the stages of lesson plan development were not guided by any directive intervention from the researchers, except for resolving potential technical issues. After completing their lesson plans, the participants were asked to answer the question, "How did you benefit from ChatGPT during the lesson planning process?" to reflect on their experience and utilization. Links to the PMTs' conversations with ChatGPT were also collected throughout the process. Additionally, the participants were administered an interview form to explore their utilization of ChatGPT during the lesson plan preparation process. The form included three main questions: "Have you ever used ChatGPT for assistance in lesson planning before?", "What are the advantages and disadvantages of using ChatGPT during the lesson planning process?", and "Do you plan to use ChatGPT in your professional career for tasks such as lesson planning and similar activities?".

3.3. Data Analysis

The data were analyzed using the content analysis technique based on the principles of the instrumental approach. ChatGPT utilization by participants, addressing both instructional and pedagogical content, was categorized into fourteen purposes. This classification identified five utilization purposes for the engagement stage, five for exploration, six for explanation, five for elaboration, and four for evaluation. The utilization purposes (with frequencies) are presented in Table 1.

Table 1
ChatGPT Utilization Purposes and Abbreviations

Themes and categories	*Utilization Purpose*	*Abbreviation*
Instructional content		
Getting Ideas	Engaging examples or ideas	EE
	Dynamic geometry software ideas	DGS
	Activity examples ideas	AE*
	Real-life applications ideas	RLA
	Homework ideas	HI
Developing learning tools	Question/problem generation	PG
	Assessment tool development	ATD
	Designing concept maps	DCM
	Material development	MD
	Learning activity development	LAD*
Pedagogical content		
Getting knowledge	Concept knowledge	CK
	Misconception knowledge	MC
Getting approaches	Learning strategies and models	LSM
	Grade-level organization	GO

Note. *AE = brief, undeveloped activity suggestions generated by ChatGPT; LAD = structured, ready-to-use learning activity designs intended for direct implementation.

Although the 5E stages were not always explicitly stated in the prompts, participants later specified the intended phase for each ChatGPT-generated response when compiling their lesson plans. This allowed the researchers to accurately classify each AI-generated output within the appropriate 5E stage, based on the participants' own planning decisions rather than researcher inference. Following the analysis of participants' interactions with ChatGPT, their 5E lesson plans were examined to determine how and to what extent they incorporated the ideas, suggestions, and instructional content provided by the tool. This cross-examination ensured consistency between the intent reflected in the lesson plans and the actual use of ChatGPT, enhancing the analytical alignment with the 5E framework. Based on the analysis of participants' interview responses, key affordances, and constraints of ChatGPT during the lesson planning process were identified. The affordances, categorized into four aspects: realizing the potential, optimized time efficiency, usefulness, and positive attitude, highlighted how ChatGPT supported participants in developing instructional content. Similarly, the constraints, grouped under careful and informed use and perceived insufficiency, reflected challenges faced by participants when integrating ChatGPT into their planning. These categories were derived through a thematic qualitative data analysis, capturing recurring patterns in participants' reflections and experiences.

Direct excerpts from participants' ChatGPT conversations, 5E lesson plans, and interview forms were included to understand their experiences and perspectives comprehensively. This approach ensures a rich, evidence-based analysis, capturing the participants' practical applications and reflective insights regarding using ChatGPT in lesson planning. To illustrate the dynamics of prompt formulation and AI response, selected sequences of interactions were examined. For example, some participants initially asked ChatGPT to generate a general activity idea (e.g., "Give me an engaging way to introduce prisms"), then refined their prompts for more contextual detail (e.g., "Make it suitable for 6th-grade students and include a real-life object"). To ensure the reliability of data analysis in the study, the researchers and a mathematics teacher randomly and independently evaluated some of the participants' data. The inter-coder reliability coefficient after these evaluations was 87.7% (Miles & Huberman, 1994). To enhance the validity and reliability of the study, data triangulation was employed, involving the collection of data through various tools and methods (Patton, 2015), including ChatGPT conversation links, lesson plans, and semi-structured interview forms.

4. Findings

The findings of this study are presented in two main themes that reflect both the functional use of ChatGPT during the lesson planning process and the participants' evolving interaction with the tool. The first theme focuses on how ChatGPT was utilized across the stages of the 5E learning model, illustrating the transformation of the tool from a static digital artefact into a context-specific instructional support. The second theme explores the affordances and constraints of ChatGPT, highlighting participants' perceptions of its benefits and limitations, as well as the strategies they developed to adapt and refine their use of the tool.

4.1. Utilization Patterns and Instructional Purposes of ChatGPT across the 5E Lesson Plan

This section presents how PMTs utilized ChatGPT across different stages of the 5E lesson plan. These patterns not only reveal stage-specific instructional intentions but also reflect participants' gradual transformation of ChatGPT from a generic digital artefact into a pedagogically meaningful tool a process consistent with the instrumental genesis framework (Rabardel, 1995). Based on instructional and pedagogical contents in Table 1, participants utilized ChatGPT across various categories to support their lesson planning process. The categories included Getting Ideas, Developing Learning Tools, Getting Knowledge, and Getting Approaches, each addressing different instructional and pedagogical needs. Within these categories, fourteen utilization purposes were identified. These purposes were further classified into stages of the 5E Learning Model, with five purposes identified for the engagement stage, five for exploration, six for explanation, five for elaboration, and four for evaluation, as shown in Table 2.

Table 2
PMTs' Utilization Purposes of ChatGPT in the 5E Lesson Plan

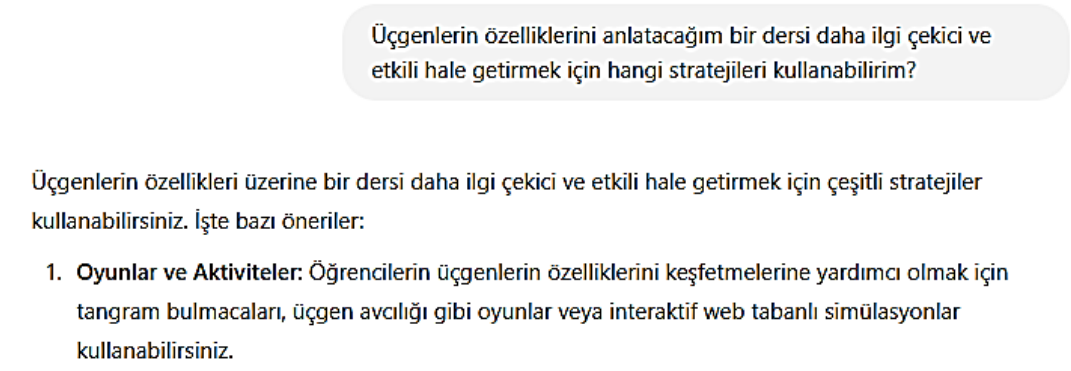
	Categories	*Engagement*	*Exploration*	*Explanation*	*Elaboration*	*Evaluation*	*Total*
IC	Getting Ideas	EE (n=15) DGS (n=2)	EE (n=2) DGS (n=7) AE (n=8)	DGS (n=9) RLA (n=4)	EE (n=1) DGS (n=3) RLA (n=4) AE (n=5)	DGS (n=3)	(n=63)
	Developing learning tools	LAD (n=2) MD (n=3)	LAD (n=2) MD (n=3)	DCM (n=2)	MD (n=3)	ATD (n=7) PG (n=2) HI (n=9)	(n=33)
PC	Getting knowledge			CK (n=2) MC (n=3)			(n=5)
	Getting approaches	LSM (n=3)		GO (n=5)			(n=8)
	Total	(n=25)	(n=22)	(n=25)	(n=16)	(n=21)	(n=109)

Note. IC: Instructional content PC: Pedagogical content.

Participants sought assistance from ChatGPT for two primary themes during the lesson planning: instructional content (n=96) and pedagogical content (n=13). For instructional content, two primary utilization purposes were identified as generating getting ideas (n=72) and developing learning tools (n=24). The purpose of getting ideas was further classified into five utilization purposes, including EE (n=15), DGS (n=27), AE (n=14), RLA (n=7), and HI (n=9). Similarly, the purpose of developing learning tools included five utilization purposes as PG (n=2), ATD (n=7), DCM (n=2), MD (n=9), and LAD (n=4). Two primary categories for the pedagogical content theme were getting knowledge (n=5) and getting approaches (n=8). Getting knowledge categories were observed in CK (n=2) and MC (n=3). The utilization purposes LSM (n=3) and GO (n=5) for getting approaches.

Participants sought assistance from ChatGPT most frequently (n=15) for the EE in the engagement stage. An example related to this purpose, prepared by PMT11, who designed a lesson plan for the triangle concept, is presented in Figure 1.

Figure 1
An excerpt from PMT11's conversation with ChatGPT



Translation of Figure 1:
PMT11: What strategies do you think I could use to make a lesson on the properties of triangles more engaging and effective?
ChatGPT: To design a lesson on the properties of triangles more engaging and effective, you can try the following strategies:
Games and Activities: Organize activities like tangram puzzles or a triangle scavenger hunt to help students explore and discover triangles' properties…

4.1.1. 5E Model: (in Engagement Stage)

> Begin the lesson with five tangram puzzles. Ask the students, "Has anyone seen or played this game before?" Draw their attention to the triangular pieces in the tangram and highlight the properties of triangles to refresh their prior knowledge. Emphasize that triangles are closed shapes formed by joining the correct pieces, with three angles and three vertices, and demonstrate these features to the class.

In the exploration stage, participants engaged with ChatGPT specifically for instructional content across five purposes. These purposes included, EE (n=2), DGS (n=7), AE (n=8), MD (n=3) and LAD (n=2) with AE being the most frequently utilized purpose (n=8). Among these, EE and LAD were the least (n=2) utilized purposes. An example related to the LAD purpose, prepared by PMT21, who designed a lesson plan for quadrilaterals and triangle areas, is presented in Figure 2.

Figure 2
An excerpt from PMT21's conversation with ChatGPT

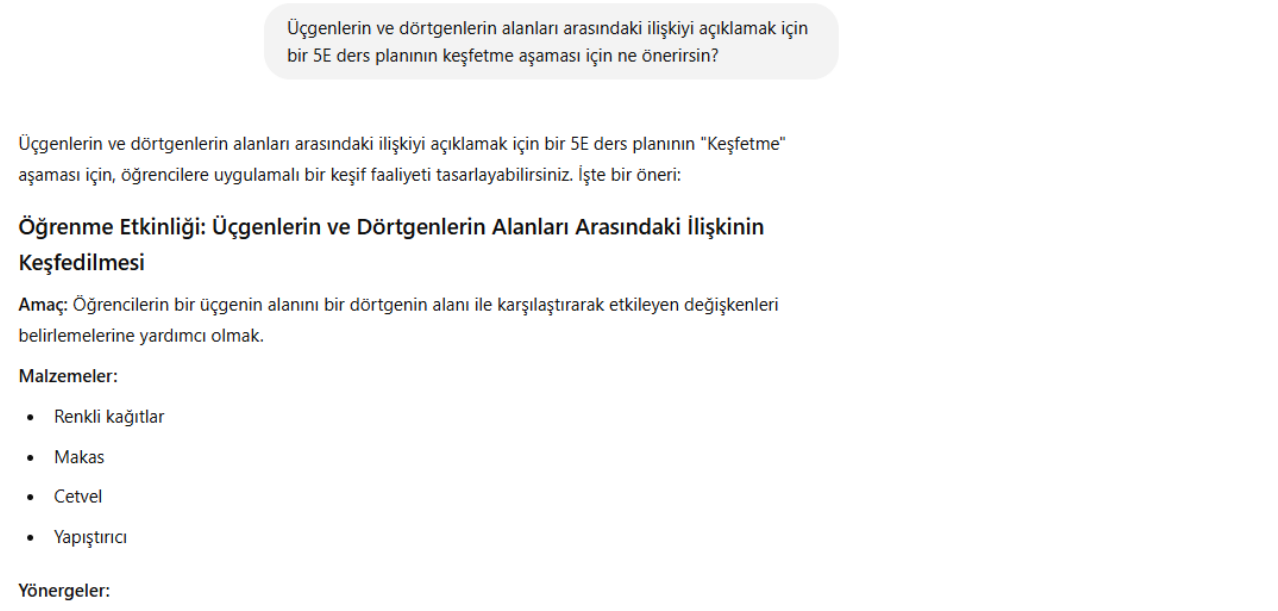
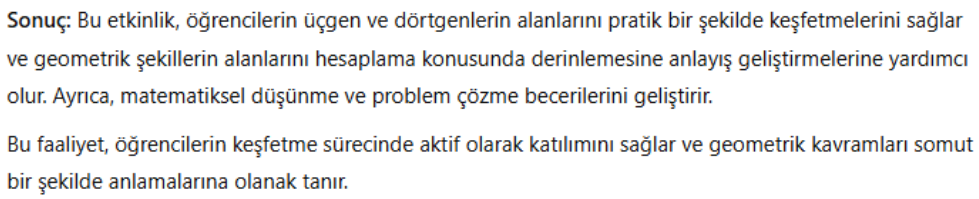


Figure 2 continued



Translation of Figure 2:
To explain the relationship between the areas of triangles and quadrilaterals during the "Explore" phase of a 5E lesson plan, you can design a hands-on exploration activity for students. Here is a suggestion:
PMT21: What would you recommend for the exploration stage of a 5E lesson plan to explain the relationship between the areas of triangles and quadrilaterals?
ChatGPT:
Learning Activity: Exploring the Relationship Between the Areas of Triangles and Quadrilaterals
Objective: Help students identify the factors affecting the area calculations by comparing the area of a triangle to the area of a quadrilateral.
Materials: Colored paper, Scissors, Ruler, Glue
…
Outcome: This activity allows students to practically explore and understand the area calculations for triangles and quadrilaterals, enhancing their mathematical thinking and problem-solving skills.

This hands-on exploration ensures active participation and facilitates a concrete understanding of geometric concepts among students.

4.1.2. 5E Model: (in Exploration Stage)

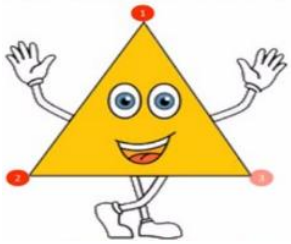
> …The teacher distributes pre-prepared quadrilateral cards to student groups. Using string, students divide the quadrilaterals into triangles by creating diagonals. They measure the dimensions of the quadrilaterals and the resulting triangles with rulers and record their findings. Subsequently, students compare the areas of the quadrilaterals and triangles, allowing them to discover the variables that determine the area of a triangle…

Participants engaged with ChatGPT in the explanation stage for five purposes, including DGS (n=9), RLA (n=4), DCM (n=2), MC (n=3), CK (n=2) and GO (n=5), for both instructional and pedagogical purposes. In the elaboration stage, participants utilized ChatGPT for only instructional content, focusing on five purposes: AE (n=5), RLA (n=4), DGS (n=3), EE (n=1), and MD (n=3). The most frequently utilized purposes in this stage were AE and RLA. An excerpt from the ChatGPT conversation of PMT17, who designed a lesson plan for the triangle concept and utilized ChatGPT for the RLA purpose, is provided as follows.

PMT17: "Can you give me examples of activities for 8th-grade students that involve real-life applications of triangles?"
ChatGPT: You can organize a fashion show with outfits inspired by triangles.
Here are some photography ideas for such a triangle-inspired fashion show:
Student-Designed Outfits:
Showcase outfits designed by students using paper triangles. These outfits can feature various colors and represent triangles (equilateral, isosceles, scalene).
Runway Design:
Create a runway for students to walk on, decorated with triangular patterns or colorful triangle shapes on the floor.

4.1.3. 5E Model: (in Elaboration Stage)

"Students are divided into groups, each assigned different triangles. Each group designs a unique costume related to their specific triangles, creates the costumes using cardboard, and presents them to their peers." (This figure was added by the pre-service teacher based on a directive provided by ChatGPT)

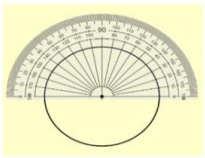


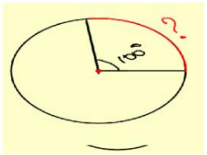
In the evaluation stage, explicitly focusing on instructional content, four utilization purposes were identified, including HI (n=9), ATD (n=7), DGS (n=3), and PG (n=2). Participants most frequently sought assistance from ChatGPT for HI (n=9) and ATD (n=7) in this stage. An excerpt from the ChatGPT conversation of PMT13, who developed a lesson plan for the circle concept and utilized ChatGPT for the ATD purpose, is presented below.

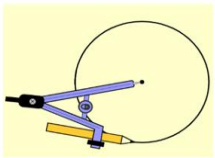
PMT13: How can I assess students' learning at the end of the lesson?
ChatGPT: Exit cards are a great tool to assess what students have learned and to observe their understanding. To evaluate students' comprehension of circles and arcs, you can consider the following suggestions for designing exit cards:
Visual Identification Cards:
Provide students with various visuals of circles and arcs. For each visual, ask them to identify and describe the features of the shapes. For example, you could ask them to describe a full circle or a semicircle.
Question Cards:
Give students cards containing questions related to circles and arcs. The questions can include simple geometric calculations or real-world applications of circles. For example, you could ask them to calculate the circumference or area of a circle.

4.1.4. 5E Model: (in Evaluation Stage)

At the end of the lesson, exit cards are handed out to students in the classroom. These exit cards include several brief activities related to the concepts learned during the lesson. Starting with the initial question, students work through progressively more challenging problems to complete the exit task.







Participants used ChatGPT in all stages of the 5E model, including engagement (n=25), exploration (n=22), explanation (n=25), elaboration (n=16) and evaluation (n=21). It was found that participants most frequently asked ChatGPT questions for the purposes of DGS (n=24) and EE (n=18). Participants utilized ChatGPT for the DGS across all stages of the 5E model. An excerpt from the ChatGPT conversation of PMT17, who developed a lesson plan for the pyramid concept and utilized ChatGPT for the DGS purpose, is presented below.

PMT17: How can dynamic geometry software explore a right pyramid's fundamental elements and geometric structure without involving area and volume?
ChatGPT: I can design a problem using dynamic geometry software that focuses on a right pyramid's key components and spatial properties, excluding calculations related to area and volume.
Problem:
A right pyramid is constructed with a square base, each side of the base is 6 cm long. The pyramid's apex is located 8 cm above the center of the base. You want to calculate the amount of material needed to cover the surfaces of this pyramid. Begin by answering the following questions to understand the structure of the pyramid better:

1. Calculate the perimeter of the pyramid's base.
2. Identify the specific term for the perpendicular line from the apex to the center of the base.
3. Using the length of the base and the height from the apex to the base center, calculate the slant height of one of the pyramid's lateral faces.
4. Draw the net of the pyramid and determine how many triangular and square faces it consists of.

4.1.5. 5E Model: (in Evaluation Stage)

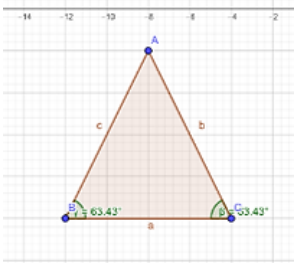
Using GeoGebra, the edges, height, and base elements of pyramids can be explored, and changes in the edges and height can be observed through a guided question. Subsequently, the net of the pyramid is displayed to enhance understanding.

The EE and MD purposes were both used in the engagement, exploration, and elaboration stages. LAD was utilized in the engagement and exploration stages, while AE was applied in the exploration and elaboration stages. RLA, on the other hand, appeared specifically in the explanation and elaboration stages. Additionally, purposes specific to particular stages were also identified. For example, PG was observed exclusively in the evaluation stage, while MC was used only in the explanation stage. An excerpt from the ChatGPT conversation of PMT2, who developed a lesson plan for the triangle concept and utilized ChatGPT for the MC purpose, is presented below.

PMT2: Can you address the common misconceptions about triangles based on their sides?
ChatGPT: Here are some common misconceptions students may encounter regarding the classification of triangles based on their sides, along with suggestions for addressing these misconceptions:
Equilateral Triangle Misconception:
Misconception: Students may think a triangle is equilateral if only two sides are equal in length.
Correction: Emphasize that all three sides of an equilateral triangle must be equal in length. Use various examples and visuals to demonstrate this concept. Additionally, compare equilateral and isosceles triangles to help students distinguish between them.
Isosceles Triangle Misconception:
Misconception: Students may fail to recognize that a triangle is isosceles when any two of its sides are equal.
Correction: Provide students with clear examples that show isosceles triangles having at least two equal sides. Use visuals and explanations to reinforce this understanding.

4.1.6. 5E Lesson Plan: (in Explanation Stage)

It has been observed that most students fail to grasp the concept of the equal base angles in an isosceles triangle. To address this misconception, the GeoGebra application can be utilized to...



4.2. Affordances and Constraints Processes in ChatGPT Use

The identified affordances and constraints can be understood in light of instrumental genesis, particularly as they developed personal strategies to improve interaction with the tool. The

findings provided insights into the participants' prior experience and future intentions regarding using ChatGPT in lesson planning. Regarding their previous experience, 14 participants indicated that they had not used ChatGPT for assistance in lesson planning, while 7 participants reported having prior experience. Despite this, all participants stated that they intend to utilize ChatGPT in their professional careers for tasks such as lesson planning and related activities, reflecting unanimously acknowledging its potential benefits. Regarding the question "What are the advantages and disadvantages of using ChatGPT during lesson planning?", PMTs identified several affordances and constraints. These findings are presented in Table 3.

Table 3
Affordances and Constraints of ChatGPT Identified by PMTs

Categories	*Excerpts from Interview*
Affordance	
Realizing the potential (n=18)	• I discovered how supportive ChatGPT can be during the lesson planning process. • I did not anticipate it would provide ideas I would not have considered while creating lesson content. • It offered numerous examples of virtual manipulatives suitable for middle school levels. • I realized that it could be highly beneficial in supporting me throughout my professional teaching career.
Optimized Time Efficiency (n=16)	• I could quickly access the conceptual information I needed for lesson planning through ChatGPT. • Collaborating with ChatGPT while preparing lesson plans or worksheets significantly streamlined my work. • ChatGPT delivered prompt and relevant ideas throughout the lesson planning process.
Usefulness (n=13)	• It was highly practical during the lesson planning process. • It proved very effective in allowing me to ask questions freely and obtain the needed information. • I was able to access the desired information with ease. • I found it incredibly straightforward and user-friendly to use.
Positive Attitude (n=11)	• ChatGPT made lesson planning a more enjoyable and less stressful experience. • I felt delighted to explore new ideas in my lesson plan thanks to the creative suggestions from ChatGPT. • ChatGPT brought a sense of excitement and satisfaction to lesson planning by inspiring me with creative and impactful ideas.
Constraints	
Careful and Informed Use (n=13)	• It is important not to accept everything ChatGPT suggests without question. • It can be helpful at certain stages, but we should avoid directly adopting everything as it is. • When I did not provide detailed information during lesson planning, it occasionally gave irrelevant responses. • ChatGPT provides much better answers when the desired information or task is explained in greater detail.
Perceived Insufficiency (n=11)	• The responses I received from ChatGPT were not very satisfying. • Some of the answers ChatGPT provided were overly general. • Offering simple examples commonly found in textbooks made me feel that it was insufficient to meet my expectations.

PMTs identified 58 affordances and 24 constraints of ChatGPT during the 5E lesson planning process (Table 3). The affordances were categorized into four key aspects, which include realizing the potential (n=18), optimized time efficiency (n=16), usefulness (n=13), and positive attitude

(n=11). The constraints were grouped into two categories, namely careful and informed use (n=13) and perceived insufficiency (n=11). The following sections provide a detailed analysis of these findings, supported by excerpts from the participants' responses.

Participants highlighted several affordances of ChatGPT during the 5E lesson planning process. For instance, 18 PMTs emphasized its role in helping them realize its potential as a supportive tool. As PMT3 explained, "I realized that it could be highly beneficial in supporting me throughout my professional teaching career." Similarly, PMT12 stated, "It offered numerous examples of virtual manipulatives suitable for middle school levels, which I had not considered before." These findings suggest that ChatGPT's ability to introduce creative ideas and resources enhanced its perceived value in lesson planning. Another frequently noted affordance was optimized time efficiency (n=16). PMT7 commented, "Collaborating with ChatGPT while preparing lesson plans or worksheets significantly streamlined my work." This view was consistent with PMT15's remark, "I could quickly access the conceptual information I needed, and ChatGPT delivered prompt and relevant ideas." Such efficiency made the lesson planning process more manageable and time-saving for participants.

In addition, 13 PMTs recognized ChatGPT's usefulness in allowing them to ask questions and obtain necessary information freely. For example, PMT9 shared, "It was highly practical during the lesson planning process, and I could access the desired information easily." Furthermore, 11 PMTs expressed a positive attitude toward ChatGPT, with PMT5 noting, "ChatGPT made lesson planning a more enjoyable and less stressful experience." This sentiment was echoed by PMT18, who remarked, "It brought a sense of excitement and satisfaction by inspiring me with creative and impactful ideas."

Despite its many advantages, participants identified constraints associated with using ChatGPT during lesson planning. One key limitation noted by 13 PMTs was the need for careful and informed use. For example, PMT4 explained, "It is important not to accept everything ChatGPT suggests without question." Similarly, PMT8 remarked, "When I did not provide detailed information, ChatGPT occasionally gave irrelevant responses, which made it less effective." These statements highlight the importance of providing clear and specific instructions when using ChatGPT to achieve meaningful outputs. Another frequently mentioned constraint was perceived insufficiency (n=11). Participants expressed dissatisfaction with some of the responses, describing them as overly general or repetitive. For instance, PMT11 shared, "Some of the answers ChatGPT provided were overly general, and offering simple examples made it feel insufficient." This view was consistent with PMT2, who noted, "It often provided examples commonly found in textbooks, which made it seem inadequate for generating innovative or tailored ideas."

5. Discussion and Conclusion

AI tools are valuable for supporting teachers in the learning process by providing engaging, flexible, and personalized original content for lesson planning and developing learning materials (Sheikh, 2020). Similarly, in this study, ChatGPT is regarded as an AI tool with the potential to assist educators in designing lesson plans (Trust et al., 2023). This study examines how PMTs use ChatGPT in designing lesson plans aligned with the 5E learning model, how this is reflected in their lesson plans, and their perspectives on the process. The findings revealed that PMTs utilized ChatGPT for various purposes during the 5E lesson planning process and reflected the feedback they received from ChatGPT in their lesson plans in diverse ways. PMTs utilized ChatGPT during the 5E lesson planning process for both instructional and pedagogical content. For instructional content, they used ChatGPT to generate ideas they perceived as creative and engaging such as novel real-life examples, cross-disciplinary connections, or culturally relevant contexts and to develop learning tools. For pedagogical content, PMTs sought assistance from ChatGPT to enhance their professional knowledge and explore practical teaching approaches.

ChatGPT enables teachers to develop ideas by generating suggestions, recommending relevant resources, and summarizing complex information (Kasneci et al., 2023; Pişkin-Tunç, 2024). The 5E

Learning Model provided a structured pedagogical lens to analyze how ChatGPT was utilized across distinct stages of lesson planning. Rather than viewing ChatGPT use as a single, uniform act, the 5E framework allowed us to examine its varied functions such as engaging students, facilitating inquiry, or supporting assessment within a well-established instructional sequence. This model helped contextualize participants' interactions with ChatGPT and revealed how its affordances shifted depending on the instructional phase. For instructional content, PMTs relied on ChatGPT to generate creative and interesting ideas and to develop learning tools, while for pedagogical content, they sought assistance to enhance their professional knowledge and explore practical teaching approaches. Additionally, PMTs utilized ChatGPT for 14 purposes throughout the lesson planning. Participants utilized ChatGPT for a wide range of purposes due to its ability to provide quick access to diverse information, instructional methods, and techniques and generate various educational content (Castro et al., 2024). Thus, the findings suggest that ChatGPT holds promising potential in supporting PMTs during the lesson planning process (Lilly, 2024).

The findings revealed that participants utilized ChatGPT most frequently for the Dynamic Geometry Software [DGS] purpose in all stages of the 5E lesson plan. The frequent use of ChatGPT for purposes related to DGS, particularly in the explanation stage, can be attributed to the visual and interactive nature of geometric learning. ChatGPT was frequently used to suggest activities involving tools such as GeoGebra, or to help participants design explanations that integrated DGS to improve students' conceptual understanding through interactive demonstrations. Notably, the DGS purpose was most commonly used in the explanation stage. The explanation stage is where misconceptions are addressed, incomplete learning is supplemented, and the teacher plays the most active role (Bybee, 2002). In this stage, PMTs may have relied on DGS for verbal explanations and utilizing visual tools and drawings, as these resources can significantly enhance students' understanding (Campbell, 2000). The most frequently preferred purposes were EE and AE. Participants sought engaging examples and ideas to capture students' attention during the engagement stage. This preference may stem from the engagement stage designed to stimulate students' interest in the topic and activate their prior knowledge (Boddy et al., 2003).

The findings revealed that participants frequently utilized ChatGPT in the exploration and elaboration stages to obtain examples of engaging and enjoyable activities. The exploration stage, where students engage in enjoyable activities to generate new ideas, may explain why PMTs most commonly relied on AE in this stage (Newby, 2004). After EE and AE, the following most frequently sought purpose was MD. PMTs utilized ChatGPT for MD in the engagement, exploration, and elaboration stages. The elaboration stage is designed for students to connect prior and new knowledge, achieving a comprehensive understanding. Using diverse materials in this stage to support learning may enhance its effectiveness, which could explain why PMTs turned to ChatGPT for material development in this phase (Öztürk, 2013). These patterns can be further interpreted through the lens of the Instrumental Genesis Theory, which provides a conceptual framework for understanding how users transform a digital artefact into a pedagogical instrument through goal-directed interaction. In this study, ChatGPT functioned initially as an unfamiliar artefact, but through repeated use and prompt refinement, PMTs began to adapt it to their instructional goals (instrumentalization) while also developing new strategies and understanding about how to use it effectively (instrumentation). This theoretical lens helps explain how participants' engagements with ChatGPT evolved from basic content requests to more strategic, phase-specific implementations within the 5E model, illustrating their growing instrumental fluency with the tool.

The findings of this study provide valuable insights into how PMTs utilized ChatGPT during the 5E lesson planning process and how they perceived its affordances and constraints. The identified affordances highlight ChatGPT's versatility in generating ideas, resources, and examples. Participants described the tool as creative and inspiring, particularly when it provided novel suggestions, such as the use of virtual manipulatives or real-life contextual activities. Time efficiency was another prominent theme—participants valued how quickly ChatGPT could

generate instructional content and streamline the planning process (Jeon & Lee, 2023; Yadav & Yadav, 2024). This supports previous findings that emphasize AI's capacity to synthesize diverse information into useful instructional material (Pavlik, 2023; Rudolph et al., 2023).

ChatGPT is positioned as a supportive tool in the future of mathematics education by facilitating personalized learning experiences, enriched learning environments, and critical thinking approaches (Ergene & Çaylan-Ergene, 2025a). Additionally, it promotes integrating technology and AI into mathematics education. The findings of this study reinforce this perspective, revealing ChatGPT's potential to simplify lesson planning processes, generate innovative ideas, and provide tailored resources for diverse instructional needs. PMTs recognized its affordances, such as time efficiency and fostering creativity, while also acknowledging its constraints, including the need for precise prompts and critical evaluation of outputs. Unlike previous studies that focused on the general use of ChatGPT for content generation, assessment, or pedagogical support in teacher education (e.g., Pişkin Tunç, 2024; Tapan-Broutin, 2024), this study introduces a phase-specific analysis by aligning ChatGPT utilization with the 5E instructional model. This structured approach enables a deeper understanding of how AI tools function within different stages of lesson planning and reveals variation in the purposes and strategies of use. By integrating a pedagogical framework into the classification, the study contributes a more nuanced perspective on AI-supported instructional design in mathematics education. This classification model may inform both teacher training practices and future research on stage-based AI integration in educational contexts. These results underscore the importance of equipping educators with strategies to effectively integrate AI tools like ChatGPT into their teaching practices, ensuring a balance between technological assistance and pedagogical expertise (Yoon et al., 2024). As AI continues to evolve, its thoughtful application in education has the potential to transform both teaching and learning processes, offering new pathways for innovation and engagement in mathematics education.

6. Limitations and Suggestions

While the study revealed promising aspects of ChatGPT's use in lesson planning, it also brought to light some challenges that should be taken into account. Participants noted that ChatGPT's responses tended to be overly general or repetitive when prompts lacked clarity and detail. This aligns with studies emphasizing the critical role of prompt clarity in obtaining meaningful AI-generated content (Pelton & Pelton, 2023; Tapan-Broutin, 2023). Some PMTs reported improved results after refining their inputs, suggesting that the tool's effectiveness is closely linked to clearly communicated instructional needs (Maheshwari, 2023). It can be anticipated that as pre-service teachers engage more frequently and intentionally with ChatGPT, its instructional potential may become more evident. With continued use, previously encountered limitations like limited specificity or unclear alignment with instructional goals may gradually lessen as users improve their prompt strategies and evaluative thinking. Increased familiarity may also contribute to developing more positive attitudes toward the tool, as a better understanding of its functions and perceived usefulness (Ergene & Çaylan Ergene, 2025b) tends to support greater confidence and openness to integrating it into instructional practices.

This study also has certain limitations that should be acknowledged explicitly. The responses generated by ChatGPT may vary depending on the model or version used. In this study, participants interacted with the free version of ChatGPT-4, which may differ in depth, accuracy, or responsiveness compared to other versions. The quality of the prompts also shaped the effectiveness of the responses. Since participants had different levels of experience in designing focused and purposeful prompts, the AI-generated content varied in relevance and usefulness. During the implementation phase, some participants faced minor technical difficulties or needed support while using the platform. These challenges may have influenced the depth or completeness of their planning processes. In addition, since the study was conducted within a

single institutional setting and involved a relatively small group of participants, the findings should be interpreted carefully when considering broader applications.

Based on the findings, several recommendations can be made for integrating ChatGPT into mathematics education, particularly in geometry and other subjects. First, targeted teacher education programs should be developed to help PMTs formulate effective prompts and evaluate ChatGPT's responses critically, maximizing its potential while addressing limitations like irrelevant or overly general outputs. Second, teacher education programs should incorporate ChatGPT as a tool for lesson planning and resource development. PMTs can use it to create engaging examples, address misconceptions, and adapt materials for various topics, including algebra and calculus, enhancing its application across different areas of mathematics. Finally, ChatGPT should be integrated into inquiry-based learning environments to support teachers in designing activities that promote problem-solving and conceptual understanding. These recommendations also align with the principles of the Instrumental Genesis Theory, emphasizing the importance of supporting pre-service teachers in transforming ChatGPT from a generic digital artefact into a pedagogically meaningful instrument through structured, reflective, and goal-oriented use.

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Ethics declaration: All subjects who participated in the study have given their consent for participation, data collection, and analysis of the collected data. The data was analyzed only in anonymized form, and personal information that could lead to the identification of the participants has been removed. No additional ethical approval was needed.

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