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A New Paradigm for Preschool Teachers: Integrating STEM and AI in Flipped Learning

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Abstract
Integrating Artificial Intelligence (AI) and STEM in early childhood education requires effective teacher professional development, yet practical and pedagogical barriers often hinder this. This study addresses this gap by examining the effects of a 13-week online flipped learning model, focused on STEM-AI integration, on 42 preschool teachers. Using an embedded mixed-methods design, the study collected quantitative data (pre/post-test scales) and qualitative data (semi-structured interviews) to measure changes in AI awareness, innovative and computational thinking skills, and teacher opinions. Quantitative results showed that the intervention had a significant positive effect on all three measured skills. Qualitative findings corroborated this, revealing that the training met teachers' expectations, expanded their understanding of AI to include complex concepts like machine learning, and critically, highlighted their significant concerns regarding data privacy and the ethical use of student data. This study provides novel evidence for the effectiveness of an online flipped learning model in developing preschool teachers' advanced pedagogical and technical competencies. Findings underscore the model's practical utility but also signal an urgent need for policies and training that directly address educators' ethical and security concerns.

Keywords Artificial intelligence · STEM · Computational thinking · Innovative thinking

Introduction

In light of scientific developments, artificial intelligence (AI) tools have been integrated into all areas of contemporary life, with education at the forefront of this transformation. AI encompasses computational systems capable of performing tasks typically requiring human intelligence, including machine learning, natural language processing, computer vision, and pattern recognition. In educational contexts, AI extends beyond mere automation to include adaptive learning systems, intelligent tutoring platforms, and predictive analytics that personalize instruction based on learner characteristics and performance data. These capabilities have prompted countries such as the USA, Canada, and China to prioritize the integration of AI into educational processes (Chiu & Chai, 2020), with the primary goal of ensuring that citizens become literate in AI while simultaneously enriching teaching and learning environments (Jiang, 2022; Long & Magerko, 2020).

The integration of AI into education offers several transformative benefits. AI-powered systems enable personalized learning experiences adapted to individual student needs, reduce tracking andministrative workload through the automation of routine tasks such as grading and progress tracking, and enrich educational environments through intelligent tutoring systems and adaptive content delivery (Ghosh & Thirugnanam, 2021; Jiang, 2022; Sun, 2022). However, these advantages must be balanced against legitimate concerns about ethics, privacy, and security that accompany the deployment of AI in educational settings (Bayer, 2024).

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Recognizing both the potential and risks, many countries have developed comprehensive AI policies to guide implementation. For example, China has established the "New-Generation AI Development Plan" (The State Council of the People's Republic of China, 2017), while the NSF and ISTE (2018) have created resources and professional development frameworks to support effective AI integration from early childhood through higher education (Yu, 2024).

The integration of AI with STEM education creates synergistic opportunities that extend across multiple dimensions. First, regarding instructional enhancement, AI-powered tools enable real-time feedback on computational projects, automate assessment of STEM problem-solving tasks, and provide adaptive scaffolding for skill development (Xu & Ouyang, 2022; Valeri et al., 2025). Second, in curriculum design support, generative AI assists educators in creating age-appropriate STEM activities, facilitating interdisciplinary connections, and adapting materials for diverse learners (Clark, 2023; Emenike & Emenike, 2023). Third, regarding skills integration, AI tools become both instruments and objects of STEM learning, where students engage with algorithmic thinking, data science principles, and computational modeling embedded within authentic STEM contexts (Joshi & Kumar, 2021). These AI-STEM convergences are particularly valuable for developing critical 21st-century competencies including computational thinking, creative problem-solving, and innovative thinking (Bybee, 2013; Xu & Ouyang, 2022).

Teachers play a vital role in translating AI-STEM innovations into effective classroom practice. They are primarily responsible for integrating these technologies into instructional processes and developing students' AI literacy (Casal Otero et al., 2023; Long & Magerko, 2020). Consequently, teachers require sufficient knowledge and practical experience to apply AI tools effectively within STEM education contexts (Salas Pilco et al., 2022). Research demonstrates that teachers' professional competencies directly correlate with student achievement outcomes (Hibpshman, 2007; Kölemen & Yıldırım, 2025), making high-quality professional development essential. Indeed, several jurisdictions have initiated large-scale teacher training programs—for example, South Korea's initiative to improve AI literacy among 5,000 teachers, and Hong Kong's systematic approach to AI professional development (Yang 2022a, b; Yıldırım and Akcan 2024).

However, significant barriers impede teachers' professional development in AI-STEM integration. Teachers working full-time during weekdays face substantial logistical challenges in accessing sustained, specialized training (Yıldırım et al., 2022). Furthermore, many educational institutions lack the resources or expertise to provide contextualized AI-STEM professional development suited to specific teaching levels and subject areas. These constraints necessitate innovative approaches to teacher education that transcend traditional time-and-place limitations. Moreover, in the preschool period, the integration of AI into STEM applications serves not only as a tool to enhance instructional quality but also allows for the appropriate integration of machine learning, deep learning, and problem-solving strategies into STEM content. In this way, AI contributes to teachers' professional development while simultaneously supporting students' learning experiences.

The online flipped learning model directly addresses these professional development barriers by restructuring the relationship between content delivery and application practice. In this model, teachers asynchronously access conceptual content—such as AI fundamentals, STEM integration principles, and pedagogical frameworks—through curated videos and digital resources at their convenience. Subsequently, synchronous sessions focus exclusively on hands-on application, collaborative problem-solving, peer feedback, and instructor guidance (Baker, 2000; Yıldırım, 2024). This pedagogical approach aligns with adult learning principles: self-paced conceptual study accommodates diverse schedules and varying levels of prior knowledge, while live practice sessions enable contextualized skill development specific to participants' teaching contexts (Abeysekera & Dawson, 2015; Talley & Scherer, 2013). Critically, the flipped model's structure mirrors the very AI-STEM practices teachers will implement with their students—using technology to personalize content delivery while preserving human interaction for complex cognitive tasks and social learning (Enfield, 2013; Yorgancı, 2020). The model's capacity for iterative content review particularly benefits AI-STEM learning, where educators may require multiple exposures to programming concepts, robotics interfaces, or AI tool applications before achieving implementation fluency. Additionally, the online flipped learning model enables participants to access diverse learning materials and perspectives, complete scaffolded activities on digital platforms, and engage in rich teacher-student and peer interactions during synchronous sessions (Fung, 2020; Kozikoğlu et al., 2021). These features make the online flipped learning model especially suitable for the dual challenge of developing both AI competencies and STEM pedagogical knowledge.

Furthermore, research reveals that preschool teachers often lack confidence and competence in STEM education even without the added complexity of AI integration (Yıldırım, 2021). Teachers report uncertainty about how to facilitate engineering design activities, a limited understanding of computational thinking concepts suitable for young children, and anxiety about their own mathematics and science knowledge. When AI integration is added

to these existing challenges, the professional development needs become substantial. Teachers must simultaneously develop STEM content knowledge, STEM pedagogical strategies, AI technical competencies, and understanding of how AI tools can support STEM learning—all while maintaining focus on developmentally appropriate practice for young children.

Literature Review

AI-STEM Convergence in Education

The integration of AI with STEM education represents an emerging pedagogical frontier that extends beyond mere technology adoption to encompass fundamental shifts in how STEM content is taught, learned, and applied. Research on AI-STEM convergence identifies several primary integration models, each with distinct pedagogical implications. Discipline-specific AI applications embed AI tools within individual STEM subjects to enhance content learning and skill development. For example, machine learning platforms support pattern recognition and predictive modeling in mathematics education, while computer vision technologies enable automated data collection and analysis in science inquiry (Xu & Ouyang, 2022). In engineering contexts, AI-powered simulation tools allow students to test design iterations rapidly and visualize complex systems that would be impractical to construct physically (Valeri et al., 2025). These applications demonstrate how AI can serve as a powerful amplifier of traditional STEM learning objectives.

Cross-disciplinary AI-STEM projects leverage AI as a unifying thread connecting multiple STEM domains within authentic problem-solving contexts. Recent implementations include sensor-based environmental monitoring projects that integrate scientific inquiry, mathematical data analysis, technological tool use, and engineering design processes, all coordinated through AI-powered data analytics platforms (Liang et al., 2023). Such integrated approaches align with contemporary views of STEM education as inherently interdisciplinary rather than as separate subject areas taught in parallel.

Regarding AI as a STEM learning object, this approach positions AI itself as content within STEM curricula, where learners explore computational thinking, algorithmic logic, machine learning concepts, and ethical considerations of intelligent systems (Valeri et al., 2025). This approach recognizes that understanding AI—not merely using AI tools—constitutes essential STEM literacy for 21st-century learners. Students engage with fundamental AI concepts such as training data, algorithm bias, and model validation through age-appropriate activities that demystify AI while building critical evaluation skills.

Teacher Professional Development in AI-STEM Integration

Effective AI-STEM integration hinges fundamentally on teacher capacity, yet professional development research reveals significant preparedness gaps across all educational levels. Teachers require not only technical competencies with AI tools but also sophisticated pedagogical content knowledge for translating abstract AI-STEM concepts into accessible, engaging, and age-appropriate learning experiences.

Recent systematic reviews underscore the scarcity of research on teacher preparation for integrated STEM education, with particular deficits at the preschool level. Professional development programs often address the technology dimension of STEM insufficiently, treating it merely as the products resulting from engineering design processes or tools used during development (Stohlmann et al., 2012; Şahin, 2015), without incorporating new technologies like AI. Therefore, providing AI and STEM content in an integrated manner is effective for ensuring professional development in both domains, contributing to the development of both STEM and AI literacy. Indeed, studies examining teacher AI literacy frameworks emphasize the necessity of moving beyond technical skills toward comprehensive competency models that encompass contextual awareness, ethical reasoning, and pedagogically meaningful applications. Teachers need to understand not only how AI tools function but also when and why to employ them, how to critically evaluate AI-generated content, and how to help students develop appropriate relationships with intelligent technologies (Cavalcanti et al., 2021). For STEM integration specifically, research demonstrates that teachers' professional competencies directly correlate with student achievement (Hibpshman, 2007; Kölemen & Yıldırım, 2025), making high-quality, content-focused professional development essential rather than optional.

Critically, few studies examine teacher training programs that simultaneously address AI integration and STEM education, particularly using innovative delivery models suited to practicing teachers' constraints. Professional development research in STEM education has documented the effectiveness of sustained, practice-based programs that engage teachers in authentic STEM activities, facilitate collaborative lesson planning, and provide opportunities for classroom implementation with feedback (Yıldırım, 2021). Similarly, emerging research on AI integration emphasizes the importance of hands-on experimentation with AI tools, exploration of pedagogical applications, and critical

examination of ethical implications (Wang & Cheng, 2021). However, these two strands of professional development literature remain largely separate, with minimal research examining how to integrate AI competencies with STEM pedagogical knowledge in coherent, efficient teacher education programs.

Beyond technical competencies, AI-STEM professional development has potential to enhance teachers' innovative thinking capacities. Research on STEM teacher professional development indicates that hands-on engagement with engineering design processes, computational tools, and open-ended problem-solving fosters creative pedagogical approaches and willingness to experiment with novel instructional strategies (Sun et al., 2024; Yıldırım, 2021). Similarly, studies examining AI tool adoption demonstrate that teachers who actively experiment with generative AI, adaptive learning platforms, or educational robotics report increased pedagogical creativity, openness to innovation, and confidence in adapting curriculum materials (Xu & Ouyang, 2022; Valeri et al., 2025). This dual-skill development—innovative thinking alongside computational thinking—is particularly relevant for preschool educators, who must creatively adapt abstract AI-STEM concepts into concrete, play-based, experiential learning activities that align with early childhood development principles.

Emerging scholarship on teachers' AI-TPACK (Technological Pedagogical Content Knowledge for AI) provides theoretical grounding for understanding the complex interrelationships between AI knowledge, pedagogical strategies, and content expertise. These frameworks demonstrate that effective AI integration requires not isolated technical skills but rather integrated knowledge systems where technological capabilities, pedagogical goals, and content learning objectives mutually inform one another. Yet these frameworks have not been applied systematically to preschool STEM contexts, where developmental appropriateness adds substantial complexity. Preschool teachers must balance AI tool affordances with early childhood learning principles, navigating concerns about screen time, social-emotional development needs, concrete versus abstract thinking, and hands-on sensory exploration (Küçükkara et al., 2024; Uyak et al., 2023).

AI-STEM Applications in Early Childhood Education

In early childhood contexts, AI-STEM integration takes distinct forms adapted to young children's developmental characteristics and learning needs. Research demonstrates that AI-supported robotics can facilitate collaborative problem-solving, language development, and early computational thinking in preschool settings (Kanaki & Kalogiannakis, 2023; You & Yang, 2024). Educational robots provide tangible, interactive representations of programming concepts that young children can manipulate through physical movement and cause-effect exploration. Project-based STEM inquiry enhanced by AI documentation tools enables young children to engage in iterative design processes while teachers use AI analytics to assess learning progressions and adapt instruction (Su et al., 2024).

AI-enhanced interactive technologies have demonstrated positive effects on children's learning attitudes, collaboration skills, and engagement with STEM content (Liao & Gu, 2022). For example, AI-powered adaptive learning systems can adjust mathematics activity difficulty based on children's performance, providing appropriate challenge without frustration. Voice-activated AI assistants integrated into science exploration centers allow children to document observations, ask questions, and access information without requiring advanced literacy skills. These applications illustrate how AI can make STEM content more accessible and engaging for young learners when thoughtfully designed and implemented.

Studies document children's engagement levels with educational robots, coding platforms, or AI-enhanced science activities, measure learning gains on specific skills, and explore developmental appropriateness of various tools and approaches (Ji et al., 2025; Joseph et al., 2024; Villarosa, 2024). However, individual pilot programs often succeed due to exceptional teacher commitment or extensive external support; broader adoption requires systematic attention to teacher preparation. While these applications show promise, the research literature remains heavily focused on child-facing outcomes (Ji et al., 2025; Joseph et al., 2024; Villarosa, 2024). This focus creates a gap between knowing what works for children and knowing how to equip teachers to implement it effectively.

Research Gaps and Study Rationale

This study is grounded in the Technology Acceptance Model (TAM), which provides a key theoretical framework for understanding how users come to accept and use technology. The TAM model explains the processes related to individuals' acceptance and adoption of new technologies based on their perceived usefulness and perceived ease of use (Davis, 1989; Özkaynar, 2024). This model provides the theoretical framework for analyzing Research Question 4, allowing us to interpret teachers' qualitative opinions and reflections on adopting this new AI-STEM-flipped learning paradigm. Therefore, this study makes an original contribution to the literature by applying TAM in this novel context.

This review highlights a significant gap: a lack of studies on teacher professional development for AI-STEM integration at the preschool level. While previous studies have

examined student-facing outcomes like AI awareness (Ji et al., 2025) and computational thinking (Huang & Qiao, 2024), this study offers a novel perspective by shifting the focus to preschool teachers' skills and awareness. This study is innovative as it is the first to integrate AI-STEM training with the online flipped learning model. The study's originality is also found in its holistic approach, considering computational thinking and innovative thinking skills together. The use of both qualitative and quantitative data enables understanding the objective reflections of teachers' opinions in the field. Therefore, the study can contribute not only theoretically but also to education policies and teacher training. This focus on integrated teacher training for the preschool level aims to fill this critical gap, ultimately contributing to better student outcomes in this age group.

Research Questions

Accordingly, this study poses the following research questions:

1. What is the effect of STEM-AI applications in the online flipped learning model on preschool teachers' AI awareness?
2. What is the effect of STEM-AI applications in the online flipped learning model on preschool teachers' innovative thinking skills?
3. What is the effect of STEM-AI applications in the online flipped learning model on preschool teachers' computational thinking skills?
4. What are the reflections of STEM-AI applications in the online flipped learning model on preschool teachers' opinions about AI?

To address these research questions, an embedded mixed-methods study was designed wherein quantitative measures assess skill development outcomes while qualitative interviews explore teachers' perceptions and experiences. The following section describes the methodology employed to investigate these questions.

Methodology

Research Design

This study used interpretive and experimental paradigms to reveal all study dimensions (Twining et al., 2017). The research question "How do STEM and AI integration applications in the online flipped learning model affect preschool teachers' AI awareness, computational thinking skills, innovative thinking skills, and opinions?" was addressed to determine the experimental and interpretive paradigms of the study. The study used an embedded mixed design from mixed research methods to examine this question. The quantitative dimension was conducted using a pre-test post-test quasi-experimental model without a control group, while a case study was used in the qualitative dimension. The main reason for choosing a control group-free experimental design for the quantitative dimension is that single-group experimental design is preferred in research where a new educational module is developed and implemented, which is in the nature of the research (Creswell, 2012). Within the scope of the study, quantitative data were collected through scales while qualitative data were collected through interview forms.

Participants

After the criterion sampling method was determined for participant selection, the training process was announced via online platforms. During the application, the 90% attendance requirement, the training process, and the interview protocols were included. As a result of the announcements made on the online platform, all teachers who voluntarily participated in the training process were accepted. While forming the study group of the research, criterion sampling method, one of the purposeful sampling methods, was used. In this method, criteria can be determined by the researchers (Marshall & Rossman, 2014). The critical cases to be determined as criteria within the scope of the research are an important factor in achieving the research's aim (Flick, 2014). However, the critical cases to be determined must be compatible with the aims of the research (Creswell & Clark, 2016). Research depends on the good determination of critical cases (Grix, 2010). Therefore, within the scope of this study, the course participation rate for participants was determined as 90%. Because, according to Yaşar and Balkis (2004), it is emphasized that those who do not attend the course and those who attend intermittently cause incomplete learning of the subject. For example, Kaplan (2009) revealed in his study that there is a direct correlation between the academic achievements of individuals who attend the course. For this reason, the criterion was determined as preschool teachers' participation in at least 90% of the training given in the online flipped learning model and full participation in 11–13 weeks of the education process. A total of 50 people participated in the training process, of these people, two dropped out after the first two weeks, and another 6 people attended 60%. On the other hand, 8 teachers were not included in the study because they could not complete the process. For this reason, 8 people who did not meet the attendance requirement were removed from the data collection process. The study group of the research consists of 42

preschool teachers. Of the participating teachers, 39 were female and 3 were male teachers. Of the teachers participating in the training process, 36 work in public schools while 6 teachers work in private schools. While the experience of 26 of the teachers participating in the training is between 1 and 10 years, the experience of the remaining 16 teachers varies between 11 and 20 years. The age range of the teachers participating in the study varies between 24 and 47.

Data Collection Tools

Innovative Thinking Tendency Scale for Preschool Teachers

The Innovative Thinking Tendency Scale for Preschool Teachers was developed by Bilir (2021) to measure the innovative thinking tendencies of preschool teachers. This scale, which is one-dimensional and consists of 10 items, has a five-point Likert type as "not suitable for me at all" (1), "not suitable for me" (2), "somewhat suitable for me" (3), "largely suitable for me" (4) and "completely suitable for me" (5) and there are no reverse items in the scale. According to the results of Exploratory Factor Analysis, the explained variance ratio was 38% and the Cronbach Alpha coefficient was 0.85. When the Confirmatory Factor Analysis results were examined, CMIN/DF was calculated as 2.411, CFI value as 0.98, GFI 0.96, NNFI 0.97 and RMSEA 0.059. When test-retest reliabilities were examined, it was concluded that the reliability in terms of stability was 0.92 high. In this case, it was seen that the validity and reliability of the measurements obtained with the "Innovative Thinking Tendency Scale" were at a high level (Büyüköztürk, 2016).

Artificial Intelligence Awareness Level Scale for Teachers

The "Artificial Intelligence Awareness Level Scale for Teachers" consists of 30 items with 5-point Likert type rating developed to measure teachers' awareness of AI. The scale consists of four sub-dimensions: AI Knowledge Level (10 items), Applications of AI in Education (8 items), AI and Ethics (7 items), and AI and Teacher Role (5 items). These sub-dimensions respectively measure participants' basic knowledge about AI, awareness of use in educational environments, sensitivity to ethical issues, and perceptions of effects on the teaching profession. The Cronbach's Alpha coefficients of the scale, which underwent validity and reliability analyses, vary between 0.82 and 0.91, and construct validity is supported by confirmatory factor analysis. The scale offers the opportunity to evaluate the educational awareness level regarding AI with high reliability.

Computational Thinking Skill Levels Scale

Within the scope of the study, the computational thinking skill levels scale was used. Within the scope of the study, before the computational thinking scale was used, its reliability was examined. Within the scope of the study, as a result of the scale's reliability being 0.88, it was decided to use the scale in the study. No language change was made during the reliability process of the scale. The scale was developed by Korkmaz et al. (2017). The Scale is a scale consisting of 29 items with a five-point Likert type developed to measure university students' computational thinking skill levels. The scale is grouped under five factors: creativity, algorithmic thinking, cooperativity, critical thinking, and problem solving. As a result of psychometric analyses, the scale was determined to be valid and reliable. The Cronbach Alpha reliability coefficient is generally 0.809. It was observed that university students' computational thinking skills are generally high, but problem-solving skills are at a lower level compared to other factors. The scale is a suitable tool for evaluating these skills and using them in education. Also, In this context, this scale was applied to university students. Since this age group includes adults, it was also used in this study. In this regard, the reliability of the scale was examined.

Semi-Structured Interview Form

Semi-Structured Interview Form Within the scope of the study, qualitative data were collected via an interview form. For the interview form, first, a question pool was created. To create the question pool, a literature review was conducted. After the literature review, the question pool was created. The created interview form was evaluated by three experts holding doctoral degrees in the fields of STEM education, AI, and preschool education. The interview form was revised in line with the opinions received from the experts. To determine if there were any unclear parts in the interview form, the interview form was sent to 2 teachers. The interview form took its final shape in line with the feedback received from the teachers. As a result of these steps, the interview form consisted of six questions (See Appendix 1).

Education Process

STEM-AI applications in the online flipped learning model were implemented for preschool teachers in a 13-week education process throughout one semester. The education process was planned in accordance with the online flipped learning model: (1) watching conceptual videos related to the topic before class, (2) doing practical and applications related to the watched videos during class, and (3)

preparation for the next class. In the process of teaching conceptual topics to be taught in the education process, the first four weeks after the orientation and pre-test week focused on conceptual knowledge and applications related to AI. In the second four weeks, while focusing on conceptual topics and applications related to STEM education, the next two weeks focused on the AI-STEM integration process. In the last two weeks, teachers did and presented their own work. In this process, teachers developed and presented lesson plans suitable for AI-STEM integration. The curriculum containing STEM-AI applications in the online flipped learning model is shown in Table 1.

For example, for the implementation of AI-STEM applications in the classroom, teachers first decided on the topic related to the lesson plan they would prepare and then developed their lesson plans. In this process, while teachers were developing their lesson plans, they started to create lesson plans in accordance with the 5E learning model after deciding on the topic. AI was also used while creating lesson plans. In this way, it was aimed to benefit from AI in the development process of lesson plans. While the lesson plan process was being developed, teachers first used a thematic approach to establish the connection of the topic they determined with STEM areas. As a result of the thematic approach, interdisciplinary connections were established. After establishing interdisciplinary connections, a problem situation that could be encountered in daily life related to the engineering field was determined. AI was also used in the process of storytelling the determined problem situation. On the other hand, teachers also received support from AI in the process of developing assessment tools they would use in the assessment part of the education process. Teachers used different AI tools in the process, especially for lesson plans, such as Gamma.app, ChatGPT 4o, Gemini 2.5 flash, Claude sonnet 3.7, Deepseek v3, Flux, and Kling. Regarding these tools used, teachers were trained during the process and were provided with the opportunity to apply the information they learned.

In the synchronous part of the 13-week training process, teachers found the opportunity to apply the information they learned about AI. In this process, when teachers encountered difficulties regarding the content they developed, they produced solutions to the points they struggled with by using AI tools. In this way, the teachers included innovative learning tools in the process. This also positively developed the teachers' innovative thinking. On the other hand, besides the difficulties experienced in the process of developing practice-oriented content for the preschool period, teachers also utilized AI tools at points where they struggled with the integration of different fields in STEM education. Indeed, when the literature is examined, it is emphasized that preschool teachers do not have sufficient knowledge about STEM fields and, consequently, exhibit negative attitudes towards STEM education (Jamil et al., 2018). Moreover, Yıldırım (2021) emphasized in his study that preschool teachers experienced difficulties in integrating STEM fields, and this stemmed from their lack of knowledge regarding STEM fields. Indeed, within the scope of this study as well, teachers utilized AI tools at points where they struggled and produced solutions to the problems they encountered. This may have enabled the development of teachers' computational thinking skills.

Data Analysis

Quantitative Data Analysis

Parametric tests were used in the analysis of quantitative data since the collected data showed normal distribution. Inductive content analysis method was used in the analysis of qualitative data.

Table 2 shows that the Shapiro-Wilk test results for pre-test and post-test scores related to innovative thinking, AI awareness, and computational thinking skills, along with skewness and kurtosis values, are between −2 and +2. This indicates that the data are normally distributed and the use of parametric tests is appropriate (George & Mallery, 2010; Tabachnick & Fidell, 2013).

Qualitative Data Analyses

Prior to data collection, participants were briefed on the interview process. Subsequently, the interview protocol was administered, and semi-structured interviews were conducted. The resulting qualitative data were analyzed using the inductive content analysis method (Patton, 2014). This process follows four distinct stages: (1) creation of transcripts, (2) analysis of transcripts, (3) creation of themes and codes, and (4) tabulation and interpretation of themes and codes (Yıldırım & Şimşek, 2016).

To ensure the validity of the analysis, the transcripts were first reviewed by two independent experts who hold doctoral degrees in STEM and AI education. These experts analyzed the transcripts separately to generate initial themes and codes. Following their independent analyses, the experts convened to discuss their findings; any codes or themes that could not be agreed upon were removed from the study. The final structure was established based on the consensus reached by these two experts. To enhance clarity and support the findings, direct quotations from participant views were selected to illustrate the finalized themes. Finally, to ensure rigorous reliability, a third expert—specializing in preschool education with specific expertise in STEM and AI—audited the tabulated themes and codes.

Table 1 Education process related to the study

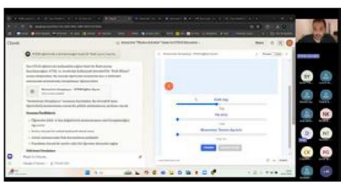
Week	Education Process	Description
	Pre-Application	Providing information about the education process to teachers participating in the education process, reading protocols related to data collection and ethics. After reading the necessary information and protocols, collecting pre-test data.
Weeks 1-4	General information about AI; Introduction of AI tools; AI ethics, privacy and security issues; AI integration into education; AI sample applications	In these lessons, basic information about AI was learned asynchronously and AI tools were introduced. Synchronously, AI and AI tools applications were emphasized. Within the scope of this lesson, videos about integrating AI into the education process were watched. In face-to-face training, applications on the integration of AI tools into education were carried out. 
Weeks 5-8	Conceptual dimension of STEM	Within the scope of these lessons, STEM education was approached holistically.

Table 1 (continued)

	education, application dimension, STEM education sample applications.	While conceptual dimensions were addressed asynchronously, the application dimension was carried out synchronously.
Weeks 9-10	AI-STEM integration	The joint integration of AI and STEM education was emphasized. Within the scope of this lesson, teachers were asked to make applications on how to use STEM education and AI in the education process. Conceptual lessons on combining AI and STEM education were carried out asynchronously, and applications for combining them were carried out synchronously.
Weeks 11-13	AI-STEM integration sample lesson plan and applications by participants	Within the scope of these lessons, synchronous development of sample lesson plans and applications for the implementation of AI-STEM integration in the classroom by teachers was emphasized.
	Post-application: Collection of data after applications.	

Visuals on the education process are embedded in the Table

This multi-stage verification process ensured the reliability and accuracy of the qualitative analysis.

Reliability and Validity

The data collection tools used in this study consist of previously developed scales whose validity and reliability have been proven psychometrically. The construct validity of the scales has been supported by confirmatory factor analyses; the high internal consistency levels have increased the scientific reliability of the obtained data (Büyüköztürk, 2016). This situation shows that the measurement tools adequately represent the characteristics they want to measure within the scope of the research. The internal validity of the study was ensured by conducting the educational application in accordance with systematic planning and by enabling all participants to access the same educational content and applications simultaneously. The controlled conduct of the

Table 2 Shapiro–Wilk normality test results for pre-test (1) – post-test (2) scores

Measurement Tool	Phase	Shapiro–Wilk	Skewness	Kurtosis
Innovative thinking	Pre-Test	0.944	0.116	0.906
Innovative thinking	Post-Test	0.860	−1.084	0.587
AI awareness	Pre-Test	0.923	0.940	1.972
AI awareness	Post-Test	0.962	−0.301	0.630
Computational thinking	Pre-Test	0.965	−0.229	0.439
Computational thinking	Post-Test	0.963	−0.377	−0.238

application process for participants allowed the measured variables to be associated only with the research process. Thus, data were obtained in an environment where external influences were minimized (Creswell, 2012). When evaluated in terms of external validity, the selection of the sample group according to certain criteria makes it possible to make meaningful inferences for teacher groups with similar characteristics (Yıldırım & Şimşek, 2022).

Findings

In this section of the research, the data collected for the study are presented. The findings related to the first, second, and third research questions of the study are given in Table 3, while the findings for the fourth research question are given between Tables 4 and 9.

Regarding AI awareness, Table 3 shows that there is a significant increase in teachers' AI awareness levels after the application ($t(41) = -4.815$; $p < .001$). While the average awareness score of teachers was 190.00 in the pre-test, this score increased to 212.64 in the post-test. This finding shows that teachers became more conscious in different dimensions such as knowledge about AI, ethics, applications in education, and teacher roles. Cohen's d value was calculated as 0.743, and this value indicates a large effect size. This result shows that the AI content in the online flipped learning model is quite effective in increasing teachers' awareness.

Regarding innovative thinking, Table 3 shows a significant increase in teachers' innovative thinking skills after the application ($t(41) = -6.024$; $p < .001$). The innovative thinking score, which was 41.97 on average in the pre-test, increased to 46.57 in the post-test. This finding reveals that teachers showed development in creative thinking, problem solving, and innovative idea generation. Cohen's d value is 0.929, indicating that this increase is highly effective. This situation supports the contribution of teachers' active participation in the education process and applied activities to innovative thinking skills.

Regarding computational thinking, Table 3 shows a significant difference between before and after the application in computational thinking skills and the scores increased ($t(41) = -4.48$; $p < .001$). The score, which was 119.00 on average in the pre-test, increased to 128.35 in the post-test. This increase shows that teachers made progress in algorithmic thinking, problem solving, collaboration, and critical thinking skills. Cohen's d value is 0.693, indicating a medium level effect. These findings reveal that STEM-Al applications in the online flipped learning model are effective in developing teachers' computational thinking skills.

The observation of significant development in all three skill areas (AI awareness, innovative thinking, computational thinking) shows that the online flipped learning model provides a holistic contribution to the professional development of preschool teachers. This model is evaluated as an effective method for teachers to strengthen both their individual and professional competencies.

Table 4 Teachers' Opinions on STEM-AI applications meeting expectations

Theme	Code
Meeting expectations	My expectations were met ($n = 34$)
	Not met ($n = 7$)
	Partially met ($n = 1$)

Findings Related to the Fourth Research Question

In the fourth research question of the study, the reflections of STEM-AI applications in the online flipped learning model on preschool teachers' opinions about AI were examined.

When Table 4 is examined, it is understood that most preschool teachers' expectations were met by the applications.

Table 3 Dependent samples t-test results for AI awareness, innovative thinking, and computational thinking scores

Variable	Phase	*N*	M	SD	df	t	*p*	Cohen's d
AI awareness	Pre-Test	42	190.00	21.44	41	−4.815	0.001*	0.743**
	Post-Test	42	212.64	22.64				
Innovative thinking	Pre-Test	42	41.97	4.89	41	−6.024	0.001*	0.929**
	Post-Test	42	46.57	3.63				
Computational thinking	Pre-Test	42	119.00	13.68	41	−4.48	0.001*	0.693**
	Post-Test	42	128.35	10.82				

*$p < .05$. **Large effect size

In addition, it is understood that some teachers' expectations were not met at an adequate level by STEM-AI applications.

When Table 5 is examined, preschool teachers see AI as a machine that imitates humans, a computer-controlled machine, and a field related to computer systems. Examples of participant views are as follows:

T1: A field that can be used in many areas, which imitates human intelligence with the developments in computer science and can perform coded situations.

T5: It makes the human load that eases life even more effective in the technological environment.

T7: The machine's generation of thought by rapidly bringing together certain algorithms.

T11: A computer-controlled robot doing what entities want.

When Table 6 is examined, preschool teachers emphasized that AI is connected to topics such as programming, machine learning, and deep learning. Examples of participant views are as follows:

T13: Anything we teach the algorithm can constitute the subject.

T15: Computer learning simulation deep learning machine learning.

T17: It consists of security, cyber, language translation programs, navigation systems to provide people with easier accessibility.

T18: Machine learning, deep learning, robotics.

When Table 7 is examined, preschool teachers emphasize that AI has different benefits such as making human life easier, data processing/interpretation, and accelerating technological developments. Examples of participant views are as follows:

T20: The basic principle of technology is to make human life easier. The reason for AI's existence is also to make human life easier.

T21: To save time and manpower.

T22: It exists to put people in a passive situation. To reduce human production.

T27: To make work faster and easier.

Table 5 Preschool Teachers' Opinions on AI Applications

Theme	Code
Opinions about AI	Machine that imitates humans ($n=32$)
	Computer-controlled machine ($n=15$)
	A field related to computer systems ($n=8$)
	Technology that makes life easier ($n=3$)
	Has machine learning ($n=2$)

*Participants may have responded more than once for each question

Table 6 Topics Connected to AI

Theme	Code
Topics connected to AI	Programming ($n=24$)
	Machine learning ($n=13$)
	Deep learning ($n=11$)
	Robotic technology ($n=9$)
	Science ($n=5$)
	Cybersecurity ($n=4$)
	Mathematics ($n=3$)
	Virtual assistants ($n=1$)

*Participants may have responded more than once for each question

Table 7 Opinions on the Benefits of AI

Theme	Code
Benefits of AI	Making human life easier ($n=42$)
	Data processing and interpretation ($n=10$)
	Accelerating technological developments ($n=8$)
	Facilitating production ($n=2$)
	Reducing human power ($n=2$)
	Developing people's competencies ($n=2$)

*Participants may have responded more than once for each question

Table 8 Teacher Opinions on designing AI applications in preschool

Theme	Code
Designing AI applications in preschool	Matching student level ($n=24$)
	Should be suitable for voice commands ($n=12$)
	Simple to complex principle ($n=11$)
	Privacy/Security principles ($n=8$)
	Ethical principles ($n=7$)
	Entertaining ($n=2$)
	Being attention-grabbing ($n=2$)
	Should be supported with concrete materials ($n=2$)

*Participants may have responded more than once for each question

When Table 8 is examined, preschool teachers emphasized that when designing AI applications in preschool, attention should be paid to matching the level of students, being suitable for voice commands, simple to complex, privacy/security and ethical principles compliance. Examples of participant views are as follows:

T30: Designs can be made with simple robots, appropriate for the child's age development.

T32: I think that the basic logic needs to be established by following a path from simple to complex.

T33: Sound sensitivity and cognitive comprehension skills should be taken into account.

T35: It should be designed in a fun way, appropriate for their age levels.

T37: It must be possible to give verbal commands, and it should be able to analyze the commands taking the children's ages into account.

When Table 9 is examined, it is understood that preschool teachers have different security/privacy concerns about using AI in preschool. Teachers have concerns especially about the use of images, use of personal data, wrong guidance, and leaking of information regarding privacy. *Examples of participant views are as follows*:

T21: My concern about this subject is [it] accessing children's pictures.

T27: I have concerns that the shared data and images could be used for different purposes. I am not sure about privacy and reliability.

T39: If precautions are not taken for children's images, voices, photos, private spaces, and personal information, they can be used, published, and shared in very bad places for bad purposes.

T40: I think necessary confidentiality measures should be taken in information sharing. Attention must be paid to security so that information about children is not shared.

When the quantitative and qualitative findings obtained in the study are evaluated holistically, it is observed that there is a significant and mutually supportive relationship between the teachers' measured skill developments and the views they expressed. While quantitative findings reveal that teachers demonstrated a significant increase in their AI awareness, innovative thinking, and computational thinking skills; qualitative data show that this development aligns with the perceptions and experiences related to the process. Teachers' definition of AI as "a tool that facilitates creativity, problem-solving, and innovative thinking" supports the cognitive and affective foundations underlying the quantitative increase in these skills.

Furthermore, the teachers' active use of AI tools (e.g., ChatGPT, Gemini, Gamma.app, etc.) during the implementation process enabled them to gain autonomy in the learning process and develop innovative solutions in their own instructional designs. This situation indicates that teachers experienced a transformation not only at the knowledge level but also at the pedagogical and applied levels. The significant increases observed in the quantitative data parallel the prominent themes in the qualitative findings (active participation, collaboration, creativity, problem-solving). Therefore, this holistic analysis, where quantitative and qualitative results complement each other, strengthens the study's internal validity and reveals that the STEM-AI based online flipped learning model creates a multidimensional impact on the cognitive, affective, and professional development of preschool teachers.

Table 9 Security/privacy concerns about using AI in preschool

Theme	Code
Security/Privacy concerns	Use of images ($n=32$)
	Use of personal data ($n=17$)
	Leaking of information ($n=12$)
	Wrong guidance ($n=2$)

*Participants may have responded more than once for each question

Discussion

The first research question investigated the effect of STEM-AI applications in the online flipped learning model on preschool teachers' AI awareness. The analysis of quantitative data shows that these applications positively improved the AI awareness of preschool teachers. A review of the literature reveals no previous studies that examined the combined effect of the online flipped learning model, STEM education, and AI on AI awareness. However, there are studies that highlight the positive impact of online flipped learning, STEM, and AI on AI awareness when addressed separately or in pairs (Amdan et al., 2024; López-Villanueva et al., 2024; Villarosa, 2024). For example, Ji et al. (2025) found that using ChatGPT in STEM education courses positively developed students' AI awareness. Su et al. (2024) emphasized the importance of fostering awareness through AI integration in STEM education. Huang et al. (2023) noted that integrating AI into flipped classrooms improved students' learning and participation, thereby enhancing their awareness. Joseph et al. (2024) also found that AI tools positively influenced students' AI awareness. The results of this study align with those found in literature. Additionally, since this is the first study to examine the effect of STEM-AI applications in an online flipped learning model on AI awareness, its contribution to the field is significant. On the other hand, we can state that the participants' views show teachers' AI awareness developed positively. Because, Awareness can

be expressed as what information individuals have about a new subject, their taking responsibility for learning, and their planning and monitoring their own learning processes (Bağçeci et al., 2011). For this reason, it can be stated that in line with the teachers' views, their awareness regarding AI developed positively. So, the qualitative findings and quantitative findings of the study overlap with each other.

The second research question explored the effect of STEM-AI applications in the online flipped learning model on preschool teachers' innovative thinking skills. The analysis of quantitative data indicates that these applications had a positive impact on teachers' innovative thinking skills. Not enough studies were found in the literature that examined the combined effect of the online flipped learning model, STEM education, and AI on innovative thinking skills. The novelty of this research lies in being the first to investigate the effects of STEM-AI applications on innovative thinking skills of teachers, thus contributing to the field. Barak et al. (2014) define innovative thinking as a cognitive process that leads to the implementation of significantly improved or new ideas. Innovative thinking skills encompass a variety of abilities such as problem-solving and creativity (Bilir, 2021).

The third research question focused on the effect of STEM-AI applications in the online flipped learning model on preschool teachers' computational thinking skills. The quantitative data analysis shows that these applications positively influenced teachers' computational thinking skills. There are no previous studies that examined the combined effect of the online flipped learning model, STEM education, and AI on computational thinking skills. However, there are studies that emphasize the positive impact of online flipped learning, STEM, or AI separately on computational thinking skills (Asunda et al., 2023). For example, Huang and Quia (2024) found that using STEAM and AI together improved computational thinking, motivation, and competence. Ameen et al. (2024) also reported a positive effect of AI on computational thinking skills. Similarly, Yılmaz and Yılmaz (2023) found that AI increased students' computational thinking, programming self-efficacy, and motivation. These findings are consistent with the results of the present study. In summary, integrating STEM education and AI has a positive effect on computational thinking skills. On the other hand, when teachers' views are examined, we see that the applications had a positive effect on teachers' computational thinking skills. Because, teachers expressed that AI is connected with deep learning, machine learning, programming, and robotic technologies. Teachers think that AI is a technological development that copies humans. These views of the teachers show that the teachers' computational thinking developed positively. This shows that the qualitative results and quantitative results of the study support each other.

The fourth research question examined the reflections of STEM-AI applications in the online flipped learning model on preschool teachers' views about AI. Most preschool teachers stated that these applications positively met their expectations. They emphasized that AI is a machine that imitates humans, a computer-controlled machine, and a field related to computer systems. Additionally, teachers highlighted AI's connections with topics such as machine learning, deep learning, programming, and robotics technologies. Mazı and Yıldırım (2025) found that teachers defined AI as a type of information technology, and similar findings were observed in other studies (e.g., Mart & Kaya, 2024). Teachers also pointed out various benefits of AI, such as making life easier, data processing/interpretation, and accelerating technological advancements. When designing AI applications for preschool, teachers stressed the importance of appropriateness to student level, suitability for voice commands, progression from simple to complex, and adherence to privacy, security, and ethical principles. Teachers expressed concerns about the use of images, personal data, and the potential for misinformation, which aligns with findings in the literature (e.g., Lamanauskas, 2025; Nissim & Simon, 2025). For instance, Kölemen and Yıldırım (2025) highlighted that using AI in early childhood education could lead to privacy and security concerns due to issues like unprotected personal data, use of children's photos, and misleading information. Ouyang and Jiao (2021) emphasized that the use of AI in education raises privacy and security issues. Chounta et al. (2022) pointed out that the collection, storage, and use of student data could create privacy and security problems. It is also stressed that countries should develop policies to address ethical, privacy, and security concerns related to AI (Kölemen & Yıldırım, 2025; The State Council of the People's Republic of China, 2017; Yang & Huang, 2022).

When teacher opinions regarding STEM-AI applications in the online flipped learning model are examined, it can be stated that the teachers' views have a holistic structure. Because, teachers emphasized that the applications met their expectations (See Table 4). These views of the teachers can explain the development of AI awareness, innovative thinking, and computational thinking skills. This shows that both qualitative and quantitative results overlap with each other. On the other hand, when teachers' views are examined, it shows that teachers perceive AI as a machine that is a computer product and imitates humans (See Table 5). These views can be interpreted as the teachers' awareness regarding AI having developed at a limited level. This situation also overlaps with the subjects with which teachers

associate AI (See Table 6). Teachers generally associate AI with machine learning, deep learning, and programming. This can also be interpreted as the teachers' awareness regarding AI having developed at certain points. Therefore, teachers' definitions regarding AI and their associations regarding AI are connected to each other. Moreover, teachers emphasized that AI facilitates life and the data processing/interpretation process (Table 7). This situation can be interpreted as teachers thinking AI could be beneficial in facilitating teaching-learning processes within the classroom. However, the fact that teachers have concerns regarding privacy and security (See Table 9) alongside their positive views regarding AI shows that teachers perceive AI as a technological development that is beneficial but has risks. This situation also overlaps with the literature. On the other hand, teachers' views emphasized situations such as appropriateness for developmental level, voice command support, and use of concrete materials in the design of AI in the preschool period. This situation shows that teachers see AI not only as a tool but also as a natural stimulus of the learning environment. When looking at teachers' views in a holistic way, it shows that teachers have awareness regarding AI and at the same time it is important in their pedagogical processes. On the other hand, teachers' concerns regarding the use of data, access to data, and misuse of data may have affected the meeting of teachers' expectations regarding AI applications (Table 4). This result overlaps with what teachers emphasized in the process regarding the design process of AI in the preschool period (See Table 8).

In summary, STEM-AI applications in the online flipped learning model have a positive effect on preschool teachers' AI awareness, innovative thinking skills, computational thinking skills, and views towards AI. These results overlap with the results obtained in the literature. Moreover, these results will also form a basis for future STEM-AI applications in the online flipped learning model.

Recommendations

In light of the quantitative and qualitative results obtained in this study, different recommendations have been made for future studies. Within the scope of the study, it was determined that STEM-AI applications in the online flipped learning model developed teachers' AI awareness, innovative thinking, and computational thinking skills. For this reason, in order to develop preschool teachers' knowledge and skills regarding AI, the development of AI-supported lesson plan creation tools, AI-supported planning tools, and professional development modules related to 'AI-STEM early childhood activity design' can be ensured. Another recommendation within the scope of the study relates to the qualitative results obtained from the teachers' views. It was determined that preschool teachers emphasized different features of AI such as being entertaining, appropriateness for children's level, ethics, and security. Therefore, in order for preschool teachers to include AI-STEM applications, data protection guidelines for AI applications, and guides regarding safe data usage and the security of digital environments can be developed. With these guidelines and guides to be developed, teachers' professional development regarding issues related to privacy and security will also be ensured. Moreover, it is understood that preschool teachers have concerns regarding security and privacy related to AI. For this reason, in order for preschool teachers to include AI in the preschool period, countries should make regulations in their AI policies by taking these concerns of teachers into account, and it would be appropriate to organize professional development programs. Furthermore, studies involving teachers of different branches can also be conducted to reveal the effects of STEM-AI applications in the online flipped learning model within the scope of the study. Moreover, due to the study being conducted for a short duration, in future studies, it is recommended to conduct long-term observation studies to see the reflection of the results of AI-STEM applications on in-class practices. Finally, the application of a new model, and the use of TAM, which forms the theoretical basis of the study and where teachers' views on the applied model are consulted, in studies related to the early childhood period, can be used to reveal the integration process of new technological processes integrated into the teachers' education process.

Limitations

The first limitation of this study is that the study was conducted with a quasi-experimental design without a control group, and the study does not include a control group. The absence of a control group within the scope of the study may mean the changes obtained could also STEM from the maturation effect. This situation may limit the generalization of the study. The second limitation is that individual differences in access among teachers participating in the online flipped learning model may have affected the teaching process and learning outcomes. The third limitation of the study relates to the motivation and willingness of the teachers participating in the study regarding their participation in the training process. The preschool teachers participating in the study were willing and had high motivation to learn STEM-AI applications. The fact that teachers' willingness and motivation towards STEM-AI applications were high may affect the teachers' views. This may cause a positive bias in the results. The fourth limitation of the study is that although teachers developed their AI awareness, innovative thinking, and computational thinking skills in a short time

within the scope of the study, the fact that a long-term study was not conducted is another limitation.

In this research, the study group was determined by criterion sampling, one of the purposeful sampling methods. The main criterion determined for the selection of participants was at least 90% attendance in the online Flipped Learning training process and active participation in the entire education process. Although this criterion was deemed necessary for participants to experience the process effectively, it limits the generalizability of the research findings. Because in this case, only teachers who provided regular attendance in the course and had high motivation were included in the research.

Furthermore, since participation in the training process was based on voluntariness, the attitudes of the teachers participating in the research towards technology, online learning, or professional development may be more positive. As this situation could lead to potential selection bias, the direct generalization of the obtained findings to the entire teacher population should be evaluated carefully. On the other hand, although 50 teachers were included in the research process, the data of 8 teachers who could not meet the 90% attendance condition were excluded from the analysis. This situation also led to the sample size being limited. Therefore, it is recommended for future similar research to work with larger samples and different teacher groups for the validity and generalizability of the findings.

Conclusion

As a result of the study, STEM-AI applications in the online flipped learning model had a positive effect on developing preschool teachers' AI awareness, innovative thinking skills, and computational thinking skills. Teachers participating in the study expressed that they have different definitions of AI, such as a machine that copies humans or a computer-controlled machine. Teachers stated that AI is connected with different fields such as machine learning, programming, and robotic technologies. Teachers emphasized that AI has different benefits such as making life easier, accelerating technological developments, and data processing/interpretation. Teachers also emphasized that when planning AI applications in the preschool period, they should be designed to be appropriate for the students' level, be entertaining, and pay attention to privacy, security, and ethical situations. Moreover, teachers revealed that they also have different privacy and security concerns related to the use of AI in the preschool period, such as the use of pictures, access to personal data, the inability to protect personal information, and misinformation.

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Data Availability The datasets generated during and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethical Considerations The data for this study were collected voluntarily from teachers. I am grateful to all the teachers who participated in this process.

Conflict of Interest The authors have no competing interests to declare that are relevant to the content of this article.

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