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Integrating artificial intelligence into preservice teacher education: enhancing AI literacy and digital material design competency

Hilal Nur Gulen[1] · **Sevda Kucuk**[2]

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Abstract

The rapid advancement of Artificial Intelligence (AI) has transformed educational tools and practices. Integrating AI into instruction supports complex thinking, enriches teaching, and helps educators in material creation and visualization. Therefore, it is essential to equip both students and educators with AI literacy and digital material design competencies in order to support pedagogically sound and ethically responsible instructional practices. Within this context, the present study examines the extent to which an AI-integrated instructional technology course influences pre-service teachers' AI literacy and digital material design competencies, as well as their perceptions and experiences of learning within an AI-integrated instructional environment. Using a mixed-methods approach, 50 pre-service social studies teachers (41 female, 9 male) participated in a semester-long course. Data were collected through the Artificial Intelligence Literacy Scale, Digital Material Design Competency Scale, and semi-structured interviews. Paired sample t-tests indicated significant gains in both AI literacy and digital material design competencies, with large effect sizes. Qualitative and quantitative findings showed that AI tools not only improved technical abilities but also enhanced pedagogical thinking. The study highlights the importance of AI-integrated curricula in preparing future teachers for modern educational challenges.

Keywords AI Literacy · Digital material design · Pre-service teachers · Instructional technology · Artificial intelligence integration

✉ Sevda Kucuk
s.sevdakucuk@gmail.com; sevdakucuk@atauni.edu.tr

Hilal Nur Gulen
h.nurgln61@gmail.com; hilalnurgulen@bayburt.edu.tr

[1] Distance Education Application and Research Center, Bayburt University, Bayburt, Türkiye

[2] Department of Instructional Technology Kazim Karabekir Education Faculty, Ataturk University, Erzurum, Türkiye

1 Introduction

The field of education has historically evolved alongside technological advancements (Casal & Kessler, 2023). In recent years, the rapid development of Artificial Intelligence (AI) and its integration into educational contexts have sparked a profound transformation in teaching and learning paradigms. The increasing use of AI in education has led to continual changes in learning environments, instructional materials, and teaching resources (Korte et al., 2024). AI technologies enhance teaching and learning through functions such as personalised learning, automated feedback, adaptive instruction, content development, virtual education, and intelligent tutoring systems (Aldosari, 2020). Educational institutions are gradually adopting these technologies in various formats (Chen et al. 2020a, b, c).

By enabling dynamic and personalised learning experiences tailored to students' abilities, prior knowledge, and course requirements, AI fosters more responsive and effective educational environments (Wang & Wang, 2024). In this context, the effective use of AI-supported tools enhances teachers' pedagogical practices and permits better instructional design. However, successful implementation critically relies on both students' and teachers' AI literacy. From a teacher education perspective, enhancing AI literacy is crucial for effectively integrating AI into classroom practices. Research has demonstrated that teacher candidates need a greater awareness and more informed perceptions of AI (Vazhayil et al., 2019). Therefore, AI literacy and integration competencies must be cultivated through well-structured higher education courses for pre-service teachers. However, the literature still lacks consensus on how these training programs should be developed (Lee et al., 2022). Nonetheless, promoting AI literacy through pre-service and in-service training, along with hands-on experiences with AI technologies, is crucial for enhancing educational quality and efficiency (Chen et al. 2020a, b, c; Kong et al. 2021a, b; Nazaretsky et al. 2022; Salas-Pilco and Yang 2022).

This study focuses on improving pre-service teachers' AI literacy and their capacity to utilise AI technologies in designing digital instructional materials. An applied course was developed for this purpose, and the effects of the instructional process on students were analysed using an experimental design.

1.1 Conceptual framework

AI literacy is regarded in the literature as an interdisciplinary concept linked with other types of literacy, such as digital literacy, media literacy, and data literacy. In this context, AI literacy not only encompasses the ability to use technology for communication, learning, and performing everyday tasks but also includes a set of cognitive and technical competencies that enable individuals to critically evaluate AI technologies and communicate and collaborate effectively with AI systems (Laupichler et al., 2022; Long & Magerko, 2020; Verma et al., 2021). These components of AI literacy empower individuals to use AI applications consciously and effectively across online platforms, workplaces, and daily life (Ng et al. 2021). Several studies have proposed AI literacy frameworks that outline the essential competencies individuals should acquire (Laupichler et al., 2022). In this study, the framework presented by Wang et

al. (2022), which includes the dimensions of awareness, usage, evaluation, and ethics, was adopted to guide the development and assessment of pre-service teachers' AI literacy (Fig. 1).

Within teacher education, the development of AI literacy is closely related to broader frameworks of teacher knowledge integration. In particular, the Technological Pedagogical Content Knowledge (TPACK) framework emphasizes the dynamic interaction between technological, pedagogical, and content knowledge required for effective technology integration in teaching (Howard et al., 2021). As artificial intelligence technologies increasingly become embedded in digital learning environments, recent studies have begun to discuss how AI-related competencies may extend teachers' technological and technopedagogical knowledge domains, often conceptualized as AI-TPACK. From this perspective, teachers are expected not only to use AI tools but also to critically evaluate and pedagogically integrate them into instructional design and learning activities (Dilek et al., 2025; Zhang & Zhang, 2024). In this context, AI literacy may support teachers in selecting, evaluating, and pedagogically applying AI tools in instructional processes. Such competencies are particularly relevant for digital material design, as teachers must critically evaluate AI-generated content while ensuring pedagogical alignment with learning objectives.

1.2 Content production with GenAI tools

The advancement of Generative Artificial Intelligence (GenAI) technologies has significantly transformed content production processes, offering enhanced speed, efficiency, and personalisation compared to traditional methods. GenAI tools are widely used for various purposes, including generating text, images, videos, audio, and presentations, as well as designing interactive digital materials (Harjamäki et al., 2024). These tools empower users to streamline tasks, improve productivity, and create tailored content using natural language inputs and multimodal interfaces.

Some of the commonly used GenAI tools include ChatGPT, Gemini, Microsoft Copilot, Fliki, Canva, Gamma, and MagicSchool AI, which offer functionalities such as writing support, visual content creation, lesson planning, and interactive media development (Moundridou et al., 2024; Harjamäki et al., 2024). These tools not only

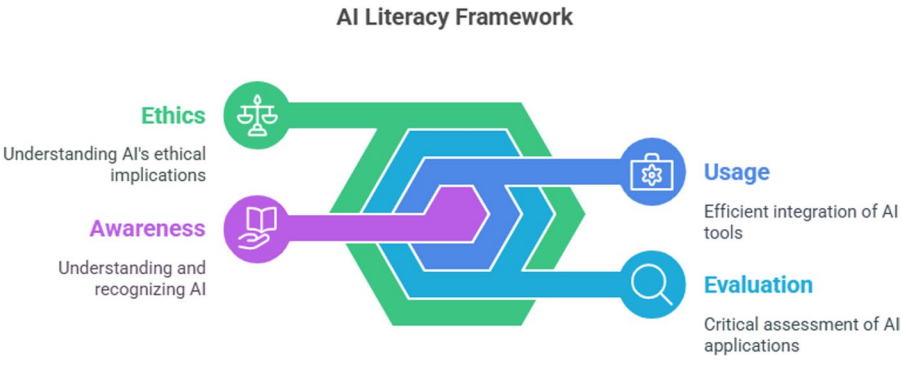

Fig. 1 AI literacy framework

assist in generating educational content but also support planning and personalisation, making them increasingly valuable in both academic and professional domains.

The use of GenAI tools for content creation enables teachers to become more effective and efficient in their profession (Kolchenko, 2018). The integration of AI technologies allows students to benefit from a safer and higher-quality learning environment supported by their teachers (Zhang & Aslan, 2021). Teachers are expected to utilise AI technologies in lesson planning, developing innovative assessment tools, and creating subject-specific instructional materials, with the goal of helping students realise their full potential (Dilek et al., 2025). Moreover, teachers' perceptions, attitudes, and levels of AI use influence the scope and effectiveness of the instructional activities they design for their students (Kolchenko, 2018). The use of AI tools also contributes to more effective classroom management (Bryant et al., 2020; Zhao & Liu, 2018). These tools assist teachers in reviewing students' past performances, monitoring their development, and improving current instruction (Siegle, 2023). In light of these impacts, it can be stated that the active use of AI tools by pre-service teachers, starting from their higher education years, is of great importance in enhancing the quality of education and increasing the efficiency of teaching processes.

1.3 Literature review

A review of the literature reveals that studies on AI literacy among teachers and pre-service teachers have predominantly focused on curriculum development (Chiu & Chai, 2020; Henry et al., 2021; Dai et al., 2023), teacher attitudes and perceptions (Ayanwale et al., 2022; Nazaretsky et al., 2022), AI ethics (Akgun & Greenhow, 2022; Gartner & Krasna, 2023), and professional development (DiPaola et al., 2023; Minami et al., 2019; Vazhayil et al., 2019). AI literacy programs and courses designed for higher education adopt interdisciplinary approaches, incorporating not only technical skills but also ethical and societal awareness (Luckin et al., 2022; Luo et al., 2022; Southworth et al., 2023). These initiatives aim to enhance students' academic performance and well-being (Dai et al., 2023), foster essential AI competencies (Long & Magerko, 2020), and support AI integration across different educational levels (Kandlhofer et al., 2016; Lee et al., 2022). Furthermore, several studies emphasise the need for tailoring these programs based on learners' individual competencies and experiences (Dilek et al., 2025; Ding et al., 2024) and highlight the interdisciplinary impact of AI literacy on academic outcomes, especially among students with diverse educational backgrounds (Kong et al. 2021a, b; Lin et al., 2021).

Regarding digital literacy, existing research among teacher candidates primarily explores their Pedagogical Content Knowledge (PCK), including the integration of content, pedagogy, and technology (Howard et al., 2021). Studies also indicate that digitally literate teachers are more inclined to participate in AI-related training (Yao & Wang, 2020), demonstrate improved problem-solving abilities (Quaicoe & Pata, 2020), facilitate more efficient teaching processes (Paetsch et al., 2023), and report enhanced self-efficacy (Lim, 2023) and professional commitment (Moreira-Fontán et al., 2019).

To the best of our knowledge, the existing literature does not yet include studies that comprehensively address pre-service teachers' AI literacy and digital material

design competencies within a practice-oriented instructional course model. Current research predominantly focuses on artificial intelligence literacy as a standalone construct. Upon examining the studies conducted, Ayanwale et al. (2024) investigated pre-service teachers' AI literacy levels and examined relationships among knowledge, ethical awareness, and problem-solving skills. Yi and Siquan (2025) explored the mediating role of AI literacy and self-efficacy in pre-service teachers' intentions to use AI. Erdem-Coşgun (2025) focused on the use of AI-based tools in assessment practices, while Sümer-Dodur (2025) examined AI literacy as a mediating variable in relation to personality traits and attitudes toward AI. Overall, these studies indicate a growing body of research on AI literacy; however, empirical studies that integrate AI literacy and digital instructional material design within a sustained, practice-based course context in pre-service teacher education remain limited.

1.4 Rationale and importance of the study

The rapid advancement of AI technologies has led to significant transformations in the field of education. As AI-driven tools become increasingly integrated into instructional processes, both students and educators are expected to develop strong AI literacy to navigate and utilise these technologies effectively. In response, AI literacy training is being introduced across various educational levels, from primary to higher education, accompanied by professional development initiatives for in-service teachers. However, while many studies focus on AI education for students or the design of general AI training programs, there remains a notable gap in research specifically addressing how to cultivate AI literacy within teacher education.

Equipping pre-service teachers, the educators of the future, with the competencies to use artificial intelligence in pedagogically sound and ethically responsible ways is essential for fostering effective AI-supported learning environments. In this context, the present study aims to propose and evaluate a course model designed to enhance pre-service teachers' AI literacy and their ability to produce AI-integrated instructional content. By embedding AI-focused activities into the existing Instructional Technology course, this study offers a practical framework for integrating AI into teacher education. The course implementation was evaluated using both quantitative and qualitative methods to provide a comprehensive understanding of its impact on pre-service teachers.

Accordingly, the aim of this study is to examine the impact of an AI-integrated instructional technology course on pre-service teachers' AI literacy and digital material design competencies and to explain these effects through their experiences and perceptions within an AI-supported instructional environment. In line with these objectives, the study sought answers to the following research questions:

- To what extent does AI-integrated instructional technology training influence pre-service teachers' levels of AI literacy?
- To what extent does AI-integrated instructional technology training influence pre-service teachers' digital material design competencies?
- What are pre-service teachers' experiences regarding an instructional technology course integrated with artificial intelligence tools?

2 Method

2.1 Research design

An explanatory mixed methods design was employed in this study (Creswell & Creswell, 2017). The Instructional Technology course was redesigned with AI integration, and its effects on pre-service teachers' AI literacy and digital material design competencies were investigated. The study employed a one-group pretest–posttest experimental design, which lacks a control group and therefore limits the extent to which observed changes can be attributed solely to the intervention. However, this design was deliberately selected due to ethical and curricular constraints inherent in teacher education. The intervention was implemented within a compulsory Instructional Technology course, making it neither ethically nor administratively feasible to exclude any participant from receiving artificial intelligence training. In line with the principles of equal learning rights and informed participation, all pre-service teachers were provided with the full AI-integrated instructional experience. While the absence of a comparison group restricts causal interpretations, it enabled the examination of participants' developmental changes within an authentic educational setting. The use of a mixed-methods approach enabled the combination of the strengths of both quantitative and qualitative methods throughout the research process while minimising potential limitations. The use of a mixed-methods approach has minimized potential limitations while enabling the combination of the strengths of both quantitative and qualitative methods throughout the research process (Yang et al., 2024). The study process was conducted sequentially. In the first stage, the focus was on the effectiveness of the intervention based on data collected through surveys using quantitative methods. In the subsequent qualitative stage, interviews were conducted to gain a more comprehensive understanding from participants and enrich the integrity of the findings.

2.2 Participants

The sample of the study consisted of 50 pre-service teachers (41 female, 9 male) enrolled in the Social Studies Teacher Education program at a public university located in the eastern region of Türkiye. The participants were first-year undergraduate students taking the "Instructional Technology" course during the spring semester. As the course was practice-based, the class was divided into two groups, both of which were instructed by the same course instructor and teaching assistant. The course was conducted in a computer laboratory where each pre-service teacher had individual access to a computer. For collaborative coursework, the pre-service teachers were divided into self-selected groups of 3–4 members. One semester after the intervention phase of the study, semi-structured interviews were conducted online via Zoom with eight randomly selected pre-service teachers (5 female, 3 male) to gather qualitative data. Ethical approval was obtained from the relevant institutional review board prior to conducting the study. Participation in the study was voluntary, and all pre-service teachers were thoroughly informed about the research process and provided informed consent prior to the study's commencement.

2.3 Data collection tools

2.3.1 Artificial intelligence literacy scale

To determine pre-service teachers' AI literacy levels, the AI Literacy Scale developed by Wang et al. (2022) and adapted into Turkish by Çelebi et al. (2023) was used. This 7-point Likert-type scale includes four dimensions: Awareness (3 items), Usage (3 items), Evaluation (3 items), and Ethics (3 items). The scale measures individuals' understanding of AI, ability to effectively use and evaluate AI technologies, and sensitivity to ethical concerns related to AI use. The reliability coefficients of the sub-dimensions range between 0.72 and 0.76, and the overall reliability (Cronbach's alpha) of the scale is 0.84, indicating good internal consistency.

2.3.2 Digital material design competencies scale

To assess pre-service teachers' digital material design competencies, the Digital Material Design Competencies Scale developed by Göçen-Kabaran and Uşun (2021) was used. This 5-point Likert-type scale consists of four dimensions: Design and Development Competence (9 items), Technical Competence (8 items), Technopedagogical Competence (8 items), and Implementation and Evaluation (6 items). The scale comprehensively measures teachers' abilities in designing, developing, implementing, and evaluating digital instructional materials. The reliability coefficients of the sub-dimensions range between 0.94 and 0.97, and the overall reliability (Cronbach's alpha) of the scale is 0.98, indicating excellent internal consistency.

2.3.3 Semi-structured interview form

To collect qualitative data, the researchers developed a semi-structured interview form. The questions were designed to examine pre-service teachers' AI literacy by addressing dimensions such as awareness, usage, evaluation, and ethical considerations. Additionally, the form included items designed to evaluate their perceived development in digital material design competencies and their ability to integrate digital technologies into educational processes. The interview questions were reviewed by two experts in educational technology and qualitative research to ensure their relevance, clarity, and alignment with the research objectives. The interview focused on how the AI-Integrated IT course influenced their competencies in these areas, encouraging participants to reflect on their awareness levels, usage experiences, and decision-making processes regarding AI tools, as well as their pedagogical adaptation of digital technologies.

2.4 Implementation

In this study, the Instructional Technology course offered to pre-service teachers in the Faculty of Education was redesigned with AI integration, focusing specifically on enhancing pre-service teachers' AI literacy and digital material design competencies. The course aims to provide future teachers with the necessary skills to use

instructional technologies effectively and efficiently in educational processes. Given the rapid development of AI tools, updating the course content has become essential for equipping educators with relevant digital skills. The knowledge and competencies gained in this course are of critical importance not only for pre-service teachers' academic success during their university education but also for their future professional practices. Teachers who are well-versed in using AI technologies ethically and pedagogically will be better prepared to integrate these tools into their classrooms and help raise digitally literate pre-service teachers.

Within the scope of this study, two educational technology experts collaborated to redesign the course. Current AI applications and their functions were reviewed, and the course content was structured in accordance with an AI literacy framework. The course was conducted in a computer lab, allowing pre-service teachers to experience AI tools through hands-on activities. Collaborative group work was also encouraged both during and outside class hours, fostering peer interaction and learning. The syllabus was revised based on feedback from experts in the field.

The course covered introductory topics, including key concepts, the historical development of instructional technologies, emerging approaches, and the competencies required by teachers and students in the AI era. Additionally, it covered AI-supported practices, including digital material design, access and editing, digital assessment, and the management of digital learning processes. A special emphasis was placed on developing pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) by enabling them to design learner-centered materials using appropriate tools. The weekly structure of the course is summarised in Table 1.

During the course, pre-service teachers were first introduced to the theoretical foundations of instructional technologies and artificial intelligence through brief lectures, followed by reflective discussions. Guided by the instructor's questions, pre-service teachers explored AI tools, developed their ideas collaboratively, and shared their reflections with peers. In the practical phase, an interactive and context-based learning environment was established. As the participants were prospective social studies teachers, they were assigned practice-oriented tasks aimed at producing concrete instructional products that demonstrated how digital and AI-supported technologies could be used to enrich future classroom lessons.

Pe-service teachers' learning processes and instructional products were evaluated using a rubric-based formative assessment approach. At the end of each class session, the instructional products developed by pre-service teachers were jointly assessed by the course instructor and the teaching assistant based on predefined pedagogical criteria. These criteria focused on the appropriateness of the selected AI-supported tools within the context of social studies education, as well as their alignment with visual design principles and multimedia learning standards. Joint evaluation and consensus-based review were employed to ensure consistency in the assessment process, and formative feedback was provided to support pre-service teachers' ongoing learning and development. In addition to weekly formative assessments, pre-service teachers completed a final project at the end of the semester. The final project required pre-service teachers to collaboratively design instructional materials and prepare an AI-integrated lesson plan aligned with curriculum objectives. Final projects were evaluated using a structured rubric emphasizing instructional coherence, pedagogical

Table 1 AI enhanced instructional technology course structure

Week	Topics	Practical Applications
1	Fundamentals and historical development of instructional technologies; Introduction to AI technologies, their scope, and ethical considerations	Membership and sample activities on platforms like ChatGPT, Gemini
2	Teaching in the Digital Age: Teachers' Digital Competencies, TPACK Framework, and Emerging Approaches in Instructional Technology.	Creating concept maps using Padlet, MindMeister, Popplet
3	Accessing educational resources (MOOC platforms); Cloud computing technologies, and file sharing in education.	Enrolling in a MOOC course, using Google Drive, OneDrive and similar platforms
4	Principles of digital material design; Visual design and multimedia learning principles	Review of good/poor design examples, classroom discussions,
5	AI-assisted content creation; Fundamentals of effective prompt writing for educational purposes	Prompt writing practices with ChatGPT, AI Studio, Monica, and Gemini
6	Principles of infographic and presentation design in digital learning environments	Using Canva, Gamma, Prezi for design and presentation
7	Principles of image and video creation and editing for instructional use	Using Microsoft Copilot, Cleanup, Midjourney, Fliki
8	Developing interactive videos for engaging digital learning environments	Creating interactive videos using CapCut, Edpuzzle
9	Creating educational animations and applying digital storytelling in teaching	Using StoryboardThat, Powtoon, Meshy
10	Gamification principles and designing educational games for classroom engagement	Designing games with LearningApps, Wordwall
11	Digital assessment and evaluation strategies; Designing AI-supported assessment tools	Using Kahoot, Quizizz for digital assessment
12	Supporting students in digital learning environments; Addressing special needs and personalized learning	Using ChatGPT, Gemini, and MagicSchool AI for personalised planning
13	Lesson planning principles; Integrating AI tools in instructional design	Developing lesson plans with ChatGPT, Gemini, MagicSchool AI
14	Final project presentations: AI-integrated digital materials and lesson plans based on the middle school social studies curriculum	Group presentations simulating teaching roles

alignment, and compliance with multimedia learning principles (see Appendix-1). The course adopted a formative assessment approach with an emphasis on the learning process, while midterm and final exams were also administered throughout the semester. The sample implementation process of the course is illustrated in Fig. 2. Some of the instructional materials prepared by pre-service teachers using AI-supported Instructional Technologies tools are provided as examples in Fig. 3.

2.5 Data analysis

All quantitative analyses were conducted using IBM SPSS Statistics 26. Prior to conducting paired-sample t tests, the normality assumption was evaluated based on the difference scores obtained by subtracting pretest scores from posttest scores, as required for paired comparisons. Normality analyses were performed using the Kolmogorov–Smirnov and Shapiro–Wilk tests for the difference scores of the total scales and their sub-dimensions. The results indicated that most difference variables did not significantly deviate from normality ($p > .05$). Although three sub-dimensions yielded significant Kolmogorov–Smirnov test results, the skewness and kurtosis values for these variables ranged between −1.5 and +1.5. According to Tabachnick and Fidell (2019), skewness and kurtosis values within this range are considered acceptable for assuming normal distribution in social science research. In addition to normality tests, Q–Q plots of standardized residuals were visually inspected to further evaluate the normality assumption. The plots indicated that the residuals were approximately normally distributed. Therefore, the normality assumption was regarded as suffi-

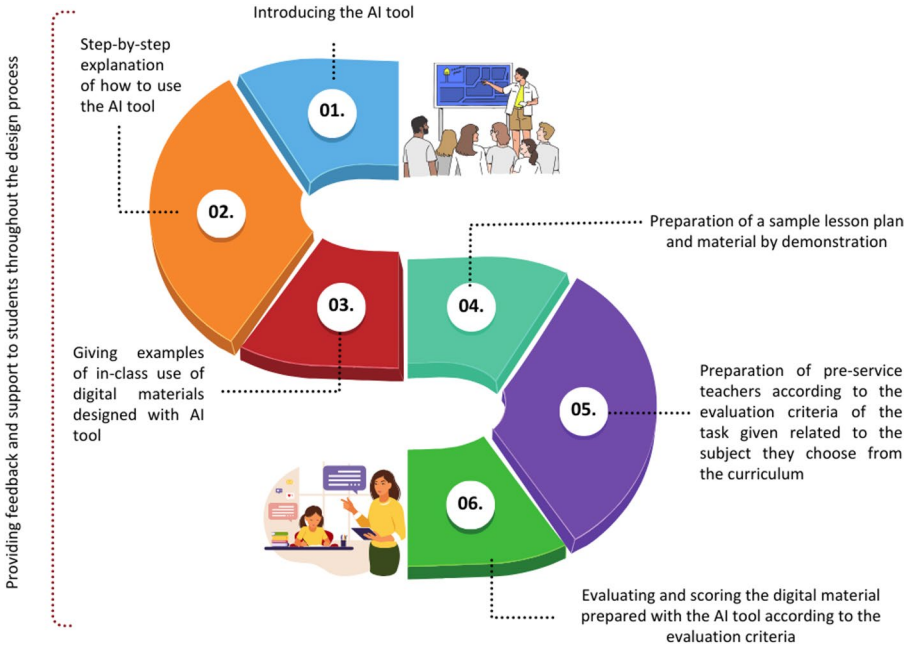

Fig. 2 Step-by-step AI tools usage process during the course

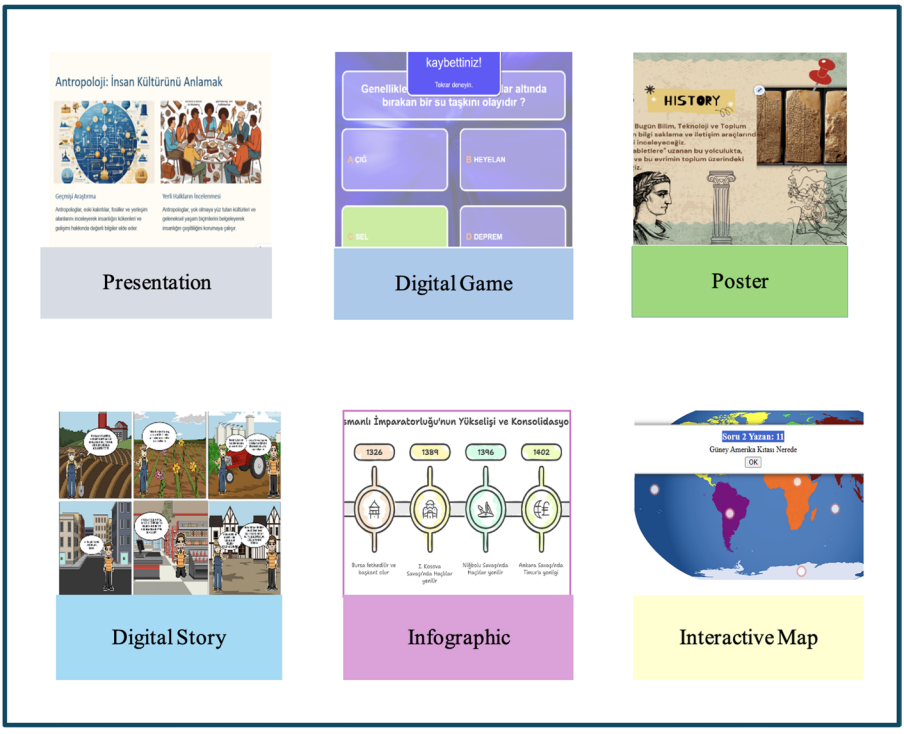

Fig. 3 Examples of teaching materials prepared using AI tools

ciently satisfied, and paired-sample t tests were applied in the subsequent analyses. Additionally, Cohen's d was calculated to determine the effect size. Effect sizes were interpreted based on Cohen's (1988) classification, where $d<0.20$ is considered negligible, $0.20\leq d<0.50$ is classified as small, $0.50\leq d<0.80$ is classified as medium, and $d\geq 0.80$ is considered large. Statistical significance was evaluated at the $p<.05$ level (De-Ruiter, 2019).

For the qualitative data analysis, a content analysis approach was adopted. The interview data were first subjected to open coding in order to identify meaningful units. These codes were then organized into categories and overarching themes, and patterns were identified by examining relationships among the emerging themes. During the analysis process, particular attention was paid to how participants described their learning experiences related to the use of artificial intelligence in instructional contexts and the development of digital instructional materials. While the themes were derived inductively from the data, their interpretation was informed by the broader conceptual focus of the study, including dimensions related to AI-supported instructional practices and digital material design processes. To ensure the trustworthiness of the analysis, intercoder reliability was established through investigator triangulation. A second researcher independently reviewed the coding structure and theme organization, and any discrepancies were discussed until full agreement was reached. Representative participant quotations were included to support each theme.

This analytical procedure contributed to methodological rigor and enhanced the credibility and validity of the qualitative findings within the mixed-methods design.

3 Results

3.1 Comparisons of pre-service teachers' AI literacy levels

Paired sample t-tests were conducted to compare pre-service teachers' AI literacy levels before and after the intervention (Table 2). The results revealed statistically significant improvements across all four dimensions of the AI Literacy Scale, each with a large effect size. The *Awareness factor* increased from a moderate level (M = 4.36, SD = 1.07) to a high level (M = 5.29, SD = 0.97), t(49) = −4.41, p <.001, d = 0.91. *The Usage factor* showed a notable improvement from a low level (M = 3.51, SD = 1.22) to a high level (M = 5.14, SD = 0.94), t(49) = −7.54, p <.001, d = 1.48. Similarly, *the Evaluation factor* rose from a low level (M = 3.83, SD = 1.48) to a high level (M = 5.71, SD = 1.00), t(49) = −7.59, p <.001, d = 1.48. *The Ethics factor* improved from a moderate level (M = 4.77, SD = 1.37) to a high level (M = 5.69, SD = 1.11), t(49) = −3.92, p <.001, d = 0.74. Overall, the total AI literacy score increased significantly from a moderate level (M = 4.09, SD = 0.93) to a high level (M = 5.45, SD = 0.79), t(49) = −8.07, p <.001, d = 1.57, indicating the effectiveness of the intervention in enhancing AI literacy.

3.2 Comparisons of pre-service teachers' digital material design competencies

Paired sample t-tests were conducted to examine the changes in pre-service teachers' digital material design competencies before and after the intervention (Table 3). Results showed significant improvements across all four dimensions of the scale, each with a large effect size. The *Design and Development Competency* increased from a low level (M = 2.36, SD = 0.70) to a moderate level (M = 3.53, SD = 0.58), t(49) = −9.56, p <.001, d = 1.79. The *Technical Proficiency* improved from a low level (M = 2.40, SD = 0.75) to a moderate level (M = 3.59, SD = 0.66), t(49) = −9.08, p <.001, d = 1.67. The *Technopedagogical Competence* increased from a low level (M = 2.61, SD = 0.87) to a moderate level (M = 3.76, SD = 0.77), t(49) = −6.52, p <.001, d = 1.38. The *Application and Evaluation* dimension increased from a low level (M = 2.63, SD = 0.89) to a moderate level (M = 3.76, SD = 0.77), t(49) = −6.32,

Table 2 Paired sample t-test results for comparisons of pre-service teachers' pre-test and pos-test AI literacy

	Pre-Experiment		Post-Experiment		t(49)	p	Cohen'sd
	M	SD	M	SD			
Awareness Factor	4.36	1.07	5.29	0.97	−4.41	0.000	0.91
Usage Factor	3.51	1.22	5.14	0.94	−7.54	0.000	1.48
Evaluation Factor	3.83	1.48	5.71	1.00	−7.59	0.000	1.48
Ethics Factor	4.77	1.37	5.69	1.11	−3.92	0.000	0.74
Total	4.09	0.93	5.45	0.79	−8.07	0.000	1.57

Table 3 Paired sample t-test results for comparisons of pre-service teachers' pre-test and pos-test digital material design competencies

	Pre-Experiment		Post-Experiment		t(49)	*p*	Cohen'sd
	M	SD	M	SD			
Design & Development	2.36	0.70	3.53	0.58	−9.56	0.000	1.79
Technical Proficiency	2.40	0.75	3.59	0.66	−9.08	0.000	1.67
Technopedagogical	2.61	0.87	3.76	0.77	−6.52	0.000	1.38
Application & Evaluation	2.63	0.89	3.76	0.77	−6.32	0.000	1.35
Total	2.50	0.71	3.65	0.60	−8.52	0.000	1.73

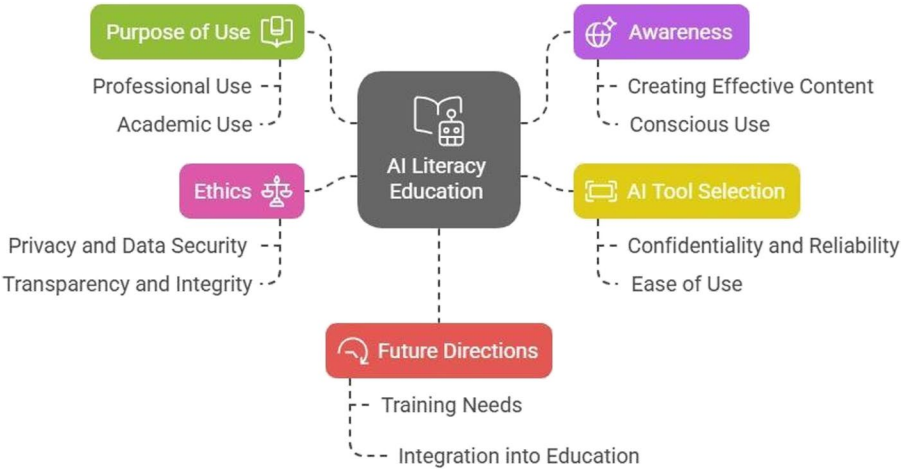

Fig. 4 Pre-service teachers' experiences in the ai-integrated instructional technology course

p <.001, d = 1.35. The overall score for digital material design competencies showed a significant improvement from a low level (M = 2.50, SD = 0.71) to a moderate level (M = 3.65, SD = 0.60), t(49) = −8.52, p <.001, d = 1.73, indicating a substantial positive impact of the AI-integrated instructional technology course on pre-service teachers' design competencies.

3.3 Pre-service teachers' experiences in the AI-integrated instructional technology course

Based on the content analysis, pre-service teachers' responses regarding their experiences in the AI-integrated instructional technology course were categorized into six main themes: Purpose of Use, Awareness, AI Tool Selection, Ethics, and Future Directions, as shown in Fig. 4. These results reveal that pre-service teachers not only gained technical skills but also developed ethical awareness and strategic decision-making in AI use, indicating the multidimensional impact of the course.

Purpose of Use Pre-service teachers reported using AI tools for both academic and professional purposes. Academic uses included activities such as searching for and

analyzing information, preparing assignments, and creating content for coursework. Professional uses included developing skills for future careers and exploring AI tools. Some of the participants' responses are as follows.

"I often use it to prepare presentations, create videos, and prepare my assignments more effectively after class." (S1).

"I generally use it frequently in daily life for health procedures, in areas such as automotive and entertainment for design and information purposes, and also in education for my courses, assignments, research, and content production" (S3).

"I generally use it in areas such as project design and content creation in my educational life. I think it has improved me compared to before the course" (S4).

"I use it for information search, source scanning, and idea testing" (S8).

Awareness This theme encompassed pre-service teachers' thoughts on their growing understanding of artificial intelligence and was categorized as effective content and conscious use. Pre-service teachers stated that the course significantly increased their awareness of AI tools and their appropriate applications. Some of the participants' responses are as follows.

"Before taking the course, my awareness level regarding artificial intelligence technologies was low, but after taking the course, it increased considerably. The instructional technology course helped me a lot in understanding how I could use artificial intelligence and how I could further improve it. By taking this course, I realized the importance of artificial intelligence in education and became much more aware of how to use artificial intelligence. (S2)

"I saw that it has a different and more useful scope than we knew, and I can say that it was very beneficial in terms of self-improvement. At the same time, I saw that applications are more effective with artificial intelligence, both individually and professionally. (S7)

"My level of awareness before the course was very limited in terms of definition, differentiation, and functions, and it was insufficient to reach a conclusion. This was because my awareness was limited to the conversations I had in online forums. I would like to emphasize that my awareness truly developed and progressed within the scope of the instructional technology course. The course process and its conclusion enabled me to distinguish between artificial intelligence tools used for different purposes and find answers to my questions about which tools I could use according to my needs and skills" (S5).

AI Tool Selection Pre-service teachers selected AI tools based on factors such as privacy, reliability, and ease of use. Several emphasized the importance of reviewing user reviews and assessing how well the tools align with their specific goals. Some of the participants' responses are as follows.

"Data privacy, ease of use. I pay attention to reliability and functionality. In terms of suitability for my purpose, I examine the features offered by the tool. I read user reviews. Before the instructional technology course, I was uninterested and unin-

formed about technology use. After the course, I started paying attention to these kinds of ethical and security issues" (S1).

"When choosing an AI tool, I first pay attention to ease of use. Secondly, accuracy and reliability are important to me. User reviews are another criterion that influences my choice. Before the instructional technology course, I didn't pay attention to these features; in fact, I couldn't even use AI tools. After taking the course, I started using them when I saw their benefits and ease of use, and they have been very helpful to me" (S6).

"First, I determine my needs. I look at the ease of use of the tool I will use. Then I look at the reviews and ratings, and then I choose the application. I started a course with zero knowledge and left with many skills and knowledge" (S3).

"I pay attention to ethical rules first. The purpose for which the tool I choose will use my data is more important to me. In the second stage, I pay attention to the variety of content and possibilities it will offer me regarding my needs. A wide range of choices directs me more towards that tool. For example, if I'm creating a presentation, it should offer various templates, or if I'm planning an activity, it should offer me the opportunity to use various materials simultaneously. I look at whether it synchronizes simultaneously, like Cloud, and thus saving time is important. Before the class, I was more hesitant, but after the class, I think I became more active and effective" (S5).

Ethics In this theme, pre-service teachers' responses reflected concerns about privacy and data security, as well as transparency and integrity. They emphasized the importance of encrypted storage, user rights, and avoiding misinformation. Some of the participants' responses are as follows.

"I had no awareness of ethics before the course. I feel that it has increased significantly during and after the course. I pay more attention to issues such as data privacy, impartiality, and transparency. Now, when using AI tools, I evaluate not only their use but also their ethical dimension and make my choices accordingly. When logging in, I examine points such as security and sharing with third parties in the terms of use" (S7).

"I can say that my awareness of ethical issues increased after taking the instructional technology course. In return, I try to pay attention to ethics when using artificial intelligence. I try to access reliable and accurate information. The reason I pay attention to these issues is that the course provided detailed and important information on this topic. When using artificial intelligence, I pay attention to issues such as privacy, fairness, and accuracy. I am careful not to spread misinformation and to protect the rights of users. This can be prevented by encrypting data, storing it securely, and providing training similar to the training we received on this topic" (S2).

"The ethical issue that first comes to mind for me is information and data privacy. Information provided must be used with attention to the limitations of private life and personal information. This can be achieved by selecting applications that store data better and keep it more secure, and by developing applications that control this security" (S4).

Future Directions Pre-service teachers shared their thoughts on the value of education and its applicability to future teaching practices. Responses emphasized the need for integration into education across various disciplines and levels, and for this integration to continue. Some of the participants' responses are as follows.

"The course made a substantial contribution to my learning, and I believe that I gained a detailed understanding of how to use AI tools effectively in educational contexts. Whether creating videos, presentations, images, audio materials, or digital magazines, I am now able to design instructional content in a more effective and engaging way. When preparing content on a specific topic, these tools help me organize key headings and learning objectives more clearly and systematically. As a result of this process, I feel more confident in my skills, and I believe that in the future I can not only use these tools effectively in my own teaching but also provide guidance and mentorship to my fellow teachers in this area." (S2).

"It made a huge positive contribution. I actively use it not only in your class but also outside of your class and in developing assignments and content in classes after the training you provided. AI tools provide us with more opportunities to express ourselves and our ideas in this regard. The most beneficial part of the course was gaining experience by doing and experiencing. In terms of areas for improvement, I think the course was very effective; I believe this type of course should be offered at every level and in every field" (S8).

"I can say that AI has taken me far beyond my current level in terms of AI and material development. The most effective part was that after learning, we immediately applied it in a concrete situation in groups. I also believe that this experience will enable me to use AI-based tools more effectively for my students when I become a teacher. " (S5).

4 Discussion

This study examined the effects of an AI-integrated "Instructional Technology" course designed to enhance pre-service teachers' artificial intelligence (AI) literacy and digital material design competencies at the higher education level. Prior to the intervention, pre-service teachers' AI literacy levels were moderate; however, following its implementation, their levels significantly increased to a high level. The AI-enhanced IT course led to a statistically significant and large effect size improvement in pre-service teachers' AI literacy. The moderate level of AI literacy observed prior to the intervention may be explained by the limited pedagogical exposure to AI technologies within teacher education programs. Although pre-service teachers may encounter AI tools through everyday digital environments such as social media or content-generation platforms, this exposure does not necessarily translate into structured pedagogical knowledge or critical evaluation skills. Interview findings also supported this interpretation, as several participants indicated that they had heard about AI tools before the course but had not previously considered their instructional applications or ethical implications in educational contexts.

Sub-dimension analyses within the AI literacy framework revealed that, before the experimental implementation, pre-service teachers' perceived competencies in the "awareness" and "ethics" dimensions were relatively higher compared to those in other dimensions. The awareness dimension refers to individuals' ability to recognize AI technologies and understand their role in everyday life, while the ethics dimension involves recognizing responsibilities related to AI usage and accurately understanding potential ethical concerns. Although participants, who belong to Generation Z, reported limited active use of AI tools prior to the course, they may have developed a certain level of awareness through exposure to AI via social media and other digital platforms. Indeed, alongside the increasing applications of AI in various fields, its ethical use has become a growing topic of public debate (Hossain et al., 2025; Zeer et al., 2023). In the course, AI technologies were addressed in a multifaceted manner, with a particular focus on their ethical use in educational contexts. As a result, pre-service teachers showed significant and high-level improvement in both awareness and ethics dimensions. Many educational programs aimed at improving AI literacy in the literature also emphasize these two dimensions (Cetindamar et al., 2022; Long & Magerko, 2020; Register & Ko, 2020).

Furthermore, pre-service teachers demonstrated significant and substantial improvements in the "usage" and "evaluation" dimensions. The usage dimension reflects individuals' ability to effectively utilize AI tools and integrate them into their daily lives, whereas the evaluation dimension pertains to the ability to select appropriate AI applications, interpret outcomes, and critically assess them (Wang et al., 2022). Through weekly in-class activities, pre-service teachers were introduced to various AI tools, given opportunities to select tools aligned with their personal goals, and practiced applying them in diverse educational scenarios. These experiences contributed to strengthening both their usage and evaluation competencies.

The findings also highlight a meaningful relationship between AI literacy and digital material design competencies. Designing instructional materials with AI-supported tools requires teachers not only to operate technological systems but also to critically evaluate AI-generated outputs, select appropriate tools for pedagogical purposes, and consider ethical implications during the design process. Therefore, improvements in AI literacy may have supported participants' ability to design pedagogically meaningful digital materials. Interview responses further indicated that pre-service teachers became more intentional and reflective when selecting AI tools for instructional purposes, suggesting that AI literacy functions as an enabling competence that facilitates the development of digital material design skills in technology-enhanced learning environments.

The integration of quantitative and qualitative findings provided deeper insight into these developments. While quantitative results demonstrated statistically significant gains across AI literacy dimensions, qualitative interview data revealed how and why these gains occurred. Participants described becoming more purposeful, critical, and ethically aware when selecting and using AI tools for instructional design, highlighting learning processes that could not be fully captured through scale scores alone. This convergence between quantitative outcomes and qualitative experiences strengthened the interpretability and validity of the findings.

While numerous studies have been conducted to improve AI literacy (Chaudhry & Kazim, 2022; Ding et al., 2024; Pinski & Benlian, 2024; Weng & Chiu, 2023), most of them have focused either on theoretical, awareness- and ethics-based models or software training. This study, however, took a more holistic and educationally grounded approach, integrating practical activities to develop these competencies. Offering such a course to pre-service teachers in Faculties of Education contributes significantly to the conscious and effective use of AI technologies in both their current academic and future professional lives (Korte et al., 2024; Laru et al., 2024).

Triangulation across data sources further indicated that qualitative themes related to awareness, purpose of use, ethical considerations, and instructional decision-making were consistent with the observed quantitative improvements in AI literacy and digital material design competencies. These findings suggest that the AI-integrated course not only improved measurable competency levels but also fostered reflective and pedagogically grounded learning experiences.

In the interviews, pre-service teachers expressed that their AI literacy had improved in ways particularly applicable to educational and professional use, and that they began to use these tools more purposefully and consciously. They also emphasized the importance of perceived usefulness and ease of use in shaping their adoption of AI tools, aligning with literature findings (Guo et al., 2025). The pre-service teachers' statements supported prior research, suggesting that AI tools can promote personalized and adaptive learning (Chiu et al., 2023; Kabudi et al., 2021), accelerate knowledge acquisition, and enhance student motivation (Chen et al. 2020a, b, c a; Chen et al. 2020a, b, c; Hwang et al. 2020).

Taken together, these findings suggest that developing AI literacy within teacher education programs may play a crucial role in supporting pre-service teachers' ability to critically and pedagogically integrate AI-supported tools into instructional design processes. In this respect, the study highlights the importance of embedding AI literacy development within practice-based instructional technology courses in order to foster both reflective and design-oriented professional competencies among future educators.

5 Implications

5.1 Theoretical implications

From a theoretical perspective, the findings of this study contribute to ongoing discussions regarding the development of AI literacy as an integral component of teachers' professional knowledge in AI-supported educational environments. Previous studies conceptualize AI literacy as a multidimensional construct involving awareness, usage, evaluation, and ethical understanding of artificial intelligence technologies (Long & Magerko, 2020; Ng et al., 2021; Laupichler et al., 2022). However, much of the existing literature has examined AI literacy primarily as an individual technological competence. The present findings extend this perspective by demonstrating how AI literacy may develop in conjunction with instructional design practices and pedagogical decision-making processes within teacher education contexts.

In particular, the results can be interpreted through the lens of teacher knowledge integration frameworks, especially Technological Pedagogical Content Knowledge (TPACK). TPACK emphasizes the dynamic interaction between technological knowledge, pedagogical knowledge, and content knowledge required for effective technology integration in teaching (Howard et al., 2021). Within this perspective, teachers are expected not only to use digital technologies but also to integrate them meaningfully into instructional design and classroom practices. The significant improvements observed in both AI literacy and digital material design competencies suggest that AI-integrated instructional experiences may support the development of teachers' technopedagogical knowledge structures necessary for integrating emerging technologies into learning environments.

Recent studies have also begun to conceptualize this integration in relation to AI-TPACK, highlighting the need for teachers to develop competencies that enable them to critically and pedagogically integrate AI technologies into instructional practices (Dilek et al., 2025; Zhang & Zhang, 2024). From this perspective, AI literacy can be interpreted as an emerging dimension of teachers' technological and technopedagogical knowledge that supports the effective selection, evaluation, and pedagogical use of AI tools in instructional design and digital content production. The findings of the present study provide empirical support for this perspective by demonstrating that structured AI-integrated instructional experiences can simultaneously enhance both AI literacy and digital material design competencies among pre-service teachers.

Furthermore, the evaluation and ethics dimensions of AI literacy identified in this study align closely with the literature on digital literacy and critical digital literacy, which emphasize individuals' ability to interpret, question, and critically evaluate digital technologies (Ng et al., 2021; Howard et al., 2021). In the context of artificial intelligence, these competencies become particularly important as educators must assess the reliability, bias, transparency, and pedagogical appropriateness of AI-generated outputs. These concerns are also central to current discussions on trustworthy artificial intelligence in education, which highlight the importance of ethical awareness, responsible data use, and critical engagement with AI-driven systems in educational contexts (Akgun & Greenhow, 2022; Luckin et al., 2022).

Taken together, these findings suggest that AI literacy should not be conceptualized solely as a technical competence but rather as an integrated professional knowledge domain that intersects with technopedagogical knowledge, critical digital literacy, and ethical reasoning. In this respect, AI-integrated instructional technology courses may play a key role in supporting the development of such integrated competencies within teacher education programs.

5.2 Practical and educational implications

In light of these findings, it is essential to promote similar AI-enhanced courses in teacher education programs across higher education. The course structure proposed in this study could serve as a model, offering a comprehensive approach that helps pre-service teachers in various disciplines to develop their content creation, instructional planning, and implementation skills using AI technologies. Practically, the findings suggest that AI literacy and digital material design competencies can be

effectively developed through practice-based instructional technology courses that prioritize hands-on engagement, iterative design, and reflective evaluation. The structured, practice-based design enabled participants to acquire not only technological knowledge but also technopedagogical expertise.

Therefore, it is critical for teacher education programs to emphasize not only the technical aspects of AI but also its pedagogical applications. Embedding AI tools into lesson planning, material development, and assessment activities allows teacher candidates to develop informed decision-making skills regarding when, why, and how AI should be used in instructional contexts. Through applied learning activities, future teachers will be better prepared to integrate AI tools into their instructional practices. Expanding similar hands-on training opportunities for both pre-service and in-service teachers is likely to support the development of educators equipped with the competencies required in the digital age. Such initiatives may also contribute to more sustainable and responsible integration of AI technologies across different educational settings.

6 Limitations and future research

This study has several limitations. First, the research was conducted with pre-service teachers enrolled in a Social Sciences Education program at a single university in eastern Turkey, which may limit the generalizability of the findings to other departments or institutional contexts. Second, data were collected using self-reported instruments, which may have introduced subjectivity. In addition, the study was implemented over a single academic term; therefore, future research should adopt longitudinal designs across multiple courses to examine the sustainability of the observed effects. Another limitation concerns the use of a single-group pretest–posttest design, which restricts causal interpretations due to potential threats to internal validity, such as maturation and history effects. Future studies employing experimental or quasi-experimental designs could compare different AI-integrated lesson structures and instructional approaches to better understand how AI-supported planning, implementation, and content creation competencies develop.

Future research is also encouraged to include qualitative evaluations of the digital materials produced by pre-service teachers in order to examine their pedagogical, technical, and visual quality in greater depth. Moreover, the potential impact of AI-integrated instructional interventions on pre-service teachers' AI-TPACK (Artificial Intelligence Technological Pedagogical Content Knowledge) should be further investigated. Such research may contribute to the ongoing restructuring of teacher education programs in terms of both content and methodology.

Finally, future studies could extend this work by applying similar research designs across different disciplines, student populations, and educational settings. Examining additional variables such as learning styles, motivation levels, and prior technological experiences may further enrich understanding of how AI-enhanced learning environments influence teacher preparation.

Appendix-1. Final project evaluation rubric

The final project was evaluated collaboratively by the course instructor and the teaching assistant using the rubric presented below. The rubric was designed to assess pre-service teachers' instructional design competencies, pedagogical alignment, and compliance with visual design and multimedia learning principles within the context of social studies education.

A. Instructional Design and Course Alignment Criteria.		
Criteria	Description	Points
Collaborative Material Development	At least three instructional materials were collaboratively designed and developed as part of the final project.	20
Lesson Plan Structure	The lesson plan clearly specifies instructional objectives, learning outcomes, activities, instructional resources, and assessment principles.	10
Instructional Presentation	An effective presentation summarizing the lesson plan and instructional materials was prepared.	10
Documentation of Materials	Instructional materials were clearly explained using screenshots, links, or visual references within the presentation.	5
Time Management	Presentation time was used effectively and appropriately.	5
B. Alignment with Visual Design and Multimedia Learning Principles		
Criteria	Description	Points
Instructional Balance	Instructional materials were integrated into the lesson in a balanced and pedagogically appropriate manner.	20
Content Sequencing	Materials were sequenced logically and aligned with lesson objectives and learning outcomes.	10
Multimedia Coherence	Materials demonstrated coherence, relevance, and appropriate temporal alignment, avoiding redundancy and cognitive overload.	10
Use of Multimedia Elements	Multimedia elements (e.g., text, visuals, audio, video) were used effectively in accordance with multimedia learning principles.	5
Appropriateness for Target Learners	Materials were clear, original, age-appropriate, and suitable for the target learner group.	5

Total Score: 100 Points

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Data availability The datasets analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate This study has received approval from the relevant institution, ensuring that all research procedures comply with ethical standards.

Consent for publication The students permitted their data and responses to be published within the scope of the study.

Competing interests The authors declare that they have no conflict of interest.

Assessment Procedure Note All final projects were jointly evaluated by the course instructor and the teaching assistant. Both evaluators used the same rubric and reached consensus on scoring to ensure consistency and reliability in the assessment process.

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