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The Effects of Artificial Intelligence and STEM-Based Education in Social Classes

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Abstract

Main objective of the study was to investigate how artificial intelligence (AI) and STEM pedagogy influence students' cognitive performance, academic success, and attitudes. A quasi-experimental design with a pretest-posttest control group was used in the study. The study was conducted among first- to fourth-year students enrolled in the Pedagogical Education Program at Korkyt Ata Kyzylorda University. The study group consisted of 66 students. The experimental group taught the unit "History of Kazakhstan" for eight sessions using activities incorporating artificial intelligence and STEM (modeling, project-based learning) pedagogies. The control group studied the same unit using traditional expository teaching methods based on the existing curriculum. Data were collected using the "Social Sciences Course Attitude Scale" and the "Achievement Test" developed by the researchers and both were tested in terms of validity and reliability analyses. The achievement test was re-applied as a retention test one month after the implementation. Findings showed that the groups were equivalent regarding attitudes and achievement levels before the implementation. The results of the experiment revealed that the group exposed to the AI×STEM intervention demonstrated significantly improved attitudes towards social sciences, higher academic achievement, and better retention of learning compared to the control group. The AI×STEM-based teaching approach proved to be more effective in enhancing student outcomes than traditional methods. Therefore, it is suggested that the national social studies curriculum be revised to integrate these skills. Based on these findings, it is suggested that AI- and STEM-based instructional practices be systematically integrated into social studies curricula to support student engagement, academic achievement, and long-term learning outcomes.

Keywords: *Artificial intelligence, STEM education, Interactive learning, Digital educational resources, Academic achievement, Attitude, Social classes.*

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Introduction

In recent years, the integration of technology into education has radically transformed the way how knowledge is structured, shared, and applied. Among these technological advancements, artificial intelligence (AI) stands out as one of the tools that has had the greatest impact on the field of education (Lima et al., 2024). AI-powered systems are now being used to personalize learning experiences, analyze student performance, and create interactive learning environments. As classrooms transform into dynamic environments shaped by digital innovations, educators and researchers have begun to examine how AI can contribute to social studies courses, where critical thinking and problem-solving skills are essential (Agudelo Rodríguez et al., 2024; Hurley et al., 2024İ Shaikh et al., 2025).

Although STEM (Science, Technology, Engineering, Mathematics) based education is originally based on the integration of science, technology, engineering, and mathematics, it has recently expanded its scope and become applicable to various disciplines (Casal-Otero et al., 2023; McSween, 2024). The integration of STEM principles in social studies courses enables students to engage in inquiry-based learning processes, develop analytical thinking skills, and generate solutions to social problems through data-driven approaches. This interdisciplinary approach allows students to combine both scientific and social perspectives (Grubaugh & Levitt, 2024; Padgett et al., 2025; Shabalala, 2024).

The integration of artificial intelligence and STEM-based education into social studies courses has gained increasing attention as a means of fostering 21st-century skills such as collaboration, creativity, critical thinking, and digital literacy. Recent studies demonstrate that AI-supported tools, including chatbots, AI-generated visual content, and data analysis systems, can enhance students' engagement, inquiry skills, and conceptual understanding by enabling personalized feedback and interactive learning experiences (Grubaugh & Levitt, 2024; Sarwar et al., 2024).

Similarly, STEM-oriented pedagogical approaches such as project-based learning, inquiry-based learning, and modeling activities have been shown to promote problem-solving skills, higher-order thinking, and interdisciplinary reasoning by engaging students in authentic, real-world tasks (Funa, 2025; Smith et al., 2022; Deák et al., 2021; García-Silva et al., 2024). While these approaches have been widely implemented and empirically validated in science, technology, and mathematics education, their systematic application in social studies remains limited and largely underexplored (Be, 2025; Kanadlı, 2019; Erbilgin et al., 2024; Essuman et al., 2025; Tang, 2024).

Existing research in the social studies context has predominantly relied on qualitative case studies or descriptive analyses, often focusing on single instructional tools rather than examining comprehensive instructional designs and measurable learning outcomes. In particular, there is a lack of quasi-experimental studies that simultaneously investigate students' attitudes toward social studies, academic achievement, and learning retention within an integrated AI- and STEM-based instructional framework. Addressing this gap, the present study examines the effects of AI- and STEM-based instructional practices on students' attitudes, academic achievement, and learning retention in social studies through a quasi-experimental research design.

In contemporary pedagogical practice, enhancing students' cognitive autonomy, critical thinking skills, and practical competencies is one of the primary objectives. The integration of modern educational technologies and innovative pedagogical approaches increases students' motivation and strengthens their professional competencies. Artificial intelligence (AI) and STEM pedagogy play a crucial role in innovative teaching. AI supports the development of students' independent research, analytical, and decision-making skills, while STEM-based pedagogy, through project- and modeling-based lessons, promotes the development of practical competencies. The aim of this study is to examine the effects of incorporating AI and STEM pedagogy elements on students' attitude and academic achievement in social study classes. Accordingly, this study aims to provide empirical evidence on how an integrated AI- and STEM-based instructional design influences students' attitudes toward social studies, academic achievement, and learning retention, the detailed research objectives and hypotheses of which are presented in the following sections.In this context, the integration of artificial intelligence technologies and STEM-based pedagogical practices in social studies teaching is considered an innovative paradigm that is expected to shape future educational models and forms the conceptual basis for the theoretical framework presented in the following section.

Research Gap and Value

While the existing literature extensively explores the potential of artificial intelligence and STEM education, a clear and specific research gap persists in the context of social studies education. Specifically, there is a lack of empirically grounded studies that examine the integrated use of AI and STEM-based pedagogical approaches within a holistic instructional design and investigate their combined effects on students' attitudes toward social studies, academic achievement, and learning retention. Existing research has predominantly focused either on the use of isolated AI tools (e.g., chatbots) or on single STEM activities (e.g., coding projects), largely within science and mathematics education, while overlooking how these approaches can be synergistically integrated to deepen students' understanding of social sciences (Kanadlı, 2019; Tang, 2024). Moreover, the literature reveals a paucity of robust experimental or quasi-experimental studies with control groups that empirically examine the cognitive and affective outcomes of AI×STEM integration in social studies contexts (Akhmadieva et al., 2023).

Despite the growing interest in artificial intelligence and STEM integration in education, a clear research gap persists in social studies education regarding empirically grounded and methodologically robust investigations. The literature largely consists of case studies, pilot applications, and descriptive research based on teacher opinions, making it difficult to reach generalizable and reliable conclusions (Chong & Quek, 2022; Thomas & Larwin, 2023). Moreover, existing studies rarely employ experimental or quasi-experimental designs with control groups to examine the combined effects of AI- and STEM-based instructional practices on students' attitudes, academic achievement, and learning retention in social studies. This prevents policymakers, curriculum developers, and teachers from making evidence-based decisions and effectively planning and implementing AI×STEM integration. The current study aims to fill this research gap and make significant contributions to the literature at the theoretical, methodological, and practical levels. In terms of practice, the research findings offer directly applicable, evidence-based design principles, sample lesson plans, and implementation recommendations for teachers, school administrators, and policymakers. In this way, they help to evolve AI×STEM integration in schools from fragmented and superficial practices to a curriculum-integrated, sustainable, and pedagogically meaningful model (Havice et al., 2018). Finally, this study makes a significant contribution to the vision of educating students not only as technology users but also as critical producers who are sensitive to societal issues, possess ethical values, and can actively participate in the digital world.

The Purpose of the Research and Research Hypotheses

The purpose of this study was to examine the effects of AI and STEM-based instructional practices implemented with students on their attitudes, achievement, and learning retention towards social sciences. For this purpose, a quantitative research design was developed using a pretest-posttest quasi-experimental design with a control group. Based on this, the following hypotheses were tested:

- H1- Students in the experimental group, where AI and STEM-based instructional practices were implemented in the social sciences course, had higher and more positive attitudes compared to students in the control group, where the current program was implemented.
- H2- Students in the experimental group, where AI and STEM-based instructional practices were implemented in the social sciences course, achieved higher levels of achievement compared to students in the control group, where the current program was implemented.
- H3- Students in the experimental group, where AI and STEM-based instructional practices were implemented in the social sciences course, achieved higher learning retention compared to students in the control group, where the current program was implemented.

Theoretical and Conceptual Framework

Artificial Intelligence and STEM/STEAM Pedagogies in Social Studies

Artificial intelligence offers innovative possibilities in social studies education that transcend the boundaries of traditional teaching methods. These technologies are fundamentally changing how students access, process, and interpret information (Acuña Fretes, 2024; El Khayati et al., 2025; Kara, 2025). A key concept emerging in this field is generative artificial intelligence (e.g., ChatGPT, Midjourney) systems that can form new and original content such as text, images, or code. In social studies classrooms, these tools can be used for purposes such as creating texts that recount a historical event from the perspective of a different character, developing policy recommendations for a specific social issue, or creating visuals depicting the future demographics of a geographic region (Önder, 2025; Pokryshen, 2024).

Another important concept is data literacy, which refers to students' ability to gather, analyze, interpret, and visualize large sets of data. AI-powered tools allow students to examine complex data, such as census data, election results, or social media trends, to uncover social patterns and connections. This helps in fostering critical thinking and evidence-based reasoning (Lue, 2019). Simulations and Geographic Information Systems (GIS) offer students the opportunity to experience abstract historical and geographic phenomena in a concrete and interactive way (Homa, 2024; Mkhize, 2023a; 2023b). For example, students can virtually tour an ancient Roman city, make strategic decisions that influence the course of a war, or model the effects of a specific environmental policy on urban planning on GIS maps. These AI applications have the potential to transform social studies education from a process of memorization-based knowledge transfer to one of active engagement, discovery, and meaning-making (Sarwar et al., 2024).

STEM teaching methods closely align with the objectives of social studies education by providing a learning experience that is interdisciplinary, practical, and focused on solving real-world problems. A key element of these methods is inquiry-based learning, where students engage in learning by asking their own questions and exploring answers through discovery (Deák et al., 2021; Mbhanyisi et al., 2025; Özkan, 2024). In social studies, this approach encourages students to research primary and secondary sources, analyze evidence, and reach their own conclusions around a question like, "What were the effects of the Industrial Revolution on family structure?" Moreover, project-based learning (PBL), in which students examine a complex and authentic problem or question over an extended period, is a cornerstone of STEM education (Smith et al., 2022). This method requires students to develop a concrete solution or product, drawing on diverse disciplines such as geography, history, economics, and civics, for a project like, "How can we sustainably manage water resources in our region?" Furthermore, the design cycle, or design thinking, consisting of empathy, definition, idea generation, prototyping, and testing, instills in students a human-centered problem-solving mindset (Toma et al., 2024). In social studies, this pedagogy can be used in activities such as designing a public awareness campaign addressing social adaptation challenges faced by immigrants or developing a mobile app prototype to prevent cyberbullying in schools (Bolatlı & Korucu, 2018). These pedagogical approaches transform students from passive listeners into active, collaborative, and creative individuals who take responsibility for their own learning (Bolatlı & Korucu, 2018; Kanadlı, 2019; Mokotjo, 2024; Tang, 2024).

Integration Models and Design Approaches

The integration of AI and STEM pedagogies into social studies education can occur at different levels of depth and complexity. These levels are generally addressed on a spectrum from superficial applications to deep and transformative integration (Doğan et al., 2019). At the most superficial level, there is the approach called "enhancement" or "enrichment." At this level, technology and STEM activities are used only to make the process more efficient or interesting, without changing traditional teaching methods (Alshammari & Al-Enezi, 2024; Rahman et al., 2021). A history teacher might use an AI-generated visual to support their lecture or have students complete a coding activity at the end of a topic. However, these activities do not change the fundamental pedagogical structure or learning objectives of the course. The next level, "integration," refers to a situation where technology and the STEM approach become an integral part of the learning tasks. At this level, the task cannot be completed without the elements (Toma et al., 2024) such as students using GIS data to analyze historical changes in land use in a specific region or designing an engineering prototype to solve a local environmental problem.

The deepest level is known as "redefinition" or "transformation." At this stage, AI and STEM form new learning tasks and experiences that were previously unimaginable (the SAMR model is frequently used to describe these levels). At this level, students, in collaboration with students from different countries, conduct AI-powered data analysis on a global issue (e.g., the refugee crisis) and present their findings in a virtual reality environment with recommendations in the end (Xu & Ouyang, 2022).

Various design principles and models are utilized to implement these levels of integration. These models help teachers create a pedagogically sound foundation for AI and STEM activities. The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes that for effective integration, teachers need to understand not only technology, pedagogy, and content knowledge, but also the intersections of these three domains (e.g., Technological Pedagogical Knowledge, Technological Content Knowledge) (Ay et al., 2015; Harmse & Dichaba, 2025; Padgett et al., 2025). In the context of social studies, this means knowing which AI simulation (technology) can best support an inquiry-based learning (pedagogy) approach to teach a specific historical topic (content knowledge). Besides, "Integrated STEM Education" models offer different typologies for how to bring disciplines together. For instance, there are approaches such as the "servant model," where one discipline serves the others, or the "integrated model," where all disciplines are equally united around a common problem (Doğan et al., 2019). These models demonstrate that integrating AI and STEM into social studies courses is not just about incorporating technology and science into social sciences. Instead, it seeks to create a meaningful integration where all disciplines complement and enrich one another.

Cognitive and Socio-Affective Outcomes

The integration of AI and STEM-based activities into social studies courses holds significant potential for students' cognitive and affective development. While traditional teaching methods often focus on rote memorization and the recall of factual information, this integrated approach encourages students to utilize higher-order thinking skills (Hebebci & Usta, 2022). Problem-solving skills, in particular, are directly targeted through pedagogies such as project-based learning and the design cycle, which are central to STEM. When students encounter complex and open-ended societal problems (e.g., urban traffic congestion, the preservation of a historical artifact), they engage in a systematic problem-solving process that involves defining the problem, exploring possible solutions, developing prototypes, and evaluating the results (Beek & Straub, 2024; Netwong, 2018). In this process, AI helps students make more informed decisions by analyzing data or simulating different scenarios.

At the same time, critical thinking skills come to the fore when students are required to question the accuracy, bias, and reliability of information (e.g., text or images) generated by AI (Alvarez Sanchez, 2024). Students learn to evaluate conflicting information from different sources, construct evidence-based arguments, and recognize the potential biases of algorithms. Systematic thinking, or systems thinking, allows students to view social phenomena as complex systems composed of many interrelated elements (e.g., ecological systems, economic systems, political systems) rather than attributing them to a single cause (Mpofu, 2020).

In addition to cognitive gains, AI×STEM integration also positively impacts students' affective and social-emotional development in learning. Students working with authentic, real-world problems and gaining greater control over their own learning significantly increases their intrinsic motivation and interest in the course (Ulum, 2022). Engaging in projects where they form a concrete product or solution, rather than learning abstract and theoretical information, makes learning more meaningful and personally valuable. Hands-on activities such as robotics, coding, and digital design, in particular, stimulate students' natural curiosity and encourage them to explore and learn through trial and error (Chatzopoulos et al., 2019). As they overcome challenges and produce successful products in this process, their belief in their own abilities, in other words their sense of self-efficacy, strengthens (Aimukhambet et al., 2023; Korkmaz et al., 2021).

Method

Research Design

This study aims to determine the impact of AI and STEM-based instructional activities on the academic achievement, course attitudes, and learning retention of students in a social sciences course. The study was conducted among first- to fourth-year students enrolled in the Pedagogical Education Program at Korkyt Ata Kyzylorda University. To achieve this objective a quantitative research method, a quasi-experimental design, with a pretest-posttest control group was chosen as recommended for educational settings where random assignment is not feasible (Mertens, 2024). Quasi-experimental designs are used when participants are not randomly assigned to groups and, in this respect, are considered "almost" true experimental designs. In such designs, instead of randomly assigning participants to experimental and control groups, the researcher examines the effect of the experimental procedure on "natural groups" (Mertens, 2024, p. 137). Within the framework of this design, a pilot implementation of the instructional activities developed by the researchers was conducted before the experimental procedure. This pilot implementation was conducted for two weeks. Necessary adjustments were made to the activities based on the feedback obtained from the pilot implementation, and then the actual experimental implementation process was initiated.

Study Group

The study was conducted among first- to fourth-year students enrolled in the Pedagogical Education Program at Korkyt Ata Kyzylorda University. Participants were randomly assigned to experimental and control groups. Random assignment ensures that each of the existing groups (sections) has an equal probability of being assigned to the experimental conditions. Based on this assignment, section B (n=34) was assigned as the experimental group, and section A (n=34) as the control group. Two students who were absent during the experimental implementation were excluded from the experimental group. As a result, the study was conducted with 32 students in the experimental group and 34 students in the control group. Upon reviewing the demographic and academic equivalence of the groups, it was determined that the experimental group included 17 females and 15 males, while the control group comprised 18 females and 16 males. The average grades on the previous year's reports, examined for academic equivalence, were 69.7 for the experimental group and 70.12 for the control group. These data show that the groups were equivalent to each other regarding gender and academic achievement level before the experimental procedure.

Implementation of the Activities

The experimental group participated in interactive lessons using digital educational resources, incorporating AI and STEM elements, particularly modeling and project-based learning, to enhance cognitive autonomy and critical thinking skills. The control group studied the same content using traditional teaching methods in accordance with the curriculum.

The implementation process began with the administration of pretests to both groups. Students in the experimental and control groups were simultaneously administered the "Social Sciences Course Attitude Scale" to determine their attitudes toward social sciences, and the "Social Sciences Achievement Test" to measure their current achievement levels. This administration took two class hours (80 minutes).

Students in the experimental group were informed about AI and STEM-based teaching, and a visual presentation was provided. In the experimental group, eight sessions (8x80 minutes) of the Social Sciences Course "Kazakhstan History Unit Theme" were taught using AI and STEM-based teaching. The Kazakhstan History Unit consisted of four subtopics: (1) the establishment of the Kazakh Khanate, (2) Russian influence and colonization period, (3) the Soviet period, and (4) the process of independence and modernization. In the study, the researchers prepared an eight-session plan (Table 1) and implemented the activities in the experimental group (Table 2).

Table 1

8-Session Teaching Plan (AI + Stem Integration)

Session	Subject / Objective	AI / STEM Application	Activity Sample	Evaluation
1st Session	Introduction: Historical thinking skills and an introduction to AI	Simple AI concepts (Chatbot, Image recognition)	*Activity:* "Can AI answer historical questions?" – Students ask questions like "When was the Kazakh Khanate founded?" via a tool like ChatGPT.	Participation observation, pre-test
2nd Session	Establishment of the Kazakh Khanate	STEM: Map technologies (GIS), data visualization	*Activity:* Students form the borders of the Kazakh Khanate on a map using Google Earth or ArcGIS.	Digital map rubric
3rd Session	Russian influence and cultural change	Text analysis with AI (Natural Language Processing)	*Activity:* Word frequency analysis (e.g. "reform", "resistance") from period documents with AI text analysis tool.	Group presentation
4th Session	The relationship between Soviet-era industrialization and STEM	STEM: Industrial development models	*Activity:* Students design small engineering models (e.g., industrial plant, railway).	Product evaluation form
5th Session	Independence process (1991)	AI: Visual production tools (DALL·E, Canva AI)	*Activity:* AI-powered poster: "The first 10 years of independent Kazakhstan"	Digital poster scoring
6th Session	Modern Kazakhstan and leadership	AI-powered biography analysis	*Activity: Students asked AI to summarize the biography of leaders such as Nursultan Nazarbayev and discuss their strengths/weaknesses.*	Discussion scoring form

Session	Subject / Objective	AI / STEM Application	Activity Sample	Evaluation
7th Session	Looking to the future: STEM and Kazakhstan's technological vision	STEM project-based learning	*Activity:* Groups develop a project called "Kazakhstan's 2050 Technology Vision".	Project evaluation
8th Session	Evaluation and exhibition	AI-powered assessment tools (quiz creation)	*Activity: AI-generated quiz + student project exhibition*	Rubric + self-assessment

Table 2

AI + STEM Sample Activity

Session 1 – Map STEM Activity: Students studied the topic "Borders of the Kazakh Khanate." *Tools:* *AI tools:* ChatGPT, Gemini, DALL·E, Canva Magic Studio *STEM tools:* Tinkercad (modeling), GeoGebra, Google Earth, PhET simulations *Assessment tools:* Padlet (mirror board), AI Quiz Builder *Task:* Digitally mark the region where the Khanate was established, important cities, and trade routes. *Artificial Intelligence Activity:* Geographic data or historical information summaries are obtained from AI. *STEM Activity:* Geographic data interpretation, digital map production, data-visualization skills. *Measurement and Evaluation* • *Formative assessment:* small tasks and rubrics in each session • *Process assessment:* project development, teamwork, digital product quality • *Summative assessment:* presentation of the "AI-supported STEM History Portfolio" *Final Product* At the end of the eight sessions, students: They analyzed different periods of Kazakhstan's history using digital tools, They generated knowledge with AI, and they created STEM-based mini-projects.

- Students in the experimental group took the attitude scale and achievement test towards the social sciences course as a posttest at the end of the eight-session AI+STEM activities teaching practice. The same achievement test was administered to the experimental group students as a retention test one month after.
- Control group students studied the following subtopics within the Kazakhstan History Unit: (1) the establishment of the Kazakh Khanate, (2) the Russian influence and colonization period, (3) the Soviet period, and (4) the process of independence and modernization, in eight sessions based on the current curriculum guidelines. Traditional teaching methods, such as presentation and question-and-answer sessions, were primarily used in this phase. Control group students were simultaneously administered an attitude scale toward social sciences and an achievement test as a posttest. One month after the

posttest, the same achievement test was administered to control group students as a retention test.

Data Collection Tools

Attitude Scale Towards Social Sciences Course

In this study, a 5-point Likert-type attitude scale was developed to measure the attitudes of students towards social sciences. In the first stage of the scale development process, the relevant literature was reviewed, and the researchers formed an item pool. In writing the items, attention was paid to using understandable language appropriate for a grade level and to keeping the wording simple. Present tense expressions were also preferred over past or future tenses. The scale has a response format ranging from "strongly disagree" (1 point) to "strongly agree" (5 points). During the submission of the developed draft form for expert review, opinions were obtained from a total of seven experts. These experts were two social studies teachers, two Kazakh language and literature experts, and three PhD holders in statistics and measurement and evaluation. Based on the feedback received, necessary revisions were made to the draft form, and a 20-item pilot study form was developed.

The validity and reliability studies of the scale were conducted with a pilot study of 180 ninth-grade students. Analyses were conducted using SPSS 27.0, using exploratory factor analysis, KMO, and Bartlett's tests, as well as Cronbach's alpha reliability coefficients. Validity analyses revealed that the attitude scale exhibited a unidimensional structure. All items had factor loadings above 0.40. The Cronbach's alpha internal consistency coefficient of the measurement tool was calculated as 0.88. These values demonstrate that the Social Sciences Course Attitude Scale is a valid and reliable measurement tool for the research purposes.

Achievement Test

To measure students' academic achievement in this study, a 20-question multiple-choice test was prepared based on topics covered in the "History of Kazakhstan" unit of the social sciences course. This test was developed by the researchers and the teacher of the relevant course. The test was administered three times: before the experimental procedure (pretest), after the procedure (posttest), and one month after the intervention (retention test). The test was prepared using the curriculum, textbook, end-of-unit questions, and expert opinions. The questions were developed considering the learning outcomes associated with the unit. To determine the 20 questions for the achievement test, a 25-question draft test was initially prepared. This draft test, designed to determine validity and reliability, was administered to a group of 10 students who had previously studied the relevant unit. Reliability analyses were conducted using SPSS 27.0. The results showed that the reliability coefficient (KR-20) was .81 and the item discrimination (rjx) values ranged from .015 to .82. Five items with item discrimination indices below 0.30 were removed from the test. According to Sünbül (2002), items with an item discrimination index of .30 or above are considered to accurately reflect individuals' achievement. Following these corrections, the final KR-20 reliability analysis revealed an internal consistency coefficient of .84 for the final achievement test, and the test was considered reliable.

Data Analysis

SPSS 27.0 statistical package program was used to analyze the quantitative data collected during the research process. In the data analysis, firstly, the means of the pretest and posttest results of the participating students were examined. Secondly, normality tests were applied to the data collection tools to determine whether the data exhibited a normal distribution. The Shapiro-Wilk and Levene's homogeneity tests performed on the pretest, posttest, and retention test for the achievement and attitude data of the groups indicated that the quantitative data were normally distributed. In this context, the descriptive statistics and the results of the normality and homogeneity tests for the Social Sciences Attitude Scale (pretest-posttest) and the achievement test (pretest, posttest, retention) are presented in Table 3.

Table 3

Normality and Homogeneity Test Scores Regarding the Achievement and Social Sciences Attitude Scale and Permanence Test Scores

		Shapiro-Wilk Normality Test			Levene's Test (Homogeneity)	
		Statistic	df	Sig.	F	p
Social Sciences Attitude Scale (Pretest)	Experimental	0,931	32	0,211	0,004	0,947
	Control	0,934	34	0,306		
Achievement Test (Pretest)	Experimental	0,977	32	0,723	0,246	0,621
	Control	0,962	34	0,284		
Social Sciences Attitude Scale (Posttest)	Experimental	0,963	32	0,136	0,039	0,844
	Control	0,974	34	0,166		
Achievement Test (Posttest)	Experimental	0,975	32	0,652	0,301	0,585
	Control	0,968	34	0,411		
Permanence Test	Experimental	0,965	32	0,379	0,871	0,354
	Control	0,952	34	0,14		

As shown in Table 3, the Shapiro–Wilk and Levene's test results indicate that the achievement and attitude data met the assumptions of normality and homogeneity (p > .05). Therefore, parametric statistical analyses were deemed appropriate for subsequent group comparisons.

Findings

Following the verification of parametric test assumptions, group comparisons were conducted to determine differences between the experimental and control groups. The findings are presented sequentially, beginning with pretest comparisons to establish group equivalence. Table 4 presents the results of the independent samples t-test comparing the pretest attitude scores of the experimental and control groups.

Table 4

Comparison of Social Sciences Attitude Scale Pretest Results of Experimental and Control Groups

PreTest	Group	N	Mean	Std. Deviation	t	p
Attitude	Experimental	32	3,16	1,019	-0,572	0,569
	Control	34	3,29	0,938		

When Table 4 is examined, it is seen that the arithmetic mean of the pretest scores on the attitude scale toward the social studies course for the students in the experimental group was 3.16, while the mean for the students in the control group was 3.29. The t-test value calculated between the mean pretest attitude scores of the groups for social studies was 0.572. According to this finding, no significant difference was found between the pretest attitude scores of the participating groups. This indicates that the attitudes of the students in both groups toward the social studies course were equivalent before the experimental procedures. Table 5 shows the results of the social studies course achievement test administered to the groups before the research process.

Table 5

Comparison of Achievement Test Pretest Results of Experimental and Control Groups

PreTest	Group	N	Mean	Std. Deviation	t	p
Achievement	Experimental	32	8,44	2,368	-0,348	0,729
	Control	34	8,65	2,509		

When Table 5 is examined, it is seen that the arithmetic mean of the pretest scores for social studies course achievement of the students in the experimental group was 8.44, while the mean for the students in the control group was 8.65. The t-test value calculated between the mean pretest scores for social studies course achievement of the groups was 0.348. According to this finding, no significant difference was found between the pretest scores of the participating groups. It is understood that the social studies course achievement of the students in each experimental and control group was equivalent before the experimental procedures.

Table 6

Comparison of Social Sciences Attitude Scale Posttest Results of Experimental and Control Groups

Post-Test	Group	N	Mean	Std. Deviation	t	p
Attitude	Experimental	32	4,16	0,723	5,476	0,000**
	Control	34	3,21	0,687		

**p<0,001

When Table 6 is examined, it is seen that the arithmetic mean of the posttest scores of the attitude scale towards the social studies course for the students in the experimental group is 4.16, while the mean for the students in the control group is 3.21. The t-test value calculated between the posttest social studies attitude score averages of the groups was calculated as 5.476. This value shows that there is a significant difference between the attitudes of the students in both groups towards the social studies course after the experimental applications ($p<0.05$). As a result of the 8-week experimental procedures, it was observed that the attitudes of the students in the experimental group towards the social studies course were significantly higher than those of the students in the control group. Table 7 presents the results of the social studies achievement posttests administered to the groups after the experimental applications.

Tablo 7

Comparison of Social Sciences Achievement Test Posttest Results of Experimental and Control Groups

Post-Test	Group	N	Mean	Std. Deviation	t	p
Achievement	Experimental	32	12,84	2,604	4,201	0,000**
	Control	34	10,32	2,266		

**p<0,001

When Table 7 is examined it is seen that the arithmetic mean of the posttest social studies achievement scores of the students in the experimental group is 12.84, while the mean of the students in the control group is 10.32. The t-test value calculated between the posttest social studies achievement scores of the groups was calculated as 4.201. This value shows that there is a significant difference between the social studies achievements of the students in both groups after the experimental applications ($p<0.05$). After the 8-week experimental procedures, it was observed that the social studies achievements of the students in the experimental group were significantly higher than those of the students in the control group.

Table 8 shows the results of the social studies permanence test applied to the groups one month after the posttest.

Table 8.

Comparison of Permanence Test Results of Experimental and Control Groups

	Group	N	Mean	Std. Deviation	t	p
Retention Test	Experimental	32	12,06	1,933	4,247	0,000**
	Control	34	9,91	2,165		

**p<0,001

When Table 8 is examined it is seen that the arithmetic mean of the social studies course retention test scores of the students in the experimental group is 12.06, while the mean of the students in the control group is 9.91. The t-test value calculated between the mean permanence test scores of the groups was calculated as 4.247. This value shows that there is a significant difference between the social studies learning retention of the students in both groups after the experimental applications ($p<0.05$). As a result of the 8-week experimental procedures, it was observed that the learning retention of the students in the experimental group in the social studies course was significantly higher than that of the students in the control group.

Overall, the hypothesis testing results directly address the research purpose of the study. The findings demonstrate that students who participated in AI- and STEM-based instructional practices exhibited significantly more positive attitudes toward social studies, higher academic achievement, and stronger learning retention compared to those receiving traditional instruction. Accordingly, the results provide empirical support for all three research hypotheses, confirming that integrated AI×STEM pedagogy has a meaningful impact on both affective and cognitive learning outcomes in social studies education.

Discussion and Conclusion

The discussion is organized around three key themes emerging from the findings: (1) the impact of AI- and STEM-based instructional practices on students' attitudes toward social studies, (2) their contribution to academic achievement, and (3) their role in enhancing learning retention.

These themes are discussed by emphasizing the strengths of the present results and systematically comparing them with previous research on AI- and STEM-supported learning environments.

The findings of the present study are consistent with recent research conducted after 2020, which highlights the positive impact of AI-supported and STEM-oriented instructional practices on students' academic achievement, attitudes, and learning retention. Recent studies emphasize that technology-enhanced and project-based learning environments foster higher levels of student engagement, critical thinking, and long-term knowledge retention by actively involving learners in meaningful tasks (Mohsin et al., 2021; Funa, 2025). Similarly, contemporary research indicates that the integration of AI tools into inquiry-based and interdisciplinary learning settings contributes to improved learning outcomes and sustained student motivation, particularly in social science–related disciplines (Tang, 2024; Sarwar et al., 2024).

The Effect of AI and STEM-Based Instruction on Student Attitudes

The findings regarding the first hypothesis of the study indicated that AIxSTEM-based instructional practices positively and significantly improved students' attitudes toward social sciences compared to the control group. This affective change observed in the experimental group did not occur to the same extent in the control group, which used traditional expository teaching methods. This confirms that the selected pedagogical intervention has a strong impact on affective learning outcomes. The significance of this result stems from the fact that the AIxSTEM integration transforms students from passive recipients of information to active participants and producers.

Students' engagement with authentic, real-world problems made the learning process more meaningful and personally valuable. Hands-on activities such as robotics, coding, and digital design, in particular, appeared to stimulate students' natural curiosity. Pedagogies such as project-based learning (PBL) and inquiry-based learning provided students with greater control over their own learning, which in turn increased their intrinsic motivation. The experience of overcoming challenges and producing a tangible product strengthened students' belief in their own abilities, i.e., their sense of self-efficacy. Positive learning experiences contributed to students developing more positive attitudes not only toward social studies but also toward school and learning in general. This finding is consistent with studies in the literature indicating that STEM approaches increase students' interest in subjects. Indeed, Altakahyneh and Abumusa (2020) report that students show positive attitudes toward STEM approaches. Ulum's study (2022) of meta-analysis also revealed that integrated STEM approaches have a positive impact on the attitudes of elementary school students. Similarly, Bolatlı and Korucu (2018) reported that STEM activities supported by Web 2.0 tools provided positive feedback on collaborative learning and the coursework process. This study contributes to the literature by extending these findings to the social studies context and adding an artificial intelligence component (AI×STEM). The intervention appears to have helped students develop a more positive perspective on both technology and the social sciences.

The Effect of AI and STEM-Based Instruction on Academic Achievement

In line with the second hypothesis of the study, the experimental group receiving AIxSTEM-based instruction was found to have significantly higher academic achievement levels than the control group. This finding suggests that an interdisciplinary, technology-focused curriculum is more effective regarding cognitive outcomes compared to traditional, expository instruction. The experimental group did not only retained factual information but also developed the ability to analyze complex social problems. This success stems from a pedagogical design that requires students to actively engage in higher-order thinking skills.

Students encountered real-world problems through PBL and inquiry-based learning. The intervention enabled students to practice data literacy skills and systematic problem-solving processes. AI tools provided students with personalized learning paths and helped them discover meaningful patterns within complex data sets. Technologies such as GIS and simulations made abstract historical and geographical phenomena concrete and interactive. This constructivist learning environment encouraged deeper processing and understanding of information. This result is consistent with literature findings showing that STEM education positively impacts problem-solving, critical thinking, and academic achievement. Hebebci and Usta (2022) reported that integrated STEM practices have positive effects on problem-solving skills and critical thinking dispositions. Similarly, Netwong (2018) stated that STEM integration supports the development of problem-solving skills. The current study demonstrates that the integration of AI technologies into this process can further enhance achievement. The TPACK framework, key to effective integration, demonstrated the successful intersection of technology, pedagogy, and content knowledge in this study. Therefore, AI×STEM integration in social studies can provide students with both digital-age technical skills and critical thinking competencies.

The Effect of AI and STEM-Based Instruction on Learning Retention

Supporting the third hypothesis of the study, students in the experimental group receiving the AIxSTEM intervention were observed to have significantly higher scores on the retention test administered one month after the posttest compared to the control group. This demonstrates that the intervention not only improved short-term success but also facilitated the transfer of knowledge to long-term memory. memoryIn the control group, where traditional teaching methods were employed, the drop in scores between the posttest and retention test was more noticeable. The primary reason for this difference in learning retention lies in the active engagement of students in the experimental group during the learning process. Rather than passively receiving information, these students actively processed, questioned, and applied the knowledge to new contexts. For example, instead of simply listening to information about Soviet-era industrialization in the Kazakhstan History unit, they designed engineering models from that period. These types of hands-on and PBL experiences ensured that knowledge was embedded more strongly and deeply in cognitive schemas. The concretization of abstract concepts through simulations and interactive tools created multiple learning pathways that facilitated recall.

Pedagogies such as design thinking require students to repeatedly use learned knowledge to solve a problem, which increases retention (Ayubi et al. 2024). This result aligns with the fundamental assumptions of constructivist learning theory and the general literature finding that active learning increases retention. The literature is quite limited in terms of studies empirically examining the effects of AI and STEM integration on retention in the social studies context. Existing studies mostly consist of case studies, pilot applications, or descriptive studies, making it difficult to reach generalizable and reliable conclusions. This study, with its quasi-experimental design with a control group, fills a significant research gap in the field by providing concrete and empirical evidence on the impact of an AI×STEM intervention on learning retention. It demonstrates how the vision of training students to transform from technology consumers into critical producers sensitive to societal issues can be achieved. Therefore, it is concluded that a pedagogically sound AI×STEM integration can develop a deep and lasting understanding beyond superficial learning.

Implications of the Findings

The findings of this study have important implications for social studies education practices, curriculum development, and teacher training programs. The positive results demonstrate the necessity of transitioning from traditional pedagogies to interdisciplinary and technology-focused models in social studies teaching. Teachers must no longer be the sole source of knowledge but rather embrace the role of "learning designers" who facilitate students' learning processes. The current study demonstrates that AI×STEM integration need not remain fragmented and superficial as suggested in the literature, but can be deeply integrated into the curriculum with a structured eight-session plan. For curriculum developers, these findings suggest that social studies programs should be updated to include not only the transmission of historical and geographic knowledge but also skills such as data literacy, digital citizenship, and systems thinking.

Artificial intelligence and STEM teaching methods provide valuable tools for developing these skills. The results highlight the essential role of teachers having the TPACK competencies needed to successfully implement the complex AI×STEM integration. As a result, there is an urgent need to update both pre-service and in-service teacher education programs to improve teachers' proficiency with these emerging technologies and teaching strategies. This study also demonstrates that these tools can be applied within a pedagogical framework to foster critical thinking and ethical awareness, addressing the ethical concerns surrounding AI in education. This integrated model can enhance students' ability to analyze complex social problems and generate creative solutions. School administrators must also provide flexible learning environments and technological infrastructure to support this transformation. Ultimately, these findings demonstrate that AI×STEM integration can play a transformative role in social studies education achieving its goal of raising better-equipped citizens for the future.

Limitations

Despite its robust findings, this study has some limitations, and the results should be interpreted within this framework. The research design was designed as a quasi-experimental design rather than a true experimental design. Participants were not individually randomly assigned to groups. Instead, existing classes (B and A) were randomly assigned to the experimental and control groups. This use of a "natural group" raises the possibility that the observed differences between groups were due not solely to the intervention but to unmeasured latent class dynamics. This sample size and single-centered structure limit the generalizability of the results. It is difficult to determine whether the findings apply to different school types, socioeconomic levels, or geographic regions. Another limitation concerns the duration of the intervention. The intervention spanned eight sessions (640 minutes in total). While this period produced a significant effect on attitude and achievement, it does not provide information about the long-term sustainability of these effects after a one-month retention test. Finally, the fact that the intervention was conducted by the researchers carries a potential risk of bias stemming from teacher factors. The researcher's belief in the process and motivation may have indirectly influenced the performance of the experimental group students.

Recommendations

Based on the findings and identified limitations of this study, several recommendations are developed for future researches and educational practices. Future researchers are encouraged to replicate this study with larger and more diverse samples (from different sociocultural and geographic regions). Where possible, using true experimental designs with individual-level randomization would enhance the internal validity of the results. Moreover, longitudinal studies that monitor the effects of the intervention over a longer period (e.g., 6 months or 1 year) rather than just one month could provide clearer information about the long-term sustainability of the AI×STEM approach. While this study focused on a quantitative design, future studies using qualitative data collection methods such as student interviews and classroom observations could provide a more in-depth understanding of the "how" and "why" of integration.

For practitioners and teachers, the eight-session curriculum and sample activities developed in this study can be used as an evidence-based model for AIxSTEM integration in social studies classrooms. It is critical that school administrators provide the technological infrastructure (e.g., GIS software, access to AI tools) to support such innovative pedagogies. To address teachers' competency gaps in this complex integration, it is recommended that in-service training programs based on the present study implementation can be designed. Social studies curricula need to be updated nationally to include AI literacy and STEM skills. Mandatory inclusion of topics such as TPACK and AI ethics in teacher training institutions will prepare future teachers for this transformation. This study has demonstrated that AIxSTEM integration can be successful even in a traditional field like social studies. Therefore, new research is needed to explore how this integration can be applied to other humanities fields.

Conclusion

This research examined the effects of integrating AI and STEM pedagogies into social studies course on students' attitudes, achievement, and learning retention using a quasi-experimental design. The study aimed to fill a significant gap in the literature in studies that empirically examine how AI×STEM integration can be implemented within the context of social studies via a holistic design and the effects of these practices on student outcomes. Unlike the fragmented and "best practices" in the literature, this study presented and tested an eight-session pedagogically structured intervention model (PBL, design-focused thinking). The main findings of the study revealed that AI×STEM-based instruction significantly increased both affective (attitude) and cognitive (achievement) gains in students compared to traditional methods. More importantly, these gains were maintained even after one month, demonstrating sustained learning. This study's most significant theoretical contribution to the literature is its presentation of an evidence-based model that successfully integrates ethical and citizenship goals specific to the social sciences with a technology- and engineering-focused framework. Practically, this research has demonstrated how AI can be used not as a threat but as a powerful pedagogical tool that supports critical thinking and problem-solving. The findings provide concrete evidence that policymakers believe that updating curricula in an interdisciplinary and technology-focused manner is not merely a technological innovation but a pedagogical imperative. Professional development programs need to be restructured to ensure that teachers acquire the TPACK competencies necessary for this transformation. Ultimately, this study has demonstrated that AI×STEM integration, when implemented with appropriate pedagogical strategies, can significantly contribute to the vision of educating students not as passive consumers of the digital age but as critical and active producers, sensitive to societal challenges.

The study demonstrates the effectiveness of applying innovative pedagogical methods and digital resources. AI and STEM elements contribute to the development of students' cognitive autonomy, critical thinking skills, and practical competencies.

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