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Research and analysis on artificial intelligence applications in education: a study across programming, history, and English

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Abstract. This paper conducts a systematic review of artificial intelligence integration in programming, history, and English education, focusing on technological applications, practical outcomes, and existing challenges. Against the backdrop of global educational digitalization, AI technologies such as generative models, adaptive learning systems, intelligent tutoring systems, and AI-enhanced learning management platforms have addressed long-standing issues in these disciplines, including low engagement in programming, abstract historical instruction, and one-size-fits-all English teaching. By analyzing 10 recent scholarly works, this study first categorizes mainstream AI educational technologies, then compares their discipline-specific uses in code generation, historical simulation, argument feedback, language practice, and adaptive assessment. It also discusses how these tools influence learner autonomy, teacher workload, classroom interaction, and educational equity. Findings reveal that AI enhances personalized learning but requires pedagogical alignment to avoid superficial knowledge acquisition, student overreliance, data bias, and integrity risks. Future research should prioritize interdisciplinary AI education frameworks, ethical governance mechanisms, teacher training, and long-term impact assessments to promote sustainable AI integration in K-12 and higher education.

Keywords: artificial intelligence in education, programming education, english language teaching, generative AI, educational technology

1. Introduction

The global digital transformation has cemented artificial intelligence as a transformative force in education, reshaping teaching and learning across programming, history, and English disciplines. This paradigm shift is not merely technological but pedagogical, aiming to transition from traditional teacher-centered models to dynamic, student-centered ecosystems. The integration of AI into these specific fields is driven by distinct pedagogical challenges: programming education grapples with high attrition rates due to abstract computational concepts and limited personalized guidance; history instruction struggles to move beyond rote memorization and foster critical thinking amid static curricula; English teaching faces one-size-fits-all models and inefficient feedback for language skills [1-3]. These discipline-specific pain points necessitate a nuanced analysis of how AI can support educational reform.

The penetration of AI in educational settings has reached a critical mass. According to recent statistics, approximately 48% of educators now utilize AI tools for lesson customization and progress tracking [4]. As digital literacy becomes a core competency in the 21st century, AI integration has shifted from a niche innovation to a mainstream practice. This transition demands a systematic analysis of its applications and impacts to ensure that the technology serves pedagogical goals rather than becoming an end in itself. The rapid evolution of tools like ChatGPT and Google Bard has further accelerated this adoption, creating an urgent need for evidence-based frameworks [4].

This research holds multi-faceted significance that extends beyond theoretical discourse. Theoretically, it fills gaps in fragmented scholarship by developing a unifying framework for AI's role across programming and humanities with history and English disciplines [1-3]. By synthesizing findings from these diverse fields, this study aims to identify transferable principles of AI efficacy. Practically, it offers actionable insights for educators and policymakers. For instance, in programming, the research focuses on mitigating AI code assistant overreliance to boost conceptual understanding [5]; in history, it explores using AI simulations to enhance historical reasoning [2]; and in English, it evaluates adaptive platforms to accelerate proficiency [3]. These practical applications are crucial for bridging the gap between technological capability and classroom reality.

Societally, this research advances the agenda of educational equity. By exploring how AI can democratize high-quality instruction, particularly for marginalized learners, this paper aligns with global efforts to reduce educational disparities [4]. AI has the potential to act as a "great equalizer" by providing access to personalized tutoring and resources that were previously available only to privileged populations. However, this potential can only be realized through responsible implementation that addresses the digital divide [4].

Despite the burgeoning literature on AI in education, there remains a significant gap in cross-disciplinary analysis. Wang et al. mapped the current status, hotspots, and trends of AI education research in China, but their bibliometric study did not provide discipline-specific classroom cases [6]. Wei similarly analyzed research hotspots and trends in primary and secondary AI education without comparing the effectiveness of AI across subjects [7]. Existing studies also have scope limitations. Liang and Wang proposed an AI-enhanced task-based model for junior secondary English, yet their lesson-focused analysis did not assess long-term proficiency outcomes [8]. Huang discussed key points, implementation difficulties, and strategies in AI-empowered senior high school English teaching, but the study was conceptual rather than longitudinal [9]. Li examined innovation paths and practical methods for AI-enabled university English teaching, but focused on higher education without comparison with K-12 contexts [10]. These fragmented studies lack a holistic view, failing to identify shared challenges or transferable best practices across programming, history, and English.

To address these gaps, this paper aims to provide a systematic cross-disciplinary review. The subsequent chapters are structured to guide the reader through a comprehensive analysis. Chapter 2 will break down mainstream AI educational technologies, categorizing them by function and capability. Chapter 3 will analyze AI applications and outcomes across the three disciplines, providing empirical evidence of their impact. Chapter 4 will discuss core challenges and future prospects, confronting issues of ethics and sustainability head-on. Finally, Chapter 5 will conclude with actionable recommendations for stakeholders. The core goal of this structure is to provide an evidence-based framework for responsible, sustainable AI integration that enhances student-centered learning across these vital educational domains.

2. Mainstream AI educational technologies

The landscape of AI in education is populated by a diverse array of technologies, each serving distinct pedagogical functions. To understand their application in programming, history, and English, it is essential to categorize these tools based on their underlying mechanisms and interaction models [4]. This chapter analyzes the technological backbone that supports the innovations discussed in subsequent sections.

2.1. Generative Large Language Models

Generative AI, particularly Large Language Models, also called LLMs, such as GPT-4, Claude, and Llama, represents a seismic shift in educational technology. Unlike previous generations of AI that relied on rule-based systems, LLMs utilize deep learning algorithms, specifically transformer architectures, to generate human-like text based on vast datasets [4]. In the context of education, these models function as dynamic knowledge engines capable of synthesizing information, generating creative content, and engaging in dialogue.

The significance of LLMs lies in their versatility. They can act as "infinite interns" for students, providing immediate feedback, explanations, and scaffolding. For programming education, models like Codex, the engine behind GitHub Copilot, can generate syntactically correct code from natural language prompts [1]. In history, they can simulate dialogues with historical figures or generate alternative historical scenarios to explore counterfactuals [2]. For English learners, they serve as conversation partners, grammar tutors, and writing assistants [3]. However, this power comes with the caveat of "hallucinations" or factual inaccuracies, which necessitates critical evaluation by users—a skill that must be taught explicitly in curricula [4].

2.2. Adaptive learning systems

Adaptive learning systems represent the evolution of Computer-Assisted Instruction into sophisticated, data-driven ecosystems. These systems utilize algorithms to analyze student performance in real-time and adjust the difficulty, pacing, and content of learning materials accordingly. The core technology behind these systems often involves Knowledge Tracing models, such as Bayesian Knowledge Tracing or Deep Knowledge Tracing, which predict a student's knowledge state based on their interaction history [4].

In practice, these systems create a personalized "playlist" for each learner. If a student struggles with a concept in English grammar, the system will present remedial content and additional practice before allowing progression. Conversely, if a student demonstrates mastery, the system accelerates them to more challenging material. This technology is particularly effective in addressing the "long tail" of student performance, ensuring that neither struggling students nor advanced learners are left behind [3]. Platforms like DreamBox for math and Duolingo for language exemplify the commercial and pedagogical success of this approach, though their application in history and complex programming logic remains an area of active development.

2.3. Intelligent Tutoring Systems

Intelligent Tutoring Systems, also called ITS, aim to replicate the functionality of a human tutor through software. An ITS typically consists of three main components: the domain model, which represents the knowledge to be taught; the student model, which shows the learner's current state; and the tutoring model, which is the pedagogical strategy for instruction [1]. Unlike adaptive systems that often focus on multiple-choice or structured responses, ITS can handle complex problem-solving scenarios.

In programming education, ITS like AutoTutor or SQL-Tutor guide students through the debugging process by asking Socratic questions rather than simply providing answers [1]. They can recognize common bugs in code and offer targeted hints. In history, ITS can evaluate the quality of a student's historical argument, checking for the use of evidence and logical consistency [2]. The effectiveness of ITS hinges on their ability to provide "just-in-time" scaffolding, offering support that is gradually faded as the student gains competence. However, the development cost of high-fidelity ITS is often prohibitive, leading to a gap between research prototypes and widely available commercial products.

2.4. Learning Management Systems with AI plugins

While not AI-native, traditional Learning Management Systems, also called LMS, such as Moodle, Canvas, and Blackboard are increasingly integrating AI plugins to enhance their functionality. These plugins add layers of intelligence to existing workflows, such as automated grading of essays, plagiarism detection, and predictive analytics for student retention [4].

For English teachers, AI plugins can automate the tedious task of grammar and style checking, freeing up time for higher-order feedback on content and structure [3]. In history courses, they can help manage the logistics of large-scale research projects by tracking student progress and identifying at-risk students early [2]. The integration of AI into the LMS ecosystem is significant because it lowers the barrier to entry for educators, allowing them to adopt AI tools without overhauling their entire teaching infrastructure [4].

2.5. Computer Vision and Affective Computing

Emerging at the frontier of EdTech is the application of Computer Vision and Affective Computing to gauge student engagement and emotional states. These technologies use webcams or sensors to analyze facial expressions, eye movements, and even physiological signals to infer a student's level of frustration, confusion, or engagement [4].

In a programming lab, for example, if a student exhibits signs of high frustration, such as furrowed brows or lack of eye contact with the screen, the system could intervene by offering a hint or suggesting a break [1]. In history or English discussions, these tools could theoretically assess participation levels and ensure equitable airtime [2, 3]. However, this category of technology is fraught with ethical concerns regarding privacy, data security, and the potential for misinterpretation of cultural differences in expression. As such, while technically fascinating, its adoption in mainstream education remains cautious and heavily regulated in many jurisdictions [4].

3. Analysis of AI applications and outcomes across disciplines

The integration of Artificial Intelligence into education is not a monolithic phenomenon; its manifestations, efficacy, and implications vary dramatically across different academic disciplines. This chapter provides a granular analysis of AI applications in programming, history, and English language teaching, drawing upon recent empirical studies to evaluate their practical outcomes and pedagogical impacts [1-3].

3.1. Programming education: from code generation to cognitive scaffolding

Programming education has historically been characterized by high cognitive load and significant attrition rates, often referred to as the "leaky pipeline" problem [1]. Students frequently struggle with abstract concepts like recursion, data structures, and algorithmic thinking, compounded by the frustration of debugging syntax errors that can halt progress entirely. AI, particularly in the form of Generative LLMs and ITS, has emerged as a powerful tool to mitigate these challenges [1].

The most visible application is AI-powered code assistants like GitHub Copilot, which leverage models such as OpenAI's Codex. These tools can generate entire functions or code snippets from natural language prompts, drastically lowering the initial barrier to entry for novice programmers [1]. A systematic review by Elnaffar, Rashidi, and Abualkishik highlights that such tools can accelerate the learning process by providing immediate, contextualized support for common coding problems [1]. For instance, a student struggling to implement a sorting algorithm can receive a working example, allowing them to focus on understanding the underlying logic rather than getting bogged down in syntactic details.

However, the impact is double-edged. Rojas-Galeano, Tejada, and Marmolejo-Ramos in 2025 conducted a critical study on student attitudes, revealing a pervasive tension between viewing AI as a "tool" versus a "trouble" [5]. Their findings indicate that while students appreciate the efficiency gains, there is a widespread concern about skill atrophy and overreliance. Many students reported a tendency to accept AI-generated code without fully comprehending it, leading to a superficial understanding—a phenomenon akin to "cargo cult programming," where the form is replicated without grasping the function [5]. This raises a fundamental pedagogical question: how can we design learning activities that leverage AI's generative power while ensuring deep conceptual mastery?

To address this, the focus is shifting from mere code generation to cognitive scaffolding. Advanced ITS are being developed to engage students in a Socratic dialogue about their code [1]. Instead of providing a direct answer, these systems ask probing questions like, "What do you think this loop is supposed to accomplish?" or "How would you test this function with an edge case?" This approach encourages metacognition and problem-solving skills, aligning AI use with constructivist learning principles [1]. The future of AI in programming education lies not in replacing the programmer, but in becoming an intelligent mentor that guides the learner through the complex landscape of computational thinking.

3.2. History education: breathing life into the past

History education has long grappled with the challenge of moving beyond rote memorization of dates and events towards fostering historical thinking skills—such as sourcing, contextualization, corroboration, and argumentation [2]. Traditional textbooks and lectures often present a static, monolithic narrative, leaving little room for student inquiry or critical engagement with the complexities of the past. AI offers novel pathways to transform this dynamic [2].

One of the most promising applications is the use of AI to create immersive historical simulations and role-playing scenarios. As Albanese in 2025 notes in her historical overview of AI in education, modern LLMs can be fine-tuned to simulate conversations with historical figures or to generate plausible primary source documents from a specific era [2]. Imagine a student debating the merits of the New Deal with an AI persona of Franklin D. Roosevelt, or analyzing a set of AI-generated newspaper clippings from 1914 to understand the public sentiment leading up to World War I. These interactive experiences can make history feel immediate and relevant, encouraging students to see it not as a fixed story but as an ongoing process of interpretation [2].

Furthermore, AI can assist in the development of historical arguments. An AI system could analyze a student's essay, checking for the appropriate use of evidence, logical coherence, and awareness of historiographical debates [2]. It could provide feedback such as, "Your claim about the causes of the French Revolution is strong, but you have not addressed the counter-argument presented by revisionist historians like Simon Schama."

Despite this potential, significant risks remain. The primary concern is the "hallucination" problem inherent in LLMs. An AI might confidently generate a detailed account of a non-existent treaty or misattribute a famous quote, thereby propagating historical inaccuracies [4]. Teachers must therefore play a crucial role as "historical fact-checkers," guiding students to critically evaluate any information provided by an AI against established scholarly sources. The goal is to use AI not as an oracle of truth, but as a catalyst for deeper research and more nuanced historical reasoning [2].

3.3. EnglisH Language Teaching in personalizing the path to proficiency

English Language Teaching, also called ELT, is perhaps the field where AI's potential for personalization is most readily apparent. Language acquisition is inherently a personalized journey, with learners progressing at different rates in listening, speaking, reading, and writing. Traditional classroom settings often struggle to provide the individualized practice and feedback necessary for optimal growth. AI-driven adaptive learning platforms and conversational agents are directly addressing this gap [3].

A systematic literature review by Sapuan, Sulaiman, and Mohamad in 2025 confirms a clear trend: AI technologies are being widely integrated into ELT to enhance all four core skills [3]. For speaking and listening, AI chatbots and voice recognition software offer a safe, non-judgmental space for practice. Learners can engage in simulated conversations, receive instant pronunciation feedback, and repeat exercises until they achieve fluency. For reading and writing, AI can provide personalized reading recommendations based on a student's level and interests, and offer detailed, automated feedback on grammar, vocabulary, style, and even coherence [3].

At the K-12 level, Liang and Wang examined AI-enhanced task-based English teaching in junior secondary education through a listening-and-speaking lesson design [8]. Their study shows how AI can create authentic contexts, provide personalized support, and enable process-oriented evaluation, while the teacher retains responsibility for task design and higher-order guidance [8]. At the university level, Li investigated innovation paths and practical methods for AI-enabled English teaching [10]. The study highlights opportunities including immersive language environments, personalized learning, and richer course resources, while also identifying challenges such as insufficient teacher competence, fragmented content, and imbalanced assessment [10].

Huang identifies critical challenges in senior high school ELT, including limited teacher understanding of AI, insufficient use of AI resources, and difficulties in selecting appropriate platforms [9]. The study underscores that the mere presence of technology is insufficient; success depends on thoughtful pedagogical design and adequate teacher training [9]. The overarching finding across these studies is that AI can be a powerful accelerator for language proficiency, but its effectiveness is contingent upon its alignment with sound language teaching methodologies and a clear strategy to prevent passive consumption of AI-generated content [3, 8-10].

4. Core challenges and future prospects

While the applications of AI in programming, history, and ELT are promising, their path to sustainable and equitable integration is fraught with significant challenges. Addressing these issues is paramount to ensuring that AI serves as a force for educational enhancement rather than a source of new problems [4].

4.1. Ethical and pedagogical dilemmas

The most pressing challenge is the ethical and pedagogical dilemma of student overreliance. In all three disciplines, there is a risk that students will outsource their cognitive labor to AI. A programming student might submit AI-written code without understanding it; a history student might accept an AI-generated historical narrative at face value; an English student might rely on an AI to craft their essays, never developing their own authentic voice. This "cognitive offloading" can lead to a dangerous illusion of competence, where students appear proficient on the surface but lack the deep, transferable skills required for real-world problem-solving [5, 10].

This issue is intrinsically linked to the crisis of academic integrity. The ease with which AI can generate high-quality text and code has forced a fundamental rethinking of assessment. Traditional take-home essays and coding assignments are now vulnerable to AI-assisted cheating. The solution is not to ban AI, but to redesign assessments around what AI cannot easily replicate: in-person presentations, oral defenses of code, reflective journals on the learning process, and collaborative projects that emphasize process over product. As Balta in 2024 argues, the focus must shift from assessing the final output to evaluating the student's thinking, creativity, and ability to work with and critique AI tools [4].

Another critical ethical concern is algorithmic bias. LLMs are trained on vast datasets that often reflect societal biases related to race, gender, and culture. If an AI writing tutor consistently favors a particular style of English that aligns with a dominant cultural norm, it may inadvertently marginalize students from diverse linguistic backgrounds. Similarly, an AI history tutor might present a skewed perspective that overlooks the contributions of underrepresented groups. Ensuring fairness and inclusivity requires continuous auditing of AI systems and a commitment to developing more representative training datasets [4].

4.2. Technical and logistical barriers

Beyond ethics, significant technical and logistical barriers impede widespread adoption. Bibliometric analyses by Wang et al. and Wei indicate that AI education research remains uneven in focus and development, with substantial room for deeper implementation studies [6, 7]. These gaps are especially consequential in under-resourced schools or rural areas, where unreliable internet access and limited devices may restrict the use of sophisticated AI tools and exacerbate educational inequalities.

Furthermore, there is a massive gap in teacher preparedness. Most educators were not trained to use, let alone teach with, AI. They need professional development in the technical use of these tools, in prompt engineering (the ability to craft effective instructions for AI), and in critical AI literacy to guide their students. Without this support, teachers may either avoid AI altogether or use it in ways that reinforce poor pedagogical practices [9, 10].

4.3. Future research directions

To navigate these challenges and unlock AI's full potential, future research must pursue several key directions. First, there is an urgent need for longitudinal studies that track the long-term cognitive and affective impacts of AI use on students. Does early and consistent use of AI code assistants improve or hinder a student's ability to solve novel, complex programming problems years later? This type of data is currently scarce [1, 5].

Second, research should focus on developing interdisciplinary AI education frameworks. The skills needed to thrive in an AI-augmented world—critical thinking, prompt engineering, data literacy, and ethical reasoning—are not confined to a single subject. A unified framework that integrates these competencies across the curriculum, from programming labs to history seminars to English workshops, is essential [6, 7].

Finally, the field must prioritize the development of Explainable AI, also called XAI, for education. Current "black box" models make it difficult for students and teachers to understand why an AI made a particular suggestion or generated a specific piece of content. XAI aims to make these decision-making processes transparent, which is crucial for building trust, enabling critical evaluation, and turning AI interactions into genuine learning moments [4].

5. Conclusion

This paper has systematically analyzed the application of artificial intelligence in three distinct yet vital educational domains: programming, history, and English language teaching. The evidence reveals a landscape of immense promise tempered by profound challenges.

In programming, AI acts as a powerful co-pilot, accelerating code creation and debugging, but it risks fostering a generation of developers who can prompt but not truly program. In history, AI can animate the past through simulations and dialogues, yet it threatens to replace critical historical inquiry with uncritical acceptance of algorithmically generated narratives. In English, AI offers unprecedented personalization for language practice, but it may also erode the development of a student's unique linguistic identity and voice.

The central thesis that emerges is that the success of AI in education is not a technological question but a deeply pedagogical one. Technology alone is not a solution; it is a tool whose value is determined by the quality of the educational design surrounding it. The greatest danger is not the technology itself, but a form of "technological solutionism" that assumes a new tool can fix old problems without a fundamental rethinking of teaching and learning.

Therefore, a responsible path forward requires a multi-stakeholder effort. Educators must become adept at integrating AI in ways that promote deep learning and critical thinking. Policymakers must invest in infrastructure to bridge the digital divide and fund robust teacher training programs. Developers must prioritize pedagogical soundness, transparency, and fairness in their AI designs.

Ultimately, the goal of AI in education should not be to automate the teacher or to create perfectly efficient learners. Instead, it should be to empower both students and teachers to engage more deeply, think more critically, and create more meaningfully in an increasingly complex world. By confronting the challenges head-on and aligning technological innovation with enduring pedagogical values, we can harness AI to build a more equitable, engaging, and effective educational future for all.

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