THE USE OF ARTIFICIAL INTELLIGENCE IN COMPUTER SCIENCE LESSONS AND ITS PEDAGOGICAL ADVANTAGES

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Abstract

The article examines the didactic potential, effectiveness and risks of using artificial intelligence (AI) tools in teaching computer science in secondary and higher education. Following the IMRAD structure, a systematic-synthetic review was conducted, comparing international empirical studies and meta-analyses on intelligent tutoring systems (ITS), large language models (LLMs) and code-generation tools. The findings indicate that ITS yield moderate-to-large gains compared with conventional classroom instruction (Cohen's d ≈ 0.66–0.76); LLM-based assistants improve task completion speed and quality among novice programmers, yet, without pedagogical guardrails, may impair independent knowledge acquisition. A five-stage didactic model of an AI-integrated computer science lesson is proposed. The results are of practical value for computer science teachers, curriculum designers and education policymakers.

Keywords: artificial intelligence, computer science education, intelligent tutoring system, large language models, personalized learning, programming education, digital competence.

Introduction

Artificial intelligence is no longer a separate institution within the educational process; it is becoming a common infrastructure for all subjects. Computer science performs two functions in this process at once: it provides knowledge about AI (as an object of study) and it is taught with the help of AI tools (as a means of instruction). In Uzbekistan, the "Digital Uzbekistan – 2030" Strategy defines the development of

digital competencies as a priority task [1], which strengthens the need to introduce modern AI technologies into computer science lessons on a scientifically grounded basis.

AI is not a new phenomenon in education: research on intelligent tutoring systems has a history of several decades [8; 9]. However, with the emergence of generative models (ChatGPT, Codex, Copilot and others) from 2022 onward, the situation has changed qualitatively: learners can now ask questions in natural language and receive text, code and explanations in return [10; 11]. The review by Zawacki-Richter and colleagues showed that most studies of AI in education focus on technical aspects, while pedagogical theory and the role of the teacher remain insufficiently addressed [5]. The same problem exists in computer science education.

The research problem is as follows: a single, systematized answer is lacking to the question of at which stage, in what form and under what control a computer science teacher should use AI tools so that learners' thinking and programming skills are strengthened rather than weakened.

The aim of this article is to identify the pedagogical advantages of using AI in computer science lessons on the basis of empirical evidence and to develop a model for its introduction into practice.

The study addresses the following research questions:

RQ1. Which types of AI tools have a positive effect on learning outcomes in computer science education?

RQ2. What are the main pedagogical advantages and limitations of using AI?

RQ3. What should a lesson model look like that maximizes the advantages and minimizes the risks?

The study relies on L. S. Vygotsky's concept of the zone of proximal development (ZPD) [23] and on J. Hattie's evidence on the effectiveness of feedback

[22]. If an AI tool acts as "scaffolding," the learner moves toward independent work within the ZPD; if the tool performs the task in place of the learner, development stops.

Methods

The study was conducted as a narrative-systematic review, and the transparency of reporting was organized in accordance with the PRISMA 2020 recommendations [20].

The inclusion criteria were: (a) peer-reviewed articles, meta-analyses and reports of international organizations published in 2011–2025; (b) a focus on AI in education, particularly in computer science and programming education; and (c) the availability of quantitative or qualitative evidence of effectiveness. The exclusion criteria were: (a) works limited to a technical description of an algorithm without reporting pedagogical outcomes; and (b) non-peer-reviewed materials of an advertising nature.

The selected sources were coded along four dimensions: the type of AI tool; the educational context (school or higher education); the measured outcome (knowledge, time, motivation, retention); and the effect size or main finding. Thematic synthesis and comparative analysis were then applied. Contradictory findings were flagged separately, and their possible causes (study design, sample size, control condition) were discussed.

Results

Intelligent tutoring systems (ITS)

According to VanLehn's analysis, the effectiveness of ITS ($d \approx 0.76$) is almost the same as that of an individual human tutor ($d \approx 0.79$) and is markedly higher than that of conventional group instruction [8]. In the meta-analysis by Kulik and Fletcher, the median effect size for groups using ITS was 0.66 [9]. These results are particularly relevant to computer science for the rapid diagnosis of errors and for adaptive sequences of exercises.

Large language models and code generation

Becker and colleagues describe AI code generators in introductory programming as a pairing of "opportunities and challenges": the tools lower the syntax barrier, but the automatic solution of routine assignments weakens the assessment system [12]. Finnie-Ansley and colleagues found that Codex performed close to the top quartile of students on introductory course examination questions [11]. In a controlled experiment by Kazemitabaar and colleagues, novice learners completed more tasks, and more accurately, with a code generator, and no negative effect was detected in subsequent independent tests [13].

The risk of unrestricted use

In a field experiment by Bastani and colleagues involving school students (approximately 1,000 participants), a standard GPT assistant increased performance during practice by about 48%, while a "GPT Tutor" constrained by pedagogical instructions increased it by 127%. However, once the assistant was removed, the standard GPT group performed about 17% worse than the control group, whereas the tutor group largely eliminated this decline [14]. Thus, the outcome depends not on the mere presence of AI but on its **pedagogical design**.

Summary of pedagogical advantages

The synthesis identified the following five advantages:

No.	Advantage	Evidence	Manifestation in computer science
1	Personalization and adaptive difficulty	[8; 9; 4]	An individual exercise trajectory for each learner
2	Rapid, explanatory feedback	[10; 14; 22]	Explaining compilation and logical errors
3	Reduced cognitive load for beginners	[12; 13]	Shifting attention from syntax to algorithmic thinking
4	Saving teacher time;	[6; 10;	Preparing tests, assignment variants and

No.	Advantage	Evidence	Manifestation in computer science
	content generation	15]	rubrics
5	Inclusiveness and multilingualism	[3; 10]	Explanations in Uzbek, Russian and English; adaptation for learners with disabilities

Identified risks

The following risks were identified: (1) learners falling into an "illusion of knowledge" [14]; (2) incorrect LLM answers and a lack of explainability [21]; (3) data privacy and algorithmic bias [3; 18]; and (4) problems of academic integrity [12].

Proposed model: the "AI-integrated computer science lesson" (five stages)

Stage	Teacher's activity	Learner's activity	Role of AI	Control
1. Problem setting	Defines the task and the expected outcome	Plans the algorithm without AI	None	Flowchart / pseudocode
2. Independent attempt	Observes	Writes a first version	None, or idea-level only	Time limit
3. AI scaffolding	Sets the "advice only" rule	Uses AI to explain errors and asks for help through questions	Socratic tutor (does not give ready-made solutions)	Dialogue log
4. Critical verification	Provides counterexamples	Tests the AI's answer with test cases and finds	As an object of analysis	Test cases

Stage	Teacher's activity	Learner's activity	Role of AI	Control
		its shortcomings		
5. Reflection and assessment	Assesses using a rubric	Completes a short independent task without AI	Switched off	Retention test

Discussion

The results lead to a two-sided conclusion. First, AI provides real advantages in computer science education: the effectiveness of ITS approaches that of a human tutor [8], and for beginners code generators lower the entry barrier [13]. Second, these advantages are **conditional**: Bastani's study shows that a tool may raise performance during work while reducing learning outcomes [14]. This is consistent with Vygotsky's theory: scaffolding should be temporary and gradually withdrawn [23]. Stages 1, 2 and 5 of the proposed model ensure exactly this principle: the learner thinks without AI and completes a final independent test.

The "lack of pedagogical grounding" noted by Zawacki-Richter and colleagues [5] heightens the importance of this model, since it places the learning outcome, rather than the technology, at the center. Selwyn likewise proposes viewing AI not as a replacement for the teacher but as a tool that supports the teacher's professional decisions [18]. The Russian-language pedagogical tradition of informatization theory also emphasizes that technology must be subordinated to didactic purposes [16; 17], which is consistent with our approach.

Practical recommendations

Announce in advance, for each topic, the zones where AI is permitted, restricted or prohibited.

Standardize prompts for a Socratic tutor that does not give ready-made solutions.

In assessment, take into account the final control task completed without AI and the learner's dialogue log.

Train teachers in AI literacy and ethics [19].

Introduce rules for protecting learners' data.

It is advisable to test the proposed model in schools and higher education institutions of Uzbekistan using a quasi-experimental design (experimental and control groups, pre-test and post-test, an 8–12-week intervention).

Limitations

The review relies mainly on English-language sources, and local (Uzbekistan-based) experimental data are scarce. Because the field of generative AI has developed rapidly, the most recent publications may not have been included in the analysis.

Conclusion

AI tools (ITS and LLM-based assistants) offer advantages in computer science education such as personalization, rapid feedback, reduced cognitive load, saving teacher time and greater inclusiveness. These advantages are preserved only under pedagogically designed use; unrestricted use may weaken long-term learning.

The proposed five-stage model combines the use of AI as scaffolding, critical verification and independent final control. Empirical confirmation of the model's effectiveness in the context of Uzbekistan remains a task for future research.

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