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RESEARCH ARTICLE

Innovation of Teaching and Learning Scenes and Models Empowered by Artificial Intelligence: Practice and Experience of AI-Powered Programming Courses

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Abstract The rapid development of artificial intelligence (AI) is accelerating the digital transformation of higher education. Today, "AI + Education" has become a key feature of Education Informatization 2.0 Action Plan in China. This study presents practical experiences in applying AI to programming courses. First, the global trends in AI-powered teaching and learning are analyzed. Key challenges in programming education that can be addressed by AI are then identified. Focusing on common teaching problems, an introductory programming course is used to demonstrate the construction of a course engine powered by large language models. This engine enables the creation of intelligent courses, driving innovation in teaching scenes, and transforming both teaching and learning methods. The exploration then extends to the design of AI-enhanced teaching and learning environments, featuring AI teaching assistants and AI learning companions. These tools provide scalable, differentiated, and personalized support for teachers. They also enable one-on-one, adaptive, and customized learning experiences for students. An integrated learning support system is proposed, which combines courses, training, competitions, testing, evaluation, and certification. The goal is to build a smart teaching ecosystem with knowledge services, personalized learning, and instructional support, as well as to realize the entire teaching process of "course–training–competition–testing–evaluation" empowered by AI for all elements and all time periods. Furthermore, the intelligent & interactive virtual massive open online courses (IMOOCs) for C programming is developed. A new hybrid teaching model based on IMOOC, which integrates virtual and real elements and promotes cross-domain collaboration, has also been explored. Potential risks of overreliance on AI tools are discussed, together with strategies to address them. Finally, future trends and challenges in "AI + Higher Education" are examined. The study argues that AI will unlock new possibilities for reshaping how higher education is delivered and experienced.

Keywords smart education, AI empowering education, innovative teaching and learning scenes, transformation of teaching and learning models, intelligent & interactive virtual massive open online courses

1 Introduction

In recent years, new generation of digital technologies, led by artificial intelligence (AI), have become a major driving force behind the latest technological and industrial revolutions. AI has accelerated the digital transformation of higher education. The digitization of higher education refers to the formation of a data-driven, human technology integrated, and cross-border open education ecosystem through a thorough and comprehensive digital transformation. This transformation aims to build a more agile, equitable, fair, and sustainable higher education system. It also seeks to provide learners with rich and diverse learning experience (Yang, 2023). Digitalization in education has facilitated the digital transformation of all elements, operations, fields, and processes in education. The digitization of higher education is a strategic issue that influences but may even determine the high-quality development of higher education. It is both a strategic choice and an innovative path to achieve the learning revolution, quality revolution, and high-quality development of higher education (Wu, 2023). As a new form of education in the digital era, smart education is a necessary choice. It helps promote equity, inclusiveness, and quality in learning. It also marks the future direction of intelligent technologies in education reform. Smart education is becoming a shared strategic vision among

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nations. It addresses critical challenges in the AI era and supports the achievement of sustainable development goals in education (Huang et al., 2024).

With the rise of generative AI (GenAI), the integration and application of AI technology in higher education has reached a new peak. Taking China as an example, the Ministry of Education of the People's Republic of China officially released the *White Paper on Smart Education in China* (Ministry of Education of the People's Republic of China, 2025), marking the official entry of Chinese education into a new era of AI deep empowerment. Also in 2025, the State Council of the People's Republic of China officially released the *Opinions on Deepening the Implementation of the "Artificial Intelligence+" Action* (State Council of the People's Republic of China, 2025). The document emphasizes the need to innovate new models of human–machine collaborative education, such as intelligent learning companions and intelligent teachers, and to promote large-scale personalized education. It provides important guidance for accelerating the advancement of the "AI+" initiative and carries profound historical and strategic significance for promoting the high-quality development of AI-enabled higher education.

The main contributions of this work are as follows:

(1) An intelligent teaching environment has been developed. It integrates knowledge services, personalized learning, and instructional support, enabling collaborative and interactive engagement among teachers, students, and intelligent systems. This environment establishes a solid foundation for AI-enhanced constructivist and situational learning.

(2) Leveraging AI and holographic rendering technologies, we trained a hyper-realistic holographic digital virtual instructor and proposed a novel approach for intelligent interactive virtual massive open online course (MOOCs). For the first time in China, we explored a hybrid teaching model that integrates intelligent interactive virtual MOOCs with virtual–real collaborative instruction across institutions and domains. At the 2023 "On-Site Promotion Meeting for MOOC Western Tour" conference, hosted by Ministry of Education of the People's Republic of China, a digital twin of a MOOC instructor was present on site through glasses-free 3D holographic display technology, coteaching with two instructors from western universities and interacting with students in real time. This dual-instructor mode offered learners an immersive, authentic situational learning experience.

(3) By introducing AI-assisted programming tools, students are guided to engage in self-directed, actively constructed, and autonomously extended learning. This enabled a paradigm shift in introductory programming courses from the traditional "handcrafted coding" model to a human–AI collaborative paradigm of "AI assistance + human analytical reasoning." Furthermore, through project-based learning and challenging problem scenes, students construct knowledge while solving real-world tasks and enhance sustainable competitive skills such as precise requirement articulation, code review, and critical thinking—capabilities that remain irreplaceable by AI.

2 Status of AI-Enabled Teaching and Learning

Recently, AI-enabled teaching has flourished. In 2023, ChatGPT and other large language models (LLMs) emerged, making a tremendous global impact. Education-specific LLMs have also gained significant traction. In 2025, the release of DeepSeek in China sent shockwaves through the AI field and sparked a new wave of development in smart education. In recent years, "AI + Education" has become a hot topic in empowering education, which refers to the deep integration of AI technologies into the education sector. It uses intelligent methods to optimize the learning environment. The aim is to fundamentally transform traditional educational models, teaching methods, and learning experiences (Si, 2024).

Currently, higher education worldwide is undergoing a transformation from being connected online, to becoming digital, and now moving toward intelligent systems. Many universities, both domestically and internationally, are actively exploring the application of AI in empowering education. For example, Codecademy, an online programming platform in the United States, uses AI to provide personalized learning resources. It analyzes learners' behavior and progress to dynamically adjust course content and difficulty. This ensures that learners can master programming skills at their own pace. The Knewton adaptive learning platform in the United States uses AI to analyze student learning data, such as learning speed, mastery of concepts, and error rates. It builds personalized knowledge graphs and dynamically adjusts learning paths. The system can accurately predict students' knowledge gaps (Yu & Guo, 2023). Yale University has introduced agents in medical education, effectively helping students learn basic medical concepts in preclinical courses (Safranek et al., 2023). Genie, an intelligent teaching assistant developed by Deakin University in Australia, can interact with students in a personalized manner and provide targeted learning strategies (Ministry of Education of the People's Republic of China, 2024a).

Numerous typical cases and tools have emerged in China that empower teaching and learning scenes with AI, as well as intelligent teaching assistants to support students (Bonfield et al., 2020; Ministry of Education of the People's Republic of China, 2024b).

For example, the "MashOn" intelligent teaching platform based on LLMs and independently developed by Beijing University of Posts and Telecommunications, has built a new intelligent programming learning environment. It offers programming tutoring and Q&A services for students. Beijing Normal University's "Intelligent Teaching Assistant," developed based on DeepSeek, provides students with academic planning, concept explanation, problem-solving inspiration, and writing assistance. These features help improve learning efficiency. The intelligent education platform "Xiaoya," developed by Central China Normal University, utilizes LLMs and knowledge graphs to enhance students' participation and learning experience. The "Shuishan Online" platform, developed by East China Normal University, collects comprehensive data on students' learning behaviors. It uses AI to create personalized teaching plans and builds a data-driven process evaluation system.

In the context of an AI-driven new wave of educational transformation, a central question widely discussed is how to leverage constructivism, situated learning, and other foundational learning theories, empowered by large-scale AI models, to shift from supply-driven resource provision to demand-oriented knowledge services and competency development. Such a shift aims to enhance student learning experiences and improve learning outcomes.

Constructivist learning is characterized by high-level cognitive engagement, deep knowledge exploration, strong relevance to real-world contexts, rich communication and interaction, and holistic social support for learners.

Smart courses provide effective support for achieving these five goals. Taking introductory programming as an example, the emergence of LLM-based AI tutoring tools and the transition toward AI-assisted programming paradigms help alleviate long-standing challenges in traditional programming instruction, including passive knowledge intake with limited active reasoning, steep learning curves inhibiting deep inquiry, restricted teacher–student interactions that are not available anytime and anywhere, and insufficient ubiquitous personalized learning support. Meanwhile, the teaching and learning scenes and models of programming courses are also experiencing profound changes.

Therefore, this paper takes programming courses as a representative case to explore effective pathways for generative AI to empower innovation in teaching–learning scenes and models. We focus on how AI learning companions, AI instructional agents, and AI programming assistants can be integrated throughout the full instructional process to enable personalized learning, intelligent teaching support, and comprehensive development of students' sustainable competencies under the AI-enhanced paradigm shift in programming education.

3 Typical Problems Solved by AI + Education

The questions of "why to learn," "what to learn," and "how to learn" are the three core issues in education. Among them, how teachers teach and how students learn have always been the main focus of teaching model and method reform.

"AI + Education" not only brings significant changes to the question of "what to learn" but also helps address many pain points in traditional teaching by transforming how teaching is delivered.

The following sections analyze how AI empowers teaching, learning, practicing, and educational scenes, and how it can help solve challenges in education.

3.1 | How Can AI Empower "Teaching" to Free up Teacher Productivity?

With the aid of specialized LLMs, knowledge graphs, subject-specific agents, and intelligent teaching assistance tools and platforms, intelligent services are provided to support teachers. These services include assisted teaching, virtual coteaching with AI teachers, virtual simulation experiments, online instruction, intelligent lesson preparation assistants, automatic grading, intelligent Q&A, and intelligent teaching assistants (Xu & Zhang, 2025).

For example, by analyzing students' feedback data, such as answer accuracy, problem-solving speed, and mastery of key concepts, the system identifies individual weaknesses and learning preferences. It then adjusts instructional content in real time, offering personalized and targeted guidance. This enhances teaching effectiveness and enables large-scale, differentiated instruction.

Meanwhile, GenAI transforms the way teaching resources like lesson plans, case studies, and exam questions are gathered and organized. Instead of relying on manual collection, educators can leverage intelligent search and generation tools. This streamlines lesson preparation, freeing teachers to focus on the more creative and irreplaceable aspects of their work.

3.2 | How Can AI Empower "Learning" to Enhance Learning Efficiency and Effectiveness?

Traditional one-size-fits-all approaches ignore individual differences. They weaken students' motivation and critical thinking, leaving them without the drive for independent exploration (Wu et al., 2025).

Leveraging specialized LLMs, knowledge graphs, and subject-specific agents, intelligent services can be provided to support students' learning activities. These services include intelligent learning companions, learning assistants, and smart learning tools. They help students engage in online self-directed learning, improving learning efficiency and experience (Xu & Zhang, 2025).

Students can pose questions to LLMs anytime and anywhere, resolving doubts as they emerge. This offers ubiquitous, real-time, one-on-one, interactive, and personalized learning support, enhancing learning efficiency. Moreover, the human–computer dialogue with intelligent teaching assistants gives students more autonomy and choice. This transforms the learning process into a self-driven and actively constructed generative learning model. This model consists of three stages: selection, organization, and integration (Zhu et al., 2023).

By shifting from passive knowledge absorption to active knowledge acquisition, this model broadens and enriches learners' channels for accessing information. Resources are matched to individual preferences and personalized learning plans are crafted. Such adaptive, ubiquitous learning ultimately leads to improved outcomes and guides students in shifting from passive knowledge reception to active knowledge acquisition.

3.3 | How Can AI Empower "Practice" to Foster Comprehensive Student Competencies?

The cornerstone of higher education is developing students' competencies. Especially in higher engineering education, there is a special emphasis on engineering technology innovation, project implementation and management, and the cultivation of students' professional abilities.

Leveraging specialized LLMs, domain-specific agents, intelligent question banks, and Q&A tools, a learning support system can be built. This system aligns with the "course–training–competitions" and "testing–evaluation–certification" framework, guided by an ability element matrix. According to students' ability asses sments, this system provides services such as curated practice sets, simulated exams, tutoring bots, and guided exercise feedback so as to promote the transformation of learning objectives from knowledge acquisition to capability enhancement.

Based on Big Data processing and deep learning, subject-specific LLMs and agents can generate practice questions and competition problems for training. These tools help learners refine their knowledge, technical skills, and problem-solving strategies. They can also customize questions and exercises according to students' progress and preferences, effectively acting as personal coaches (Xu & Zhang, 2025).

3.4 | How Can AI Empower "Scenes" to Drive Innovation in Teaching Models and Improve Students' Learning Experience?

In traditional face-to-face classrooms, teaching is constrained by time and space. The teaching environment and methods are relatively simple, and the relationship remains a "teacher–student" binary structure. However, by leveraging LLMs and digital humans, it becomes possible to construct intelligent teaching scenarios that foster "teacher–student–machine" collaboration and interaction, thereby significantly expanding both the depth and breadth of education. The educational paradigm shifts to the collaborative teacher–student–machine trinary structure. Interaction shifts from solely human-to-human to rich human–machine dialogue.

This evolution not only enriches the dimensions of teaching but also gives rise to many new teaching models and scenes. For instance, by integrating top online educators with offline resources, institutions can implement a "smart dual-teacher" mode. In this setup, expert instructors and AI co-teach across time and space. Students benefit from a more immersive, flexible, and personalized learning experience.

4 Paths for AI Empowering Innovation in Teaching Scenes and Models

In response to the typical teaching problems that AI can solve, as discussed in the previous section, this section explores effective ways to apply AI in programming courses. The research approach follows "industry–academia collaboration, joint school–enterprise development, inter-school coordinated practice, and practice-based improvement." Taking programming courses as an example and supported by teaching resources and a knowledge system, this study focuses on problem-solving and aims at skill development. It details the research process and implementation plan for AI-powered innovation in teaching scenarios and transformation of teaching and learning methods. The specific measures are as follows.

4.1 | Build a Smart Teaching Environment that Integrates Knowledge Services, Personalized Learning, and Teaching Support

To support blended intelligent teaching applications and uphold student-centered educational philosophy, this approach uses large model groups such as DeepSeek, Zhipu AI, and Qwen as the technical foundation and computing power.

A dedicated course knowledge base is built based on course resources. Technologies like data governance, knowledge extraction, and retrieval-augmented generation form a course engine. By precisely injecting knowledge, guiding capabilities, and enforcing behavior constraints into general LLMs, the controllability of content generation is enhanced. Course-specific instruction sets and intelligent agents are designed to meet course needs. The AI course system consists of a vector knowledge base, a knowledge graph, an AI toolbox, a digital avatar, and a set of intelligent agents.

This system provides students with 24/7 one-on-one ubiquitous learning support and offers teachers precise, efficient, and personalized teaching assistance. The AI support extends beyond simple teaching assistants to include intelligent lesson planning, automated grading, AI teaching companions, and other teaching applications. This improves teaching efficiency and effectiveness, transforming the course from mere resource provision to knowledge service.

4.2 | Build an Intelligent Practice Platform for Integrated Smart Learning

Independent practice, lab exercises, project work, competitions, and corporate training are all key steps and effective methods to improve students' hands-on skills and problem-solving abilities.

To effectively integrate course learning with these practical activities and motivate students' active participation, it is necessary to build a practice teaching platform that supports an integrated "course–training–competition–testing–evaluation" competency development system.

LLMs like DeepSeek should be connected to this platform to provide intelligent support, such as problem analysis and question answering. This creates a closed loop of guidance, teaching, learning, practice, testing, and evaluation with the AI course. This in turn enables a cycle of learning guided by practice, practice encouraged by evaluation, training driven by competitions, courses connected through training, and knowledge applied in real situations.

4.3 | Build Intelligent Interactive Virtual MOOCs with Digital Human Interaction to Enhance Interactivity

To support situated learning, multiple technologies are integrated. These include speech recognition, natural language understanding, LLMs, retrieval-augmented generation, holographic rendering, fusion wake-up, and voice-driven digital avatars and gestures. Together, they enable the creation of hyper-realistic holographic digital humans (Figure 1).

Figure 1 Holographic hyper realistic digital virtual teacher.

These virtual instructors enable students to engage in real-time, voice-based interactions. They provide an entirely new, immersive learning experience. By integrating AI and holographic rendering, MOOCs are upgraded to intelligent & interactive virtual massive open online course (IMOOCs) (Figure 2), offering richer scenes and deeper engagement.

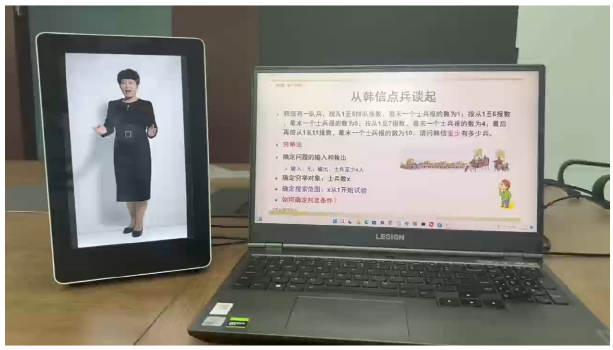

Figure 2 Real-time voice interaction with digital virtual teachers in a Q&A scene. A teacher is teaching the enumeration algorithm online, taking Han Xin's troop counting as an example.

MOOCs are the product of "Internet + Education". Over the past decade, MOOCs have had a crucial role in promoting the digital transformation of higher education (Xu, 2023); IMOOCs go beyond traditional MOOCs. They use holographic imaging, digital twins, and AI to project lifelike digital avatars into the classroom. This creates an immersive, face-to-face learning environment. Students can ask questions and interact with these virtual instructors in real time. This effectively boosts students' interest and participation (Si, 2024). As a fusion of intelligence, virtualization, and education, IMOOCs represent a next generation classroom model. In this model, virtual instructors and learners engage in truly interactive, immersive sessions (Xu & Su, 2024).

Recently, through an industry–academia co-construction collaboration, we have jointly developed the C Language Programming intelligent course with several online learning platforms, such as XuetangX, Wisdom Tree, and Chaoxing. In addition, a complementary practice-oriented intelligent course has also been collaboratively developed and launched on the EduCoder platform, with a cumulative total of over 100,000 learners.

5 AI-Driven Applications and Practices in Teaching and Learning Programming Courses

Based on the implementation path outlined above, this section focuses on the application and practice of AI-powered teaching and learning in programming courses. Aiming to improve students' learning abilities and outcomes and using MOOCs and other teaching resources as a foundation, an AI course for C programming was developed on the XuetangX Online platform. This course integrates knowledge services, personalized learning, and teaching support into a smart teaching environment (Figure 3).

The project applied and practiced AI-enabled education, exploring a full-process, all-element, and all-time AI-powered system covering courses, training, competitions, testing, and evaluation. The goal was to achieve personalized learning, precise teaching, and intelligent services. This approach has enhanced teaching quality and promoted the transformation of education from connectivity to digitalization and intelligence. The specific initiatives and practices are outlined below.

5.1 | Establish AI-Enhanced Teaching Spaces to Provide Continuous, Personalized, and Precise Instructional Support

Create AI-enhanced teaching spaces to provide personalized instructional support services for teachers. These services include intelligent lesson preparation assistants, AI teaching companions, intelligent question generation, and intelligent grading, etc.

Before class, teachers can use AI technologies to efficiently generate customized teaching materials and resources. With the help of intelligent lesson preparation assistants, they can optimize their instructional design by using command templates. This allows automatic generation of lesson plans, lecture notes, and case studies, significantly improving preparation efficiency. Additionally, AI-powered one-click Q&A generation facilitates the rapid expansion of question banks, significantly reducing workload.

During class, AI teaching companions co-lead instruction. They design interactive activities and introduce innovative pedagogies. Classroom interactions are enriched through screenshot Q&A. At the same time, speech recognition technology can transcribe lectures and automatically create mind maps of key concepts, enhancing clarity and pacing.

After class, virtual teaching assistants can take over repetitive Q&A tasks, freeing teachers to focus on high-value, creative tasks. The intelligent platform can collect teaching data and analyze students' learning progress and pain points. It can generate teaching analysis reports that provide in-depth insights into student engagement, course completion rates, and other data.

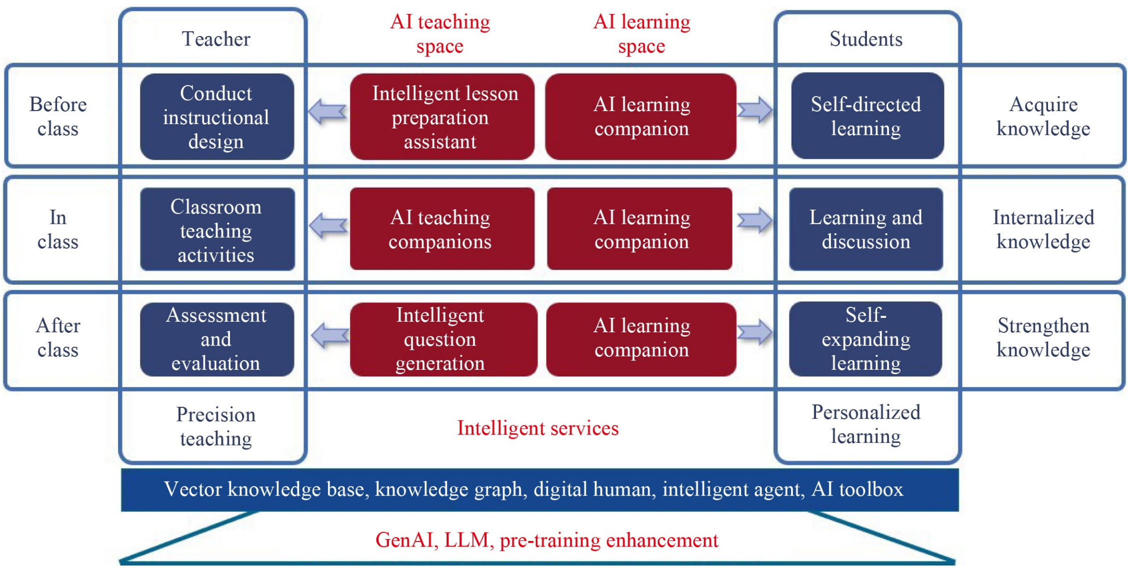

Figure 3 An intelligent teaching environment that integrates knowledge services, personalized learning, and teaching support. GenAI: generative artificial intelligence; LLM: large language model.

This helps guide personalized training, customizes differentiated homework, and adaptively adjusts teaching progress and strategies. It provides a robust foundation for precise, individualized teaching and evaluation.

5.2 | Build AI-Enhanced Learning Spaces for 24/7, One-on-One, Adaptive Personalized Support

Create an AI-enhanced learning space that supports collaboration among teachers, machines, and students ("teacher–machine–student" model). Each student is paired with a 24/7 AI learning companion. It delivers truly personalized, one-on-one tutoring and instant feedback. Learning difficulties are addressed as they arise.

Through interactions with the round-the-clock intelligent learning companion, students can have their questions answered at any time during their MOOC journey. The AI companion guides them through multiple dialogue rounds. It stimulates thinking and helps build a dynamic chain of "problems–thinking–competency".

Leveraging MOOC content, we have developed several types of knowledge graphs. These graphs clarify the relationships among different concepts, preventing fragmented or disjointed learning. A question graph, structured around Bloom's taxonomy, spans three tiers: from remembering and understanding, to applying and analyzing, and finally to evaluating and creating. Additionally, we constructed a competency graph aligned with the course's learning objectives.

Using the knowledge, question, and competency graphs, we established a capability-development pathway that links knowledge acquisition, problem solving, and goal attainment.

By tracking students' learning progress and leveraging the knowledge graph, the system helps identify and eliminate knowledge gaps. It enables students to clarify knowledge structures efficiently. Based on individual learning preferences, AI recommends personalized learning paths and matches appropriate learning resources. This approach encourages students to transition from passive, instructor-led learning to active, goal-oriented, problem-solving, self-driven, exploratory, and constructivist learning.

5.3 | Exploring IMOOC-Based Hybrid Teaching Models with Virtual–Physical Integration and Cross-Domain Collaboration

Through an industry–academia–research collaboration, we developed an IMOOC platform and piloted a hybrid teaching model. This model melds virtual and physical classrooms with cross-domain collaboration.

Leveraging glasses-free 3D holographic projection, a digital avatar of the MOOC instructor can "appear on-site" alongside local faculty, co-teaching in real time. This dual-instructor setup, unconstrained by time or space, offers students an immersive, lifelike learning experience.

We have also established a collaborative ecosystem. It includes joint curriculum design, shared platforms and resources, faculty exchanges, and cross-institutional talent training. This effort addresses the shortage of instructors and limited teaching resources in western China.

By implementing this "small classroom" solution, we have gained valuable experience in improving access to quality education. It expands learning opportunities for students across regions and promotes more balanced educational development (see Figure 4).

Participants believed this approach could effectively deliver high-quality teaching resources, such as MOOCs, to universities in western China. It was seen as a powerful way to promote the sharing of teaching resources between eastern and western regions. The model also showed promise in improving educational quality and talent development in the west.

The IMOOC demonstration class provided students with a brand-new learning experience and instructional impact. Students commented that the class was refreshing and engaging. They were impressed by how the online instructor seamlessly "entered" the physical classroom to create a vivid sense of presence.

Figure 4 Live demonstration of an IMOOC-based hybrid teaching model with cross-institutional and virtual–physical integration.

The real-time interactions throughout the lesson significantly boosted their motivation and improved their overall learning experience.

5.4 | AI-Powered Integrated, Seamless Competency Development across Courses, Training, Competitions, Testing, and Evaluations

By developing game-based labs and programming skill training platforms, it is possible to guide learning through practice and promote practice through assessment. Automated evaluation can guide students toward self-directed training. Differentiated feedback encourages critical thinking and helps learners pinpoint mistakes. Error-analysis tools diagnose coding errors and support targeted problem-solving. Additionally, intelligent programming assistants offer hints and alternative solution strategies (see Figure 5).

Experimental projects are designed around real-world industry scenes. They guide students to follow standard software development workflows. This not only strengthens their foundational competencies but also aligns their software engineering skills with practical industry requirements.

Competitions are used to refine teaching content. Course topics are closely aligned with competition tasks. This integration enhances learning by using competitions to enrich and improve the course. Encouraging participation in competitive programming further enhances students' abilities and expands their problem-solving toolbox.

Together with AI-powered courses, these efforts create an intelligent learning environment that forms a closed loop of guidance, teaching, learning, practice, testing, and evaluation.

This enables the construction of a personalized learning support system. It ensures traceable knowledge, solvable problems, supported skill development, and trackable learning progress. By blending virtual and real-world experiences and facilitating collaborative guidance from multiple instructors, students receive precise, individualized assistance.

Ultimately, this culminates in an integrated competency-development model. Courses, training, competitions, testing, and evaluations are seamlessly connected.

5.5 | AI-Powered Transformation of the Programming Learning Paradigm

In course instruction, leading domestic AI programming tools, such as Tongyi Lingma, Baidu Comate, MarsCode, and Tencent Cloud CodeBuddy have been introduced. These tools offer functions like code generation, intelligent completion, error detection, code optimization, code explanation, and comment generation. With AI assistance, students can quickly grasp programming syntax and master coding skills. They can write code beyond their current level, helping them overcome the steep learning curve of mastering their first programming language. Code explanation and comment generation enhance their understanding of key concepts and logic. Automatic review and optimization help students detect and fix potential security issues. By analyzing AI-generated code, learners acquire

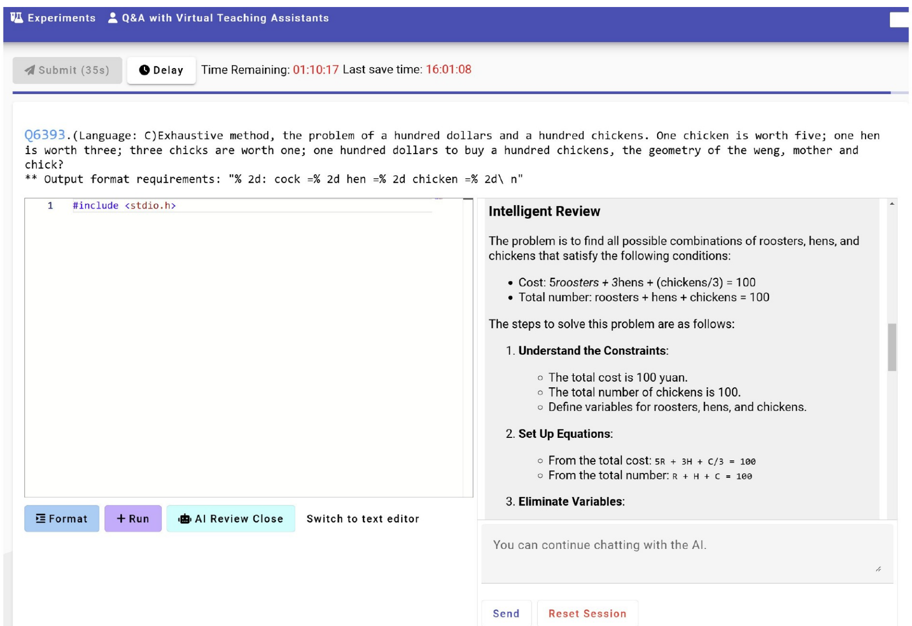

Figure 5 An actual interface screenshot of the AI-assisted programming training platform.

new techniques and explore diverse programming styles; teachers also benefit from this process. Intelligent code completion improves live coding and guided demonstrations, which boosts teaching efficiency and supports in-class exercises.

To better strengthen the cultivation of practice-oriented abilities in the context of AI, we revised the 2025 undergraduate curriculum by renaming the university-wide course from C Language Programming to Computing and Intelligent Programming. The course adopts a teaching model of lectures combined with hands-on practice, project-based learning, and group discussions. Through project implementation and collaborative discussions, students' programming skills and practice-oriented abilities are enhanced. Moreover, by engaging in program development, students gain a deep understanding of scientific and engineering thinking as well as computational and intelligent thinking. This approach promotes the integration of computational thinking, AI thinking, and discipline-specific thinking, thereby building a solid programming foundation for students across disciplines to design, construct, and apply various computational and intelligent systems to solve disciplinary problems in the future.

After two years of research and practice, we found that applying AI to programming course instruction requires attention to two key aspects.

The first point is guiding the shift toward a human–AI collaborative learning paradigm, from writing code independently to expressing intent and generating code through AI prompts. This shift calls for the development of three key new skills:

The ability to accurately express requirements to AI. The usability of AI-generated code largely depends on the quality of the prompts. This involves prompt engineering for LLMs. By comparing effective and ineffective examples, students gradually learn the basic structures and techniques for writing successful prompts, including being accurate, clear, specific, focused, detailed, and avoiding ambiguity.

Advanced skills in reviewing and analyzing code with AI assistance. With AI-assisted programming, teaching priorities have shifted toward fostering advanced programming thinking. The emphasis is on guiding AI to produce high-quality, well-structured code. Students are encouraged to focus less on syntax details and more on core logic and problem-solving strategies. This transition helps address longstanding issues in programming education, such as overemphasizing knowledge over ability, syntax over thinking, and language over design.

Critical thinking. Given the hallucination issues associated with LLMs, AI-generated code should be used only as a reference. Students must learn not to rely blindly on AI tools. Instead, they should develop independent thinking, discern truth from error, and cultivate sound judgment. From another perspective, encountering errors during learning can be both challenging and engaging, deepening students' appreciation for precise language and critical analysis. Ultimately, this fosters their ability to distinguish between "truth" and "hallucination" in AI-generated content.

The second point that has to be borne in mind while applying AI to programming course instruction is promoting the proper use of AI and addressing the issue of overreliance. Students should be guided not only to use AI tools effectively but also to avoid becoming overly dependent on them or falling into the trap of "click equals truth." Thus, AI should not become a mere answer generator for learners.

In short, the strengths of both AI tools and human intelligence should be leveraged to build a more effective model of human–AI collaboration in education. AI should be a tool that sparks critical thinking and accelerates student growth, not a crutch that fosters laziness.

To prevent students from becoming too reliant on AI and losing their ability to code without support, two key strategies are needed. First, conduct regular core skill training without AI assistance. Second, reform assessment methods. For example, remove daily homework scores to prevent students from relying on LLMs for solutions. Instead, use closed-book programming tests at key stages to assess learning progress and require in-person defenses for open-ended projects to verify real understanding and contribution.

In summary, compared to traditional instruction without AI, AI-powered programming courses offer many advantages, as shown in Table 1.

6 Development Trends and Prospects of AI in Higher Education

AI is transforming the form of education, profoundly changing its paradigm. It is driving the digital transformation of higher education, accelerating its development with greater depth, speed, and intensity. In the future, the application of AI to teaching and learning will evolve in the following key directions.

6.1 | Course Form will Evolve from MOOC to IMOOC and Further Develop into Open Metaverse Course

Supported by AI technologies, MOOCs are evolving into IMOOCs. In the future, with the support of AI and metaverse technologies, IMOOCs will further develop

Table 1 Comparison of programming course instruction with and without AI assistance

Aspects	Without AI assistance	With AI assistance
Learning curve	Steep learning curve with a high entry barrier, often leading to frustration	Smoother learning curve with lower entry barriers, fostering a sense of achievement (Feng et al., 2025)
Programming paradigm shift	Learn syntax first, then write code, like learning to walk before running	Write code via prompts, like learning to run before walking (Feng et al., 2025)
Interaction model	Traditional teacher–student model, Q&A through forums and one-to-many tutoring	A triadic model of teacher–student–AI, with real-time, one-on-one interaction with AI assistants (Feng et al., 2025)
Learning mode	Passive and prestructured learning	Active, self-driven, and constructivist adaptive ubiquitous learning (Feng et al., 2025)
Learning goals	Knowledge acquisition	Skill development, including the ability to use AI effectively in learning
Skill requirements	Ability to write and debug code independently	Human–AI collaborative coding with new skills like prompt engineering, code review, and critical thinking (Denny et al., 2024; Feng et al., 2025)
Learning outcomes	Can write code but often struggles to produce high-quality solutions	Can quickly produce high-quality code beyond current level of expertise
Teacher role	Knowledge transmitter, grader, traditional instructor	Learning designer, growth coach, and value guide
Teaching environment	Physical classroom, real-world context	Mixed-reality, immersive scenes across time and space
Teaching model	One-size-fits-all, industrialized model	Personalized, learner-centered model

into open metaverse courses (OMCs), which is a new teaching form supported by metaverse, AI, and other technologies, takes place in virtual or hybrid spaces. This model emphasizes student-centered, cross-temporal and cross-spatial, immersive, interactive, experiential, and collaborative learning. Compared to MOOC and IMOOC, an OMC brings the digital twins or digital natives of both teachers and students into metaverse-based virtual environments. It enables fully virtual or hybrid teaching within immersive scenes, offering both teachers and students a highly realistic, even surreal learning experience (Xu & Su, 2024). It is foreseeable that intelligent OMCs will redefine classroom education, offering students contextualized, experiential, and embodied learning experiences in immersive settings (Impagliazzo & Xu, 2024; Xu & Impagliazzo, 2024; Xu & Li, 2023).

By integrating LLMs with metaverse and other technologies, smart classrooms will shift from a "teacher–student–machine" relationship to a "teacher–student–agent" triadic collaboration (Secretariat of the Global MOOC and Online Education Alliance, 2024). The teaching space will exhibit a "physical–virtual–social" triadic fusion characteristic. Additionally, with the support of AI technologies such as brain-machine interfaces and eye-tracking systems, the new teaching scene of human–machine symbiosis can be further enhanced. These tools enable richer interaction, closer collaboration, and seamless integration. Both teachers and students will benefit from an enhanced teaching and learning experience (China Academy of Information and Communications Technology, 2025). While intelligent OMCs are being advanced, technology cost should also be addressed and data privacy risks mitigated.

6.2 | Teaching Approaches will Emphasize on Scene-Based Practical Operational Experience

With the support of AI, augmented reality, mixed reality, and the metaverse, more advanced intelligent teaching platforms can be developed. These platforms will break the limitations of physical space, enabling a shift in learning environments from "bounded" to "unbounded." They enable immersive, multimodal, and interactive learning in virtual–physical integrated scenes. Such environments can better meet the personalized learning needs of different learners in various contexts. Students will gain more realistic embodied learning and observation experiences, as well as hands-on practice opportunities, allowing them to rapidly strengthen their skills.

At the same time, through industry–academia collaborative education and AI-powered competency-based teaching processes, it is possible to integrate learning, training, competition, testing, evaluation, and certification. This promotes a shift in higher education from a knowledge-centered to a competency-centered instruction and reform. The approach systematically enhances students' abilities, fostering innovative talents with sustainable competitiveness for the digital-intelligent era.

6.3 | Form of Textbooks will Evolve to Digital Textbooks and Further into "Intelligent Tools + Textbooks + Services"

Textbooks are fundamental components of education and teaching. In the future, the form of textbooks will evolve from traditional printed versions to new types of digital textbooks. These digital textbooks will enable multidimensional retrieval of content based on knowledge graphs. They will present information through multimedia and multimodal formats such as audio, images, text, and video. This will enhance both reading experience and learning effectiveness.

Furthermore, supported by AI and service computing technologies, the publishing and usage of textbooks will undergo major transformations. A new form of intelligent, service-oriented textbooks will emerge. Future digital textbook service platforms will integrate LLMs, agents, augmented reality, mixed reality, and digital humans. These intelligent tools will be embedded into the textbook service system, providing smarter and more personalized learning services to a broader audience. The large-scale development and commercialization of digital textbooks also depend on robust digital intellectual property protection technologies.

6.4 | Teaching Tools such as Knowledge Graphs will Evolve into "LLMs + Agents" and "Scene-Based Intelligent Teaching and Learning Services"

In the future, teaching tools will move beyond static knowledge graphs and question banks. They will integrate general LLMs, education-specific models, and subject-specific agents to build intelligent teaching support tools. These tools will provide more comprehensive, flexible, and personalized teaching support services. The new intelligent teaching tools will be capable of dynamic and adaptive updates of knowledge graphs. They will also support flexible combinations and generation of knowledge points. In addition, they will offer teaching services that intelligently generate learning scenes matched with specific knowledge points and competency elements. This will enable students to engage in contextualized, interactive, and personalized learning within realistic or simulated scenes.

A sober view should also be taken of AI as a double-edged sword. Because AI algorithms lack explainability, it is hard to ensure their accuracy in guiding learning. This may create information echo chambers. Overreliance on AI tools in such cases can lead to declining cognitive abilities, poor knowledge internalization, and increased risk of wrong decisions. Therefore, compared to traditional teaching, it is even more important to strengthen students' critical thinking skills. It is essential to find a proper balance between technological support and cognitive training; only then can students grow into individuals who are not merely users of AI but individuals who can leverage it as a powerful tool, like a lever to move the Earth.

6.5 | Role of Teachers will Shift to Learning Designers and Coaches Who Guide and Plan Students' Learning Using Intelligent Tools

With the deep integration of AI into education and teaching, the role of teachers will undergo significant changes. At the same time, the demand for teachers' digital literacy will increase significantly. Teachers will shift from being simple "knowledge transmitters" to becoming "learning designers" who plan students' learning with the help of AI tools. They will also act as "mentors" who inspire thinking and unlock potential and as "coaches" who guide practice and support growth. Teachers will no longer be the sole "authority" on knowledge. Instead, they will become "partners" who explore and learn alongside students.

In the future, in intelligent and immersive metaverse-based teaching spaces, teachers will need to collaborate with virtual instructors, teaching assistants, and digital characters. They will be expected to innovate with intelligent OMCs, engage in co-teaching models, and adapt to new technological teaching environments. These changes present new challenges for university educators, requiring strong AI literacy and the ability to skillfully leverage digital and intelligent tools to enhance teaching effectiveness and outcomes.

7 Conclusions

This paper presents the exploration and practice of AI-powered teaching and learning scenes and models in programming courses. From our study, it is clear that AI technology not only helps transform the programming learning paradigm but also enables many new teaching scenarios and models. These innovations improve the efficiency and effectiveness of teaching and learning and have an important role in enhancing students' comprehensive abilities. In practice, the majority of students reported that the introduction of AI tools broadened their horizons and enabled them to rapidly overcome the novice stage. However, approximately 10% of students relied excessively on AI when completing assignments, showing limited independent thinking. Additionally, about 20% indicated that they could not fully understand the AI-generated code or struggled to identify what was "wrong" with it. This indirectly highlights the need for instructors to place greater emphases on developing students' code review and analytical skills under the new AI-assisted programming paradigm. In short, even as AI is actively embraced, the potential problems and risks of overreliance and misuse should also be carefully considered. It is essential to guide students appropriately and adopt targeted strategies to mitigate these challenges as AI continues to reshape programming education.

The transition from the "Internet+" initiative to the "AI+" initiative reflects a profound shift in China's digital economy from connection-driven empowerment to intelligence-driven transformation. The deep integration of AI into the education sector presents a tremendous opportunity, offering not only the move from standardized to personalized and inclusive education but also an efficiency revolution from manual to intelligent practices and an international opportunity to shift from following to leading.

Looking ahead, with the rapid development of GenAI, the metaverse, Big Data, digital twins, and other digital technologies, AI-powered course formats, teaching models, textbook forms, teaching tools, teacher roles, and learning methods will undergo tremendous changes. These changes will further promote the intelligent upgrading of course, textbook, and teaching systems.

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