Machine Learning and Intelligent Systems
J.-L. Kim (Ed.)

doi:10.3233/FAIA241225

Construction and Implementation of Human-Machine Collaborative Practice Teaching Mode Based on AI — Take the "Python and Web Crawler" Lesson as an Example

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Abstract. With the rapid development of information technology, artificial intelligence technology gradually penetrates the field of education, providing new possibilities for the innovation of teaching mode. The traditional teaching mode often has problems such as single teaching resources, low student participation and insufficient cultivation of practical ability. To solve these problems, this paper proposes a practical teaching mode based on the concept of Human-Machine collaboration. It aims to harness the advantages of human and machine and improve teaching efficiency and quality. Taking the course "Python and Web Crawler" as an example, a teaching framework includes four modules: knowledge learning, practical training, evaluation feedback and personalized tutoring. An AI-assisted teaching system integrating the functions of knowledge base, adaptive learning, automatic evaluation, virtual practice and teacher assistance is also developed. The application of this model in practical teaching shows that the Human-Machine collaborative teaching model is effective. According to the experimental results of this research, firstly, the average learning time of students this semester has decreased by about 20% compared to the previous semester, but the average score of the final grade has improved by about 5%. Secondly, the students' project works are better than in the previous semester in terms of code quality and functional completion, especially the improvement in code quality is the most obvious. Finally, based on ten questions, the overall evaluation of the students on the course this semester is significantly higher than that of the last semester. Therefore, we firmly believe that this research provides a useful exploration for the application of AI in education.

Key words. AI, Human-Machine Collaboration, Teaching Framework, Python, Web crawler

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1. Introduction

The traditional teaching method primarily relies on conventional approaches, with instructors imparting knowledge through lectures, blackboard writing, and PowerPoint presentations. The content and pace of instruction are uniform, making it challenging to customize teaching to individual student needs. Students passively receive knowledge, and individual differences are often not adequately addressed. The instructional content is fixed within textbooks and course syllabi, with long update cycles that hinder the rapid integration of new technologies. Extracurricular tutoring and Q&A sessions typically involve one-on-one interactions between teachers and students, which are inefficient due to the limited time and energy of the teachers, making it difficult to meet the needs of all students. Study groups and self-directed learning serve as important means for students to compensate for classroom inadequacies, but their effectiveness depends on the students' initiative and the competence of group members. Students often spend significant time searching for external resources to supplement concepts not fully understood in class, but the quality of these resources varies, resulting in low learning efficiency. Traditional teaching assessments mainly rely on periodic exams and tests to evaluate student learning outcomes. However, the limited frequency of these assessments makes it difficult for teachers to monitor student progress in real-time and adjust teaching strategies accordingly. Course design is typically based on the expertise of experienced educators, with content fixed and updates occurring infrequently, making it difficult to respond swiftly to industry changes. In contrast, the introduction AI-assisted teaching tools can dynamically adjust instructional content and difficulty based on students' learning progress and knowledge mastery, providing personalized learning paths. The collaboration between teachers and AI systems can alleviate the instructional burden, enhance teaching efficiency, and offer students richer learning resources and immediate feedback, thereby better addressing students' individual learning needs.

The rapid development of artificial intelligence (AI) technology is driving educational reform and innovation of teaching modes. New technologies and ideas, such as intelligent assisted teaching, adaptive learning, and virtual reality, are constantly emerging, bringing new opportunities for improving teaching quality and enhancing the learning experience. Human-Machine Collaboration (HMC), as an important concept in the era of artificial intelligence, emphasizes the complementary advantages of humans and machines, and realizes the effect of "1 + 1 > 2" through man-machine collaboration. The construction of a teaching mode based on man-machine collaboration is helpful in leveraging the advantages of teachers and AI systems to improve teaching efficiency and quality.

Taking "Python and Web Crawler" as an example, this paper discusses the construction and realization path of a human-machine collaborative [1-2] practice teaching mode based on AI. This course is an elective course of management science and technology, which mainly includes Python programming foundation, web crawler principles and practice, etc. The course teaching object is sophomore students, who have a certain programming foundation. Through the introduction of AI auxiliary tools, human-machine collaborative teaching and learning are expected to improve students' learning efficiency and programming practice ability.

2. Construction of Human-Machine Cooperative Practice Teaching Mode

2.1. Theoretical Basis

(1) Human-machine collaboration theory

According to the theory of man-machine collaboration, man and machine have their own strengths and weaknesses. Through the complementary advantages, collaborative work, can develop a "1 +1 > 2" effect [3-4]. People have the advantages of creativity, judgment and emotional intelligence, while machines are good at high-speed computing, big data processing and pattern recognition. In the teaching process, teachers can give full play to the advantages of creative thinking and heuristic guidance, while the AI system can provide personalized guidance, automatic evaluation and knowledge reasoning, etc. The two can promote each other and cooperate with each other.

(2) Constructivist learning theory

Constructivist learning theory emphasizes the importance of learners' actively constructing knowledge [5]. In the teaching mode of man-machine collaboration, the AI system can provide personalized learning resources and guidance according to the learners existing knowledge and learning progress, so as to promote them to construct a knowledge system actively [6-7]. At the same time, teachers can guide students to conduct inquiry learning and encourage them to improve their ability to solve practical problems through practice.

(3) Situational cognition theory

Situational cognition theory suggests that knowledge acquisition and application exist in specific situations [8]. In the teaching mode of man-machine collaboration, the AI system can simulate the real work situation, provide students with opportunities such as virtual practice and project practice to promote the internalization of knowledge and skill cultivation [9-10]. Teachers can design situational teaching and guide students to apply what they have learned to practical problem solving.

2.2. Human-Machine Collaborative Practice Teaching Mode Framework

Based on the above theoretical basis, the following man-machine collaborative practice teaching mode framework is constructed (as shown in Figure 1):

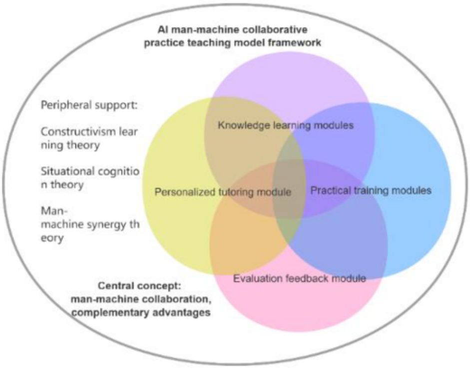

Figure 1. Human-Machine Collaborative Practice Teaching Mode Framework based on AI

This mode includes four main modules: knowledge learning module, practice training module, evaluation feedback module and personalized tutoring module.

(1) Knowledge learning module

The knowledge learning module is mainly undertaken by the teachers, who are responsible for the systematic knowledge explanation and case analysis. Teachers can use multimedia courseware, video resources and other auxiliary means to display the knowledge points vividly and stimulate students' interest in learning. At the same time, teachers also need to design reflection questions and discussion questions to guide students to construct a knowledge system actively. The AI system intelligently pushes personalized learning resources, such as videos, articles and interactive exercises, etc., according to the learners' existing knowledge and learning styles. In this environment, learners can construct knowledge actively, interact with AI for learning, and form a deep understanding of knowledge [11].

(2) Practical training module

The practical training module is jointly undertaken by the AI system and the teacher. AI system can provide students with a platform for practical exercises by providing an online programming environment, automatic assessment tools and virtual project scenarios, etc. Teachers need to design the corresponding practical tasks, and guide and supervise the students' practice process. In such an environment, learners can improve their skills and develop the ability to solve practical problems [12].

(3) Evaluation and feedback module

Evaluation is an important part of teaching. In this module, teachers provide comprehensive evaluation and give guidance and suggestions for the performance of learners. The AI system automatically evaluates learners' performance, such as assignments, and tests, providing immediate feedback. At the same time, the AI system can also analyze students' learning data, understand the learning difficulties and knowledge mastery situation, providing a basis for personalized tutoring. Learners adjust their learning strategies through the feedback to form a closed-loop learning process [13].

(4) Personalized tutoring module

The personalized tutoring module is jointly undertaken by the teacher and the AI system. According to the learners personalized needs, the AI system can recommend personalized learning resources, practice questions and customized personalized learning plans based on students' learning data. Combing the analysis results of the AI system, teachers can provide one-to-one tutoring and Q & A for students to help them solve specific learning difficulties. Learners study through the plan and interact with AI and teachers to ensure the maximum learning effect [14].

3. Realization of Human-Machine Cooperative Practice Teaching Mode

To realize the above human-machine collaborative practice teaching mode, we developed an AI-based auxiliary teaching system and applied it to the course teaching of "Python and Web crawler". The system mainly includes the following modules:

3.1. Knowledge base module

The knowledge base module is the core part of the system, including all the knowledge points, cases and practice questions involved in the course. The knowledge points are organized by tree structure and divided into different chapters and sub-themes. Each knowledge point has detailed text descriptions, illustrations, and code examples. To build a high-quality knowledge base, we adopted a combination of artificial and AI methods. First, the preliminary knowledge framework and content were compiled by the course teachers and the teaching assistant team, and the py2neo library was used to connect the Neo4j graph database and create a knowledge graph representing the nodes of "Python and Web crawler" and the relationship between them [15-17]. Then, the large language model (such as GPT-3) is used to expand and optimize the content, and automatically generate the explanatory text and code examples of some knowledge points. Finally, manual review and revision by the faculty team to ensure accuracy and readability of the knowledge content [18], as shown in Figure 2

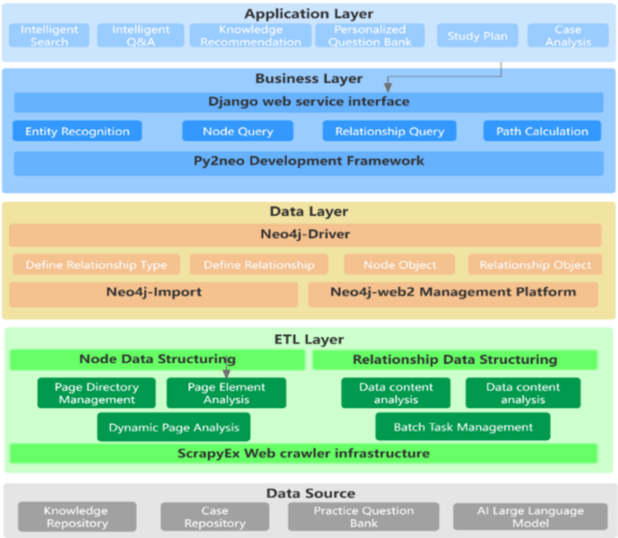

Figure 2. Knowledge base framework

3.2. *Adaptive learning module*

The adaptive learning module is based on students' learning data (such as learning progress, homework scores, knowledge mastery, etc.), and recommends personalized learning paths and resources for each student.

At the core of this module is a learning diagnostic model based on the theory of knowledge space [19-20]. The model abstracts the knowledge points into a directed acyclic graph, and the edges represent the prior relations between the knowledge points. Suppose we have a set of knowledge points $(K = \{k_1, k_2, \ldots, k_n\})$. The preposition relation between these knowledge points can be expressed as a directed acyclic graph $G = (V, E)$, where:

- V is the set of nodes, corresponding to the knowledge point K.
- E is a set of edges, representing a preposition relationship between knowledge points.

Through the analysis of students' historical learning data, the model can estimate each student's mastery of each knowledge point. Based on this, the system will recommend the most appropriate learning objectives and resources for each student, avoid repeating the content that has been mastered, and will not give too difficult content. The core of the learning diagnosis model is to estimate each student's mastery of each knowledge point [21-23]. We can define a student s learning state vector $\boldsymbol{x_s}$, where each component $\boldsymbol{x}_{s,i}$ represents the student s mastery of knowledge k_i, with the value range [0,1]. Let $\boldsymbol{X}$ represent the learning state matrix for all students, where the s row is the learning state vector $\boldsymbol{x_s}$ for students s.

For each student s, the learning diagnostic model is updated $\boldsymbol{x_s}$ based on the student's historical learning data (e.g., learning progress, homework grades, knowledge mastery, etc.). Specifically, the following formula (1) can be used to represent the student's mastery of knowledge point k_i:

$$x_{s,i} = f(\mathbf{h_s}) \tag{1}$$

Where $\boldsymbol{h_s}$ represents the historical learning data of the student s, and f is a mapping function that can be implemented by a machine learning model.

At the same time, this module also integrates a knowledge recommendation algorithm based on reinforcement learning [24-26]. The algorithm will dynamically adjust the recommendation strategy according to the students' learning preferences and effects, and constantly optimize the personalized learning path. We use a Markov decision process (MDP) [27-29] to model, where:

- State S indicates the student's current learning state $\boldsymbol{x_s}$.
- Action A indicates a recommended learning resource or goal.
- Reward R represents feedback received by students after completing recommended learning (e.g., improvement in test scores).

The goal is to find the optimal strategy π to maximize the student's cumulative reward. Specifically, policy updates can be represented by the following formula:

$$Q(s,a) \leftarrow Q(s,a) + \alpha \left[r + \gamma \max_{a'} Q\,(s',a') - Q(s,a)\right] \tag{2}$$

Among them: $Q(s,a)$ represents the value of the selected action a in the state s. α is the learning rate. γ is the discount factor. r is an instant reward. s' is the new state after performing the action a.

By constantly updating Q values, reinforcement learning algorithms can gradually optimize recommendation strategies to provide personalized learning paths and resources that best fit each student [30].

3.3. Automatic evaluation module

The automatic evaluation module can automatically evaluate students' programming assignments and project practices, including code correctness, efficiency, readability and other dimensions, and give specific feedback [31-32].

At the core of the module is an automatic evaluation engine based on test cases [33-34]. The faculty team designed multiple test cases for each programming practice, covering a variety of correct and incorrect input situations. After the student submits the homework, the evaluation engine automatically runs these test cases and gives corresponding scores, and feedback based on the results.

In addition to the traditional test case evaluation, the module also integrates AI-based code quality analysis tools [35]. Using machine learning models, code readability, maintainability, and best practice adherence can be automatically assessed, providing more comprehensive feedback to students.

3.4. Virtual internship module

The virtual internship module provides a student with a practical platform to simulate the real working environment, aiming to cultivate the students' project development and teamwork skills.

The module contains multiple virtual project scenarios, such as data collection of news websites, price monitoring of e-commerce platform, etc. Each scenario has a detailed description of the requirements and constraints that simulate the real work tasks. Students need to plan and implement web-crawler projects independently according to their needs.

During the project implementation process, students can use the online development environment provided by the system for encoding and debugging. At the same time, the system also provides project management and collaboration tools to support multi-person collaborative development. Teachers can remotely monitor students' project progress and provide guidance and feedback in time.

3.5. Teacher auxiliary module

The teacher assistance module provides teachers with a series of tools to support course resource management, learning data analysis, and online Q&A, and other functions, to help teachers better carry out online and offline hybrid teaching.

The core of this module is a teaching-aid system based on big data analysis [36]. The system can automatically collect and analyze students' learning behavior data, and generate various visual reports, such as knowledge points mastery, learning progress distribution, common error types, etc., as shown in Figure 3. According to these data, teachers can understand the overall learning situation of the whole class and adjust their teaching strategies accordingly.

At the same time, the module also provides online answer questions and discussion area functions. Students can ask questions online, and teachers can answer them uniformly or open discussions. The system also integrates an intelligent question-answering module based on natural language processing [37], which can automatically answer some common questions and reduce the workload of teachers.

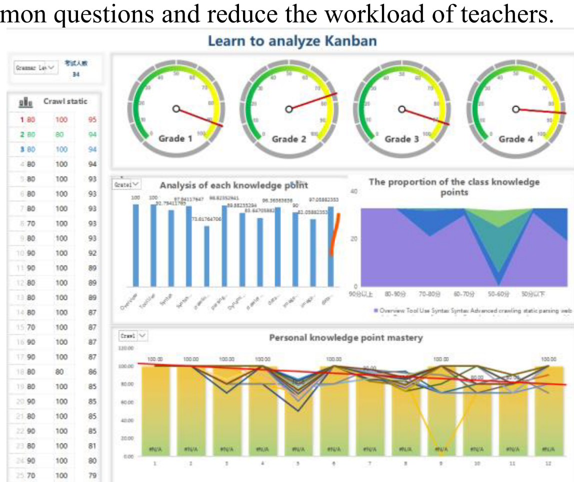

Figure 3. learn to analyze Kanban

4. Teaching practice and effect evaluation

4.1. Teaching practice

We have fully introduced the above human-machine collaborative practice teaching mode in the course of "Python and Web crawler" in the spring semester of 2024. The course, with 32 students, uses a mixture of online and offline teaching methods.

(1) Knowledge learning link

In the process of knowledge learning, teachers give classroom lectures in the traditional way, and use multimedia courseware, video resources and other auxiliary means to enhance students' learning experience. After each class, the teacher will set aside the thinking questions and discussion questions to guide the students to actively construct a knowledge system. Students can also review the course content at any time through the systematic knowledge base module.

(2) Practical training link

The practice training link is mainly carried out on the systematic practice platform. Teachers will design corresponding programming exercises and project tasks, and students can complete code writing and debugging online. The system's automatic evaluation module will score and give feedback on students' homework to help students understand their weak links.

During the project practice phase, students were divided into multiple groups to simulate the real work environment. Each group needs to complete a virtual project scenario, which can be developed with the collaboration tools provided by the system. Teachers will regularly check the project progress and provide necessary guidance.

(3) Personalized tutoring link

Based on the learning data collected systematically, teachers can understand each student's knowledge mastery and learning difficulties. For students in need, teachers will provide one-to-one personalized tutoring to help solve specific learning problems. At the same time, the system will also recommend personalized learning resources and practice questions according to the students 'performance, so as to promote the students' independent learning.

4.2. Effect evaluation

To evaluate the effect of the man-machine collaborative practice teaching mode, we made a comparative analysis of the students in this semester and the last semester (using the traditional teaching mode), mainly from the three dimensions of learning efficiency, practical ability and learning experience.

(1) Learning efficiency

We counted the average study time and the final grades of the students in the two semesters, and the results are shown in Figure 4:

The average study time of students this semester is about 20% compared with the previous semester, but the average score of the final grade has improved. This shows that the learning efficiency of students has been significantly improved in the man-machine collaboration model. Personalized learning path and resource recommendation help students to master knowledge more efficiently; automatic evaluation tool reduce repetitive work and save learning time.

(2) Practical ability

We scored the two semesters of student programming projects, and investigated the three aspects of code quality, functional completion and innovation. The results are shown in Figure 5:

According to the data, students' project works are better than last semester in terms of code quality and functional completion, especially the improvement of code quality is the most obvious. This is due to the automatic evaluation module of the system, which can find the code defects in time and give suggestions for improvement, thus promoting the improvement of students' programming practice ability.

(3) Learning experience

We also conducted a survey on the learning experience of students in two semesters, mainly including the evaluation of course difficulty, teaching organization and teacher-student interaction. The results are shown in Figure 6:

The overall evaluation of the students on the course in this semester is significantly higher than that of the last semester. Although the difficulty of the course has been improved, the students' evaluation of the teaching organization and the interaction between teachers and students has been greatly improved. This shows that the hybrid teaching method under the human-machine collaboration mode can provide better learning experience and enhance students' learning enthusiasm and initiative.

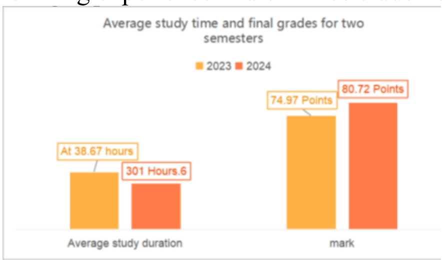

Figure 4. Average study time and final grades of the students in the two semesters

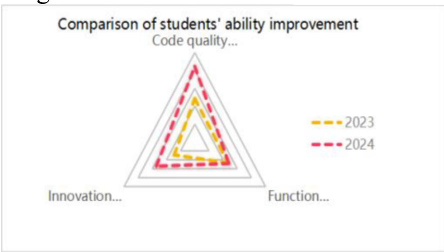

Figure 5. Evaluation results of project work in two semesters

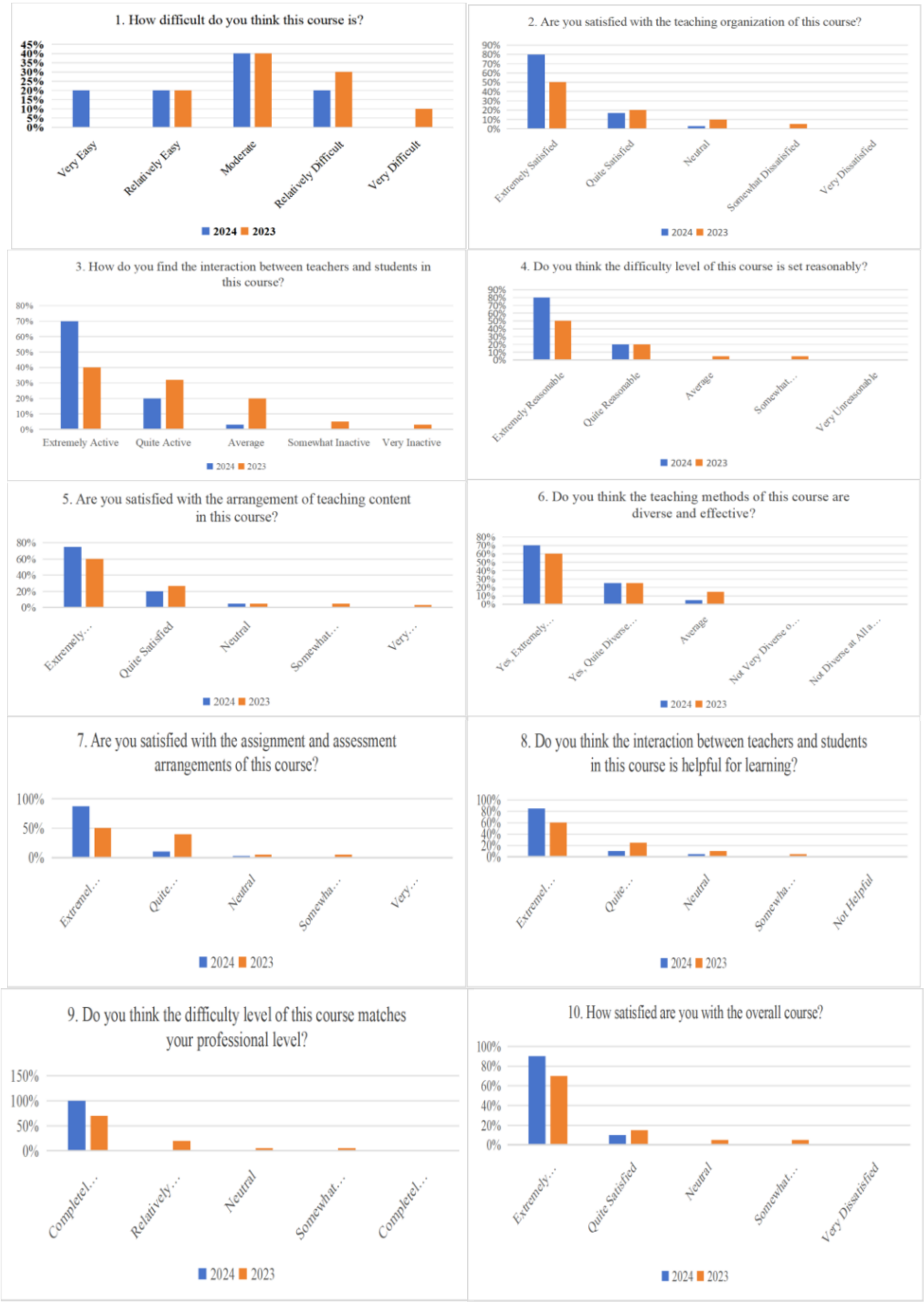

Figure 6. Survey results of learning experience in two semesters

5. Conclusion

This paper discusses the construction and implementation of the Human-Machine collaborative practice teaching mode based on artificial intelligence in the computer professional course " Python and Web crawler". This teaching mode gives full play to the advantages of both human and machine. Teachers can play the role of creative thinking and heuristic guidance, while the AI system provides personalized tutoring, automatic evaluation, virtual practice and other functions. The two work together to form the effect of "1 + 1> 2".

Through the practical teaching practice, the man-machine collaboration mode shows the following main advantages:

(1) Improve the learning efficiency. Personalized learning path design and resource recommendation help students master knowledge more efficiently; automatic evaluation tool reduces repetitive work and saves learning time. The data showed that the average student study time decreased by 20 percent, but their final grades improved.

(2) Enhanced the practical ability. The automatic evaluation module of the system can comprehensively evaluate the code quality, find the defects in time and give suggestions for improvement, thus promoting the improvement of students' programming practice ability. The code quality and functional completion of the student project works are significantly better than the traditional teaching model.

(3) Optimize the learning experience. The hybrid teaching mode of man-machine collaboration provides flexible learning methods and personalized tutoring support, enhances students' learning initiative and interaction, and significantly improves the overall learning experience.

Of course, the implementation of this teaching mode also faces some challenges, such as the cultivation of artificial intelligence literacy of teachers, and the resource input of system development and maintenance, which need sufficient support and attention from educational institutions. In the future, we will further improve the system functions, expand to more courses, and strengthen the long-term tracking and evaluation of the teaching effects, and constantly optimize the human-machine collaborative teaching mode.

In general, the man-machine collaborative practice teaching mode based on artificial intelligence is a promising innovative teaching concept, which can give full play to the advantages of both man-machine and improve the teaching quality and learning effect. This study provides useful practical exploration for the application of artificial intelligence in the field of education and has certain reference significance for promoting the modernization of education and the reform of teaching mode.

Declaration of competing interest

All authors declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Compliance

Not applicable.

Conflicts of Interest

There are no conflicts to declare.

Acknowledgments

This research was funded by the Industry-University-Research cooperation and basic and applied basic research project cooperation, Zhuhai, grant number 2220004002437.

Reference

[1] Jarrahi, M. H. (2018). Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making. *Business Horizons, 61*(4), 577-586.
[2] Gao, Q., Lu, Y., Wang, X., & Zhou, Y. (2021). Construction and practice case of man-machine collaborative classroom teaching mode in the era of artificial intelligence. *Journal of Distance Education, 39*(4), 24-33.
[3] Gao, D., & Li, R. (2022). Research on the construction of precision teaching mode of AI double teachers in the era of artificial intelligence. *Journal of Baoding University, 35*(6), 91-97.
[4] Cai, L., Liu, J., & Zhou, Y. (2021). Human-machine collaboration and students' development of core literacy: Analysis based on the three-dimensional model of social intelligence. *Open Education Research, 27*(1), 24-31.
[5] Licklider, J. C. (1960). Man-computer symbiosis. *IRE Transactions on Human Factors in Electronics, (1)*, 4-11.
[6] Zhou, Q., & Wen, X. (2020). The practice form of "AI + teachers" collaborative teaching in the intelligent era. *Journal of Distance Education, 38*(2), 37-45.
[7] Gao, Q., Lu, Y., Wang, X., & Zhou, Y. (2021). Construction and practice case of man-machine collaborative classroom teaching mode in the era of artificial intelligence. *Journal of Distance Education, 39*(4), 24-33.
[8] Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development, 39*(3), 5-14.
[9] Ma, X., & Zhang, J. (2020). Explore the ways to realize ideological and politics in AI-based innovation and entrepreneurship education. *Youth and Society, (2)*.
[10] Gao, D., & Li, R. (2022). Research on the construction of precision teaching mode of AI double teachers in the era of artificial intelligence. *Journal of Baoding University, 35*(6), 91-97.
[11] Chen, K., He, Y., & Zhong, G. (2018). Connotation transformation of information literacy and target positioning of AI education from the perspective of AI intelligence: Also on AI curriculum and teaching implementation path in basic education stage. *Journal of Distance Education, 36*(1), 11. https://doi.org/10.32629/er.v3i5.2688
[12] Zhu, Z., & Peng, H. (2020). The practical path of technology-enabled intelligent education. *China Journal of Education, (10)*, 1-8.
[13] Shute, V. J., & Zapata-Rivera, D. (2009). Stealth assessment in computer-based games to support learning. In *Computer Games and Instruction* (pp. 501-525).
[14] Woolf, B. P., Lane, H. C., Chaudhri, V. K., & Koedinger, K. R. (2010). AI grand challenges
[15] Peng, L., Chang, L., & Yin, J. (2020). Take the "Computer Programming Language (Python)" course as an example. *Educational Research, 3*(5). https://doi.org/10.32629/er.v3i5.2688
[16] Li, M. (2022). Research on the design of Python Language Programming system based on knowledge graph. *China Science and Technology Economy News Database Education, (7)*, 6.
[17] Zhang, C., Zhou, Y., Wu, J., et al. (2024). Intelligent question and answer implementation method integrating large model and knowledge base, system and medium: 202311155853 [P]. [2024-04-02].

[18] Chen, W., Chen, B., & Liu, W. (2022). Apply knowledge space theory to explore the key learning path of middle students: Take the ninth grade "chemical equation" learning as an example. *Chemistry Teaching, (9)*, 24-28.
[19] Falmagne, J. C., Doignon, J. P., Koppen, M., Villano, M., & Johannesen, L. (1990). Introduction to knowledge spaces: How to build, test, and search them. Psychological Review, 97(2), 201-224. https://doi.org/10.1037/0033-295X.97.2.201
[20] Desmarais, M. C., & Baker, R. S. (2012). A review of recent advances in learner and skill modeling in intelligent learning environments. User Modeling and User-Adapted Interaction, 22(1-2), 9-38. https://doi.org/10.1007/s11257-011-9106-8
[21] A, Y. L. , B, H. L. , C, Y. X. , B, H. Z. , B, J. Z. , & D, L. Z. , et al. (2022). Logistics-involved service composition in a dynamic cloud manufacturing environment: a ddpg-based approach. Robotics and Computer-Integrated Manufacturing, 76, 102323-.
[22] Liu, G., Deng, W., Xie, X. , Huang, L. , & Tang, H. . (2021). Human-level control through directly-trained deep spiking q-networks.
[23] Shamsuddinova, S., Heryani, P., & Naval, M. A. (2024). Evolution to revolution: critical exploration of educators' perceptions of the impact of artificial intelligence (ai) on the teaching and learning process in the gcc region. International Journal of Educational Research, 125.
[24] Velankar, M., & Kulkarni, P. (2024). Employing cumulative rewards based reinforcement machine learning for personalized music recommendation. Multimedia Tools and Applications, 83(16), 48007-48020.
[25] Yang, G., Xie, G. , & Liu, G. Y. . (2024). Adaptive task recommendation based on reinforcement learning in mobile crowd sensing. Applied Intelligence: The International Journal of Artificial Intelligence, Neural Networks, and Complex Problem-Solving Technologies, 54(2), 2277-2299.
[26] Songyang, L. (2024). Simulation of association rule mining based on sensor networks in chinese language learning recommendation system for college students. Measurement: Sensors, 33.
[27] Sadri, S., Ghomi, S. M. T. F., & Dehghanian, A. . (2024). Analysis of a time–cost trade-off in a resource-constrained gert project scheduling problem using the markov decision process. Annals of Operations Research, 338(1), 535-568.
[28] Liu, T., Wang, H., Ma, M., & He, M. E. (2024). Federated Learning with Efficient Aggregation via Markov Decision Process in Edge Networks.
[29] Songyang, L. (2024). Simulation of association rule mining based on sensor networks in chinese language learning recommendation system for college students. Measurement: Sensors, 33.
[30] Jinming, W., Haixia, S., Jiayang, W., & Qing, Q. (2022). Continuous risk prediction of acute kidney injury in elderly critically-ill patients based on electronic medical records. Journal of Capital Medical University, 43(4), 600-609.
[31] Quan, J., & Quan, J. (2024). Building a korean language teaching resource library based on python crawler. Applied Mathematics and Nonlinear Sciences, 9(1).
[32] Du, B. (2024). Research on the recommendation algorithm based on deep reinforcement learning and knowledge graph.
[33] Desmarais, M. C., & Xu, P. (2022). A review of knowledge tracing: Modeling student knowledge acquisition. *arXiv preprint arXiv:2205.07345*.
[34] Li, J., Duan, Y., Liu, N., et al. (2024). A teaching quality evaluation system based on AI and big data analysis:
[35] Allamanis, M., Peng, H., & Sutton, C. (2018). A convolutional attention network for extreme summarization of source code. In *International Conference on Machine Learning* (pp. 2091-2100).
[36] Romero, C., & Ventura, S. (2020). Educational data mining and learning analytics: An updated survey. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 10*(3), e1355.
[37] Huang, X., Liu, Q., Zhu, X., & Xing, Z. (2022). Question answering in education. *arXiv preprint arXiv:2205.01095*.