A Study on the Transformation of Human–Machine Collaborative Teaching Models in Higher Education Under the AI-TPACK Framework

Chuanyu Peng[1], Tsewang Tshomo[2]

[1,2] *School of Public Administration, Southwest Jiaotong University, Chengdu 610031, China*
[2]*Corresponding author. Email: zewangcimu@my.swjtu.edu.cn*

ABSTRACT
Human-machine collaborative teaching has become an inevitable trend of education reform in the intelligent era. However, the current teaching transformation in colleges and universities still faces multiple difficulties, such as weak teachers' mathematical literacy, insufficient classroom personalized adaptation, and lagging discipline education system. Therefore, based on the AI-TPACK framework, this study integrates three dimensions of digital intelligent technology (AI-TK), teaching method (AI-PK) and subject content (AI-CK), and constructs the transformation path of human-computer collaborative teaching mode in colleges and universities : (1) Strengthen teachers ' digital literacy and AI ethical judgment ability at the technical level ; (2) Construct the whole process intelligent teaching mode of "'pre-middle-post' class at the level of teaching methods; (3) Develop interdisciplinary knowledge system and intelligent evaluation mechanism at the content level. The purpose is to respond to the practical needs of teaching transformation in colleges and universities in the era of number intelligence, and to provide a theoretical reference for promoting the deep integration of AI and classroom teaching and building a smart teaching system of man-machine symbiosis.

Keywords: *Human–machine collaborative teaching, AI-TPACK framework, Transformation of teaching models, Digital-intelligent technology.*

1. INTRODUCTION

The iterative evolution of artificial intelligence technology is profoundly reshaping the form of education and promoting teaching to a new stage of human-computer collaboration and intelligent education [1]. In the field of higher education, generative artificial intelligence technology, with its advanced natural language processing, content creation tools and interactive learning assistants, has emerged in innovating teaching methods, promoting personalized learning, strengthening teacher-student interaction and innovating teaching models. These advances are expected to break through the traditional teaching practice, change the relationship between teachers, students and digital intelligence technology in the teaching scene, optimize the training mode and improve the teaching quality. It can be said that digital intelligence technology is becoming a key force driving the high-quality development of education [2]. At the same time, this change also means that it is necessary to re-examine the role of teachers in the classroom. No matter how sophisticated the technology is, the essence of classroom teaching is still inseparable from the wisdom and subjective initiative of teachers [3]. Therefore, how to promote the deep cooperation between teachers and machines in the teaching scene and realize the transformation of man-machine collaborative teaching mode is particularly important.

Based on this, under the framework of AI-TPACK, this study constructs a transformation path of human-computer collaborative teaching mode in colleges and universities empowered by digital intelligence technology, which covers three-dimensional integration of digital intelligence technology, teaching method and teaching content, sorts out the current difficulties faced by the teaching transformation of colleges and universities empowered by digital intelligence, clarifies the reconstruction logic of various elements of teaching

system under the human-computer collaborative relationship, responds to the realistic needs of the transformation of teaching mode in colleges and universities in the era of digital intelligence, and provides a theoretical reference for promoting the deep integration of AI technology and classroom teaching in colleges and universities and building a smart teaching system with human-computer symbiosis.

2. DILEMMAS IN THE TRANSFORMATION OF UNIVERSITY TEACHING MODELS IN THE AI ERA

2.1 The Dilemma of Adaptation Between the Demands of Teachers' Literacy and Digital-Intelligent Development

First of all, there is a mismatch between teachers' technical literacy and the needs of digital-intelligent transformation. On the one hand, despite the rapid development of artificial intelligence, its application in educational context is still very exploratory. Some complex technologies (e.g., deep learning) create considerable professional barriers that require teachers to invest a lot of time and cognitive resources to master them, thus increasing their teaching workload [4]. On the other hand, in the traditional standardized teaching paradigm, the role of teachers as teaching executors is deeply rooted, and they habitually follow predetermined lesson plans for knowledge transfer. In the face of the subversive impact of digital intelligent technology, some educators may have technical fear and defensive psychological reactions, and lack the internal motivation to actively explore how these technologies catalyze teaching innovation [5].

Secondly, there is a deviation in teachers' cognition of the role of AI technology and their own teaching subjectivity. On the one hand, some teachers hold a negative attitude towards the use of AI, adopt a "one-size-fits-all" disabling strategy, and lack the subjective responsibility consciousness of scientifically guiding students to use AI reasonably. On the other hand, some teachers rely too much on the information and data analysis conclusions generated by AI, blindly trust the content of AI output, and create new ethical challenges in AI information judgment [6].

2.2 The Dilemma of Adaptation Between Classroom Teaching and Personalized Learning Needs

First of all, pre-class teaching design is not enough to support personalized learning needs. Instructional design still mainly depends on teachers' experience judgment, which makes it difficult to accurately capture the overall class profile or individual students' cognitive differences. Pre-class preparation resources are usually composed of unified textbooks or fixed text materials, failing to provide adaptive learning resources that adapt to diverse knowledge bases and learning preferences. In addition, teachers' pre-class time is mainly consumed by mechanical and repetitive tasks, such as curriculum planning and slide preparation, and there is not enough preparation space to analyze students' knowledge structure and cognitive characteristics. This limits the institutions of teachers in promoting creative teaching tasks.

Secondly, classroom teaching is still mainly teacher-centered one-way teaching. The current university classroom continues to rely on teachers as lecturers. The theory-oriented content dominates the teaching and lacks the resources to participate in the classroom. Therefore, students' intrinsic interest in learning and active participation are still difficult to activate. The limited interactions that do occur tend to focus on students who are actively vocal, while the difficulties and needs of silent learners are not given enough attention, further widening the achievement gap between students. Therefore, classroom teaching is difficult to adapt to students' differentiated knowledge base, cognitive habits and development aspirations.

Third, after-school learning feedback and continuous interactive support are still underdeveloped. At present, university teaching is still mainly focused on the delivery of classroom content. Once the course ends, the interaction between teachers and students and between peers usually stops completely. The lack of continuous after-school learning support and collaboration space makes teachers unable to answer students' questions in time.

2.3 The Dilemma of Adaptation Between the Subject Teaching System and the Concept of Diversified Talent Training

First of all, the traditional subject teaching system restricts the construction of students'

interdisciplinary knowledge structure. The concept of diversified talent training in the era of digital intelligence emphasizes the cultivation of versatile talents with interdisciplinary ability. However, the current university curriculum is characterized by isolation, with strict disciplinary boundaries and course content, and failure to integrate materials from social reality, industrial development and local culture. In addition, there is a lack of comprehensive practical tasks, interdisciplinary projects and immersive interdisciplinary teaching scenarios that connect art and science to promote students' understanding of complex content.

Secondly, the traditional score-oriented evaluation system is inconsistent with the diversified training direction. The traditional subject teaching system relies heavily on standardized examinations and summative assessments, mainly focusing on the assessment of static knowledge memory. This method cannot capture process-oriented behavior data, including learning duration, time allocation, frequency of seeking help and classroom interaction rate. In addition, the evaluation power is still entirely concentrated in the hands of teachers, and there is a lack of standardized implementation of student self-assessment and peer assessment. Students are unable to participate in self-examination and collaborative reflection based on visual learning trajectory, which makes it difficult to cultivate metacognitive and self-reflection ability. The resulting narrow evaluation perspective greatly limits the incentive function of the overall talent development evaluation.

3. FROM TPACK TO AI-TPACK: A DISCIPLINARY PEDAGOGICAL KNOWLEDGE FRAMEWORK INTEGRATING ARTIFICIAL INTELLIGENCE TECHNOLOGIES

TPACK is a mature theoretical framework for guiding technology-enhanced teaching, emphasizing the deep integration of technology, content and teaching methods in subject teaching[7]. With the continuous iteration of artificial intelligence technology, generative artificial intelligence has begun to intervene in all aspects of teaching design, teaching implementation and evaluation, and its role in the education scene has also changed from a single auxiliary tool to an important collaborative participant in teaching activities[8]. In this regard, the researchers put forward the AI-TPACK construct, which integrates artificial intelligence into the TPACK framework, emphasizing the key role of digital intelligence technology, teaching methods and subject content in promoting teaching reform. This provides a new theoretical perspective for analyzing the development of teachers' teaching knowledge and the reconstruction of higher education teaching mode in the era of artificial intelligence [9]. Based on this theoretical basis, this study establishes the following analytical framework:

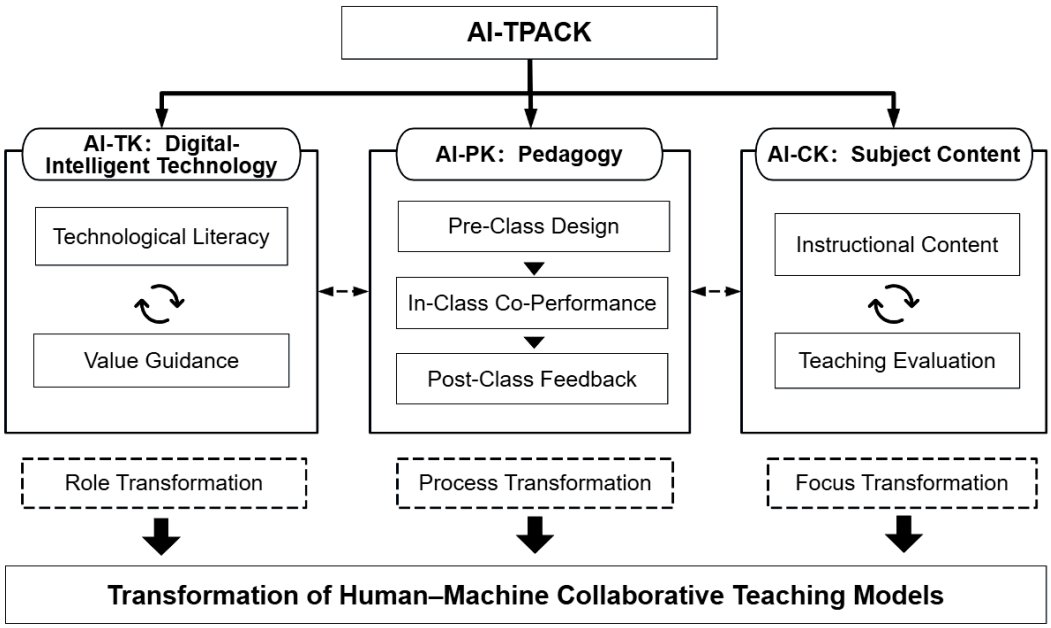


Figure 1 Transformative pathway for human-machine collaborative teaching based on the AI-TPACK framework.

4. A TRANSFORMATION PATHWAY FOR HUMAN–MACHINE COLLABORATIVE TEACHING MODELS IN HIGHER EDUCATION UNDER THE AI-TPACK FRAMEWORK

4.1 The Digital-Intelligent Technology Layer (AI-TK): Improving the Digital Intelligent Teaching Literacy of University Teachers

Firstly, it's important to establish a training and incentive guarantee mechanism for teachers' digital intelligence literacy. On the one hand, universities should develop a hierarchical and classified artificial intelligence teaching ability training system to design differentiated training content for teachers of different ages and disciplines. Such projects should avoid homogenizing technical operation training, but emphasize the cultivation of teachers ' comprehensive ability to apply artificial intelligence tools to teaching design, teaching adjustment and evaluation in the context of specific disciplines. On the other hand, supportive incentive policies should be introduced to encourage teachers to actively explore innovative models of integrating artificial intelligence into classroom teaching. At the same time, universities should establish an inclusive trial and error mechanism to alleviate teachers ' concerns about the use of new technologies, and gradually improve their digital intelligent teaching literacy through practical exploration. It promotes the transformation of teachers' role from "teaching executor" to "education leader".

Secondly, strengthen the role of teachers in guiding students' values. With the empowerment of artificial intelligence, teachers are no longer just the transmitters of knowledge, but the promoters and facilitators of students' learning. Students have also transitioned from passive knowledge recipients to active participants in the learning process. On the one hand, teachers should go beyond the negative attitude towards students' use of artificial intelligence or simple prohibition strategies, consciously assume the main responsibility of guiding students to use artificial intelligence tools scientifically and normatively, and help students develop compliance and rational use habits of artificial intelligence tools. On the other hand, the role and task division between teachers and artificial intelligence should be clarified. Artificial intelligence should undertake transactions and auxiliary tasks, such as material generation, data statistics, etc. However, it is necessary to strengthen the core role of teachers in the key links including value guidance, moral education and emotional cultivation. Promote teachers to change from the role of "knowledge instiller" to "learning facilitator".

4.2 The Pedagogical Method Layer (AI-PK): Constructing the Whole Process Intelligent Teaching Model of "Pre-Middle-Post" Class

First of all, pre-class intelligent diagnosis. The scientific rigor of pre-class teaching design directly affects the classroom effect. First, artificial intelligence helps teachers design learning materials of different types and difficulty levels - such as cases, videos or knowledge maps - allowing students to choose materials that are commensurate with their level of understanding or interest in the pre-class stage. Next, using multi-source data including students' historical learning files and learning behavior trajectories, artificial intelligence supports the generation of overall classroom learning profiles and individual student learning feature reports, providing teachers with scientific and quantifiable teaching goal recommendations. Then, teachers can carry out differentiated and dynamically adjusted instructional design. In addition, artificial intelligence can take the responsibility of automatically scoring preview assignments, compiling problem lists, and generating teaching slides, thereby liberating teachers from monotonous, repetitive, and mechanical tasks. This enables teachers to devote more energy to creative efforts, such as innovating teaching plans and guiding students' thinking, and realizing man-machine collaborative teaching in the pre-class stage.

Second, multi-directional classroom interaction. Classroom teaching is the core link of teacher-student interaction and knowledge construction. This stage should realize the transformation from one-way knowledge transfer to multi-way interaction among teachers, students and intelligent systems. First of all, with students as the center, artificial intelligence should play the role of " intelligent assistant, " using video, animation, VR, AR and other technologies to realize the rich media presentation of teaching resources, and create a more real and natural learning experience for students. Secondly, artificial intelligence supports

intelligent grouping, collaborative task design and allocation, and assists in organizing classroom discussion activities. Through the intelligent monitoring of the group process, students can be guided to carry out cooperative interaction and collaborative learning. In addition, teachers should guide students to train critical thinking and provide cognitive guidance in a timely manner according to the real-time learning progress of students and learning groups. With the help of artificial intelligence, stratified and classified classroom tests are carried out according to the different performance of students or groups, so as to understand students ' learning situation and adjust teaching strategies in time.

Thirdly, after-class collaborative feedback. After-class feedback is a key link to consolidate learning outcomes and optimize teaching quality. First, intelligent feedback channels should be established for continuous after-school interaction. Through the intelligent course platform, students can review key course contents, analyze teaching difficulties, receive homework feedback, and participate in online communication. Artificial intelligence question and answer assistants can answer students' after-school questions at any time, solve basic knowledge problems and guide solutions to problems, so as to meet students' decentralized learning needs. At the same time, students' error correction status is tracked and recorded, and the progress of task completion is reviewed in real time. Through personalized reminders and learning suggestions, students are helped to cultivate autonomous learning and self-regulation ability. Secondly, a human-machine collaborative feedback mechanism should be constructed. For quantifiable learning tasks, such as objective problems and standardized assignments, artificial intelligence scores them and generates error sets. According to the differences of students, it provides targeted analysis and consolidation exercises to achieve immediate evaluation and immediate correction. For open and creative subjective learning tasks, artificial intelligence helps teachers to conduct preliminary job screening and statistical analysis of common problems, and then feed the problems back to the teacher side. Teachers provide targeted improvement suggestions and value guidance, so as to improve the efficiency and accuracy of after-school learning feedback.

4.3 The Subject Content Layer (AI-CK): Constructing a Student-centered Intelligent Teaching Content System

First of all, it is to build students' interdisciplinary knowledge system. The teaching content of the subject should focus on breaking down the obstacles of the subject and constructing a knowledge system combining students ' interdisciplinary, virtual and real learning. Firstly, artificial intelligence can bring together cutting-edge achievements, industry trends and core issues in the field of professional disciplines, build a subject knowledge map, and help students better correlate knowledge. Secondly, teachers can rely on artificial intelligence to integrate teaching resources such as social life, scientific and technological development, professional practice and local culture, and design interdisciplinary practical tasks. Using extended reality technology (XR), etc., abstract concepts are transformed into sensory experiences to enhance the sense of existence and authenticity of teaching content, so that students can obtain lifelike teaching content.

Second, it is to establish an intelligent interactive teaching evaluation process. First of all, with the help of artificial intelligence, teachers can continuously collect students' learning behavior data throughout the teaching process, including quantifiable indicators such as accuracy rate and homework completion rate, as well as process information such as learning time, time allocation, repeated learning time and frequency of seeking help, and comprehensively analyze students' knowledge mastery, ability development level and academic performance to form students' subject evaluation results. Secondly, expand the space of students' self-evaluation and mutual evaluation. Through AI visual learning trajectory and comparative analysis, students can conduct self-examination based on objective evidence, and carry out mutual evaluation in the peer community to stimulate the sense of reflection and promote collaborative improvement.

5. CONCLUSION

Under the framework of AI-TPACK, this study aims to solve a series of problems faced by digital intelligent teaching in colleges and universities, such as the mismatch between teachers' digital literacy and teaching transformation needs, the obstruction of individualized teaching methods and the lag of teaching content system. Furthermore,

from the three dimensions of digital intelligent technology, teaching methods and subject content, the transformation path of man-machine collaborative teaching is constructed, and the key measures and cooperation mechanism of each dimension are clarified. However, there are some limitations in this study, and the analysis of the cross field of AI-TPK and AI-TCK in AI-TPAK is still insufficient. In the future research, we can choose different majors such as art, science and engineering to carry out teaching experiments, improve the implementation plan of hierarchical classification teaching transformation, and constantly optimize the man-machine collaborative teaching mode under the AI-TPACK framework, so as to provide a more practical scheme reference for the reform of intelligent teaching in colleges and universities.

ACKNOWLEDGMENTS

This research is funded by the 2024 Sichuan Provincial Teaching Reform Project titled "Research on the Development Model for Digital Empowerment of Innovative Public Administration Graduate Students" (Grant No. YJGXM24-C140).

REFERENCES

[1] Qian, Y. Pedagogical Applications of Generative AI in Higher Education: A Systematic Review of the Field. TechTrends, 2025:69(5), 1105–1120. https://doi.org/10.1007/s11528-025-01100-1

[2] Yang, J., Shi, G., Zhu, W., & Sun, Y. Intelligent technologies in smart education: A comprehensive review of transformative pillars and their impact on teaching and learning methods. Humanities and Social Sciences Communications, 2025:12(1), 1239. https://doi.org/10.1057/s41599-025-05444-0

[3] Hava, K., & Babayiğit, Ö. Exploring the relationship between teachers' competencies in AI-TPACK and digital proficiency. Education and Information Technologies, 2025:30(3), 3491–3508. https://doi.org/10.1007/s10639-024-12939-x

[4] Wang, D. D., & Wang, Y. Dilemmas and countermeasures of artificial-intelligence-empowered university classroom teaching. Journal of Harbin University, 2024:45(11), 132-135.

[5] Chen, Y., Jiang, Y. S., Ma, X. T., & Liu, D. J. Application of agents in human-AI collaborative teaching: Scenario adaptation, value implication and dilemma transcendence. China Educational Technology, 2025:(11), 26-33.

[6] Nguyen, A., Ngo, H. N., Hong, Y., Dang, B., & Nguyen, B.-P. T. Ethical principles for artificial intelligence in education. Education and Information Technologies, 2023:28(4), 4221–4241. https://doi.org/10.1007/s10639-022-11316-w

[7] Mishra, P., & Koehler, M. J. Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. Teachers College Record: The Voice of Scholarship in Education, 2006:108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

[8] Zhai, X. Transforming Teachers' Roles and Agencies in the Era of Generative AI: Perceptions, Acceptance, Knowledge, and Practices. Journal of Science Education and Technology, 2025:34(6), 1323–1333. https://doi.org/10.1007/s10956-024-10174-0

[9] Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. TPACK Development in Science Teaching: Measuring the TPACK Confidence of Inservice Science Teachers. TechTrends, 2009:53(5), 70–79. https://doi.org/10.1007/s11528-009-0328-0