Research on the Construction of Human-Machine Collaborative Teaching Model in Universities Based on Symbiosis Theory

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Abstract: With the development of artificial intelligence technology, human-machine collaborative education has become the theoretical foundation for promoting the transformation of teaching and learning methods and exploring the mechanism of learning occurrence in the artificial intelligence era, and has reshaped the patterns of teaching and learning for teachers and students. Technology-empowered smart education to advance the design and practice of human-machine collaborative education systems has become a major research focus at present. Based on a review of the relevant academic history, this paper conducts a dialectical integration study of symbiosis theory and human-machine collaborative teaching, explores the construction of symbiotic units, symbiotic models and symbiotic environments in the human-machine collaborative teaching model of universities, and takes the course Circuit Analysis as a carrier to discuss the implementation path of the symbiotic teaching model. The research aims to promote the advancement of human-machine collaborative teaching from the intermediate stage to the advanced stage, drive the in-depth integration of intelligent technology and classroom teaching, and boost the high-quality development of future education.

Keywords: Artificial Intelligence in Education; Symbiosis Theory; Human-Machine Collaboration; Teaching Model

1. Introduction

Based on the investigation of primary-stage human-machine collaborative teaching models such as “human-machine collaboration + dual-teacher classroom” and “human-machine collaboration + flipped classroom” [1], this paper studies the construction of a university human-machine collaborative teaching model grounded in symbiosis theory, and explores the practical path of “human-machine co-teaching” with human teachers and machine teachers as symbiotic units, taking the course Circuit Analysis as a case study. The research objective is to promote the integration and symbiosis of humans and machines in classroom teaching, and propel university human-machine collaborative teaching from the intermediate stage to the advanced stage.

2. Review of Academic History and Research Trends

The concept of “symbiosis” originates from the field of biology in natural science. From the perspective of academic research, it is a broad concept that generally refers to an interdependent fate relationship of mutual promotion, common prosperity and harmonious unity formed between things or units [2]. Against the backdrop of the artificial intelligence era, the “human-machine symbiosis” which applies symbiosis theory to education and teaching refers to the application form presented by the integration of intelligent technology into the education field [3]. It aims to clarify the mutually beneficial coexistence mode of intelligent technology with teachers, students, teaching content and teaching processes in the teaching system, so as to respond to the question of how to achieve the in-depth integration of intelligent technology and classroom teaching. Specifically for higher education, human-machine symbiosis, under the premise of human-machine collaborative teaching, leverages the functional advantages of intelligent technology to provide learners with personalized learning content, enabling students to conduct autonomous learning in a state of human-machine co-learning [4]. Ultimately, learners acquire intelligent learning capabilities with higher-order thinking to solve problems in

complex situations, and the relationship between human and machine intelligence is transformed into one of symbiosis and integration.

Human-machine collaborative teaching refers to the form of "human-machine co-teaching" by human teachers and machine teachers. The connotation of human-machine collaborative teaching has been interpreted differently with the development of artificial intelligence technology. According to the development level of artificial intelligence technology, human-machine collaborative teaching can be divided into the primary stage, intermediate stage and advanced stage. Figure 1 sorts out the tasks and functions of human teachers and machine teachers in human-machine collaborative teaching at each stage. In terms of specific systems, for example, the "Serago Adaptive Learning System" is an auxiliary memory learning tool for students, helping them preview, learn or review knowledge points [5]. As a representative of the teacher's role in traditional education, the teaching and learning theories embodied in this system only stay at the behaviorism and cognitivism stages, making it difficult to cultivate students' higher-order thinking abilities, thus it is a typical primary-stage human-machine collaborative teaching system. Another example is the "Huique Adaptive Learning System", which has achieved excellent results in human-machine teaching competitions. It is characterized by embedding a large number of simulated experiments in online courses to enable students to "learn by doing". The system conducts complex algorithmic processing based on students' learning behaviors, and revises curriculum design through human-machine interaction and feedback. This system realizes knowledge creation and the cultivation of students' higher-order thinking abilities, belonging to a typical intermediate-stage human-machine collaborative teaching system.

With the popularization of artificial intelligence technology, human beings will increasingly rely on intelligent machines to understand and transform the world. In the field of education, the intelligence level of artificial intelligence determines the degree of human-machine collaboration [6]. According to research, most current human-machine collaborative teaching systems are in the primary stage shown in Figure 1, a learning form where teachers are dominant, machines play an auxiliary role and students learn passively; only a few systems can achieve the intermediate-stage learning form of mutual teaching and learning between humans and machines. Under the current background of artificial intelligence technology, both humans and machines play their respective roles in the educational ecosystem. Only by learning from each other's strengths, achieving symbiosis and integration, and forming a new ecosystem of complementary advantages between humans and machines, can educational benefits be maximized and human-machine collaborative teaching advance to the advanced stage [2].

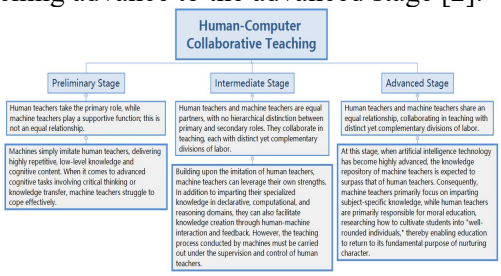

Figure 1. Overview of the Development of Human-Machine Collaborative Teaching

3. Construction of Human-Machine Collaborative Teaching Model Based on Symbiosis Theory

3.1 Dialectical Integration of Symbiosis Theory and Human-Machine Collaborative Teaching

Symbiotic relationships between things are a universal basic state, which is reflected not only in interdependence, but also in a dynamically coordinated and mutually conditional form of existence. An ideal human-machine collaborative teaching system can be essentially regarded as a typical symbiotic system. Symbiosis theory consists of three core elements: symbiotic units, symbiotic models and symbiotic environments. Among them, symbiotic units are the foundation, symbiotic models are the key, and symbiotic environments are the prerequisite [1]. The essence of a symbiotic system lies in the formation of an orderly and sustainable co-evolutionary relationship between different units through the exchange of material, energy and information. This relationship has both inherent regularity and dynamic coordination, enabling the overall system to achieve functional benefits that surpass the simple addition of individual units.

In the field of education, human teachers and

machine teachers in the human-machine collaborative teaching model are two heterogeneous symbiotic units; the collaborative relationship between these two units constitutes the symbiotic model; and internal and external factors such as technology, cost and policies form the foundation for symbiotic units to function through the symbiotic model. With the in-depth development of artificial intelligence technology, the collaboration between human teachers and machine intelligence has gradually evolved from simple tool assistance to in-depth system integration, which is the realistic basis for the vivid embodiment of symbiosis theory in the teaching system. In this system, human teachers and machine teachers, as two heterogeneous but functionally complementary units, jointly serve teaching objectives and realize the overall optimization of teaching effects through effective interaction and division of labor [3].

3.2 Research on the Construction of University Human-Machine Collaborative Teaching Model Based on Symbiosis Theory

The construction idea of this teaching model is guided by curriculum training objectives and aimed at developing students' higher-order learning abilities. It studies the mechanism of symbiosis theory acting on human-machine collaborative teaching, constructs the three elements of symbiotic units, symbiotic models and symbiotic environments. It creates complex problem scenarios for corresponding courses by developing machine teachers and organizes teaching activities; implements personalized learning and intelligent evaluation through human-machine collaboration; and conducts teaching management and decision-making through data analysis [7]. The overall framework of applying symbiosis theory to human-machine collaborative teaching systems is shown in Figure 2.

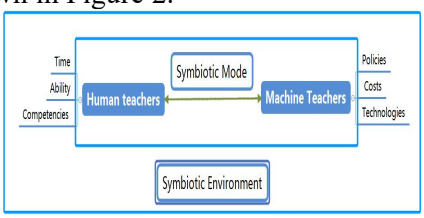

Figure 2. Overall Framework of the Application of Symbiosis Theory to the Human-Machine Collaborative Teaching System

3.2.1 Construction of symbiotic units

Symbiotic units are the basic units of energy production and exchange that constitute a symbiotic system, serving as the fundamental material condition for the formation of symbiosis. The symbiotic units of human-machine collaborative teaching are human teachers and machine teachers, who conduct material exchange and symbiotic energy transmission, and maintain complex dynamic interactions. Human teachers possess the abilities of emotional understanding, value guidance, creative thinking and complex decision-making; machine teachers have technical advantages in data processing, pattern recognition, personalized recommendation and continuous interaction. Though different in attributes, such differences form the basis for functional complementarity and synergistic improvement. The quality of symbiotic units directly affects the efficiency of the symbiotic system, thus it is necessary to focus on improving the digital literacy of human teachers and optimizing the educational appropriateness of machine teachers. The broader the scope, the deeper the level and the greater the complexity of interactions between symbiotic units, the higher the probability of symbiotic harmony, which means better effectiveness of human-machine collaborative teaching.

3.2.2 Construction of symbiotic models

Symbiotic models refer to the forms and mechanisms of interaction between symbiotic units, reflecting the modes, intensity and dynamic change characteristics of collaboration among units. In human-machine collaborative teaching, the symbiotic model is manifested as the collaborative relationship between human teachers and machine teachers, such as jointly constructing problem scenarios in the instructional design stage, realizing human-machine division of labor and real-time interaction in the teaching implementation process, and collaboratively completing formative and summative assessments in the teaching evaluation stage. Symbiotic models are not fixed; they should be dynamically adjusted according to teaching tasks, student status and technical conditions, forming a continuously iterative and gradually optimized collaborative process. An effective symbiotic model can maximize the integration of human and machine advantages and drive teaching towards more advanced collaborative development.

In specific implementation, the human-machine collaborative symbiotic model should also be adjusted in real time with the changes of symbiotic environments such as college students' personalities, data feedback, classroom realities and costs, forming a dynamically updated human-machine collaborative teaching model.

3.2.3 Construction of symbiotic environments

Symbiotic environments represent the sum of external conditions affecting symbiotic units and symbiotic models, including multiple factors such as technical foundation, institutional policies, resource costs and cultural atmosphere. For example, a university's information infrastructure, educational data security guarantee mechanisms, teacher training systems, funding support, as well as social cognition and acceptance of artificial intelligence in education, all belong to the components of the symbiotic environment. The symbiotic environment can either provide support for the operation of the system or impose certain constraints [8]. Therefore, constructing an ecological environment conducive to the development of human-machine collaborative teaching requires systematic design and support in technology, policies, resources, culture and other aspects.

The construction of this part needs to discuss the support degree of the human-machine symbiotic environment for the development of collaborative tasks according to the specific situation of universities. This includes exploring solutions when machine teachers carry out teaching tasks but the symbiotic environment (fixed policies and costs) cannot fully support the corresponding behaviors of machine teachers; and discussing the relationship between the teaching effect of actual teaching scenarios and the costs incurred, so as to obtain optimization strategies for the collaborative tasks of human teachers and machine teachers.

4. Implementation Path of Symbiotic Teaching with Circuit Analysis as the Carrier

Under the guidance of symbiosis theory, taking the course Circuit Analysis as the carrier, this paper constructs and practices the implementation path of the human-machine collaborative teaching model. The aim is to realize the symbiotic evolution of the circuit analysis teaching system through the in-depth collaboration between human teachers and machine teachers, and promote the cultivation of students' higher-order thinking abilities.

4.1 Preliminary Preparation: Laying the Foundation for Symbiosis

4.1.1 Alignment and deconstruction of teaching objectives

Systematically sort out the curriculum objectives of Circuit Analysis, reconstruct the traditional knowledge objectives (e.g., mastery of Kirchhoff's laws, Thevenin's theorem) into a competency objective matrix, and clarify the higher-order thinking abilities to be cultivated, such as systematic thinking, modeling ability, fault analysis and innovative design.

Based on the objective matrix, define the boundary of human-machine teaching tasks: human teachers focus on principle interpretation, thinking guidance and engineering ethics education; machine teachers are responsible for personalized exercise delivery, virtual experiment simulation, real-time data analysis and feedback.

4.1.2 Capacity building of the teaching team

Carry out workshops for improving teachers' digital literacy, focusing on training teachers' abilities in the collaborative use of circuit simulation tools, interpretation of learning data analysis, and human-machine collaborative instructional design.

Encourage teachers to integrate cutting-edge cases into teaching resources based on their own research directions (e.g., power electronics, embedded systems), enhancing the advancement and practicality of teaching content.

4.2 Construction of Symbiotic Units: Development of the "Circuit Analysis Machine Teacher"

4.2.1 Functional requirement analysis and technical cooperation

In collaboration with the university's information technology team or third-party educational technology companies, clarify the core functional requirements of the machine teacher based on curriculum objectives, including: (1) Intelligent circuit simulation engine: supporting students to build, debug and analyze complex dynamic circuits; (2) Error

diagnosis and feedback system: identifying common logical errors and conceptual misunderstandings of students in problem-solving or simulation, and providing targeted prompts and correction paths; (3) Personalized learning path planning: dynamically recommending theoretical content, cases and challenging projects according to students' prior knowledge level and learning behavior data; (4)Virtual experiment collaboration platform: supporting multi-person collaborative completion of virtual experiments, with the machine teacher acting as an "experiment collaborator" to provide real-time data monitoring and safe operation reminders.

4.2.2 Development and curriculum integration

Taking 1-2 core chapters (e.g., "Sinusoidal Steady-State Analysis" or "Two-port Networks") as pilots, the teaching team provides the logic of teaching content and typical error cases, and the technical team implements algorithms and interactive design. Feedback is continuously collected during the teaching process, and functional debugging and iteration are carried out 1-2 times per semester to ensure that the teaching behaviors of the machine teacher are coordinated with the teaching rhythm and depth requirements of human teachers.

4.3 Operation of Symbiotic Model: Implementation of Dynamic Teaching Process

4.3.1 Pre-class

Before the start of the course, conduct human-machine collaborative lesson preparation and learning situation prediction. Human teachers design core question chains and inquiry tasks; machine teachers predict students' learning difficulties based on previous data and generate personalized preview material packages (e.g., micro-videos, interactive simulation warm-up tasks).

4.3.2 In-class

During the course teaching, implement dual-teacher collaborative teaching and real-time intervention. In the theoretical teaching session, human teachers focus on explaining the physical meaning and engineering background of principles; machine teachers synchronously provide visual dynamic models (e.g., real-time generation of current and voltage waveforms) and push in-class concept assessment questions. In the experiment and practice session, students conduct virtual experiments through the machine teacher platform. Human teachers patrol and provide guidance, and conduct centralized explanations for common problems; machine teachers provide real-time data recording, error alarms and safety specification prompts. In the case discussion session, human teachers introduce complex engineering cases (e.g., fault troubleshooting of power supply design) and guide students to conduct group discussions; machine teachers provide simulation environment support for hypothesis verification, and generate group participation and thinking logic analysis reports based on discussion process data for teachers' precise guidance.

4.3.3 Post-class

After the course, implement personalized consolidation and expansion. Machine teachers push differentiated exercises and extended reading materials according to classroom performance and homework data. Human teachers use the learning dashboard generated by machine teachers to identify the overall weak points of the class and individual learning obstacles, and record targeted explanation videos or arrange offline tutoring.

4.4 Support of Symbiotic Environment: Institutional and Technical Guarantee

4.4.1 Policy and resource support

Strive for the university to incorporate the "reform of human-machine collaborative teaching" into key educational reform projects, and provide funding support and class hour recognition. Establish a regular seminar system for interdisciplinary teaching and research teams (circuit theory teachers, artificial intelligence experts, educational psychologists).

4.4.2 Technical platform and data integration

Construct a unified teaching data center to integrate machine teacher data, laboratory management systems and curriculum evaluation systems, realizing the collection and analysis of the whole-process learning data. Ensure that the platform has open interfaces to support teachers to flexibly access new tools or resources according to teaching needs.

4.5 Evaluation and Iteration: Closed-Loop Optimization Mechanism

4.5.1 Multi-dimensional teaching evaluation

First, conduct the evaluation of students' learning effectiveness, comprehensively

assessing students' knowledge mastery and ability development by combining the formative data of machine teachers (e.g., completion degree of simulation tasks, evolution of error patterns) with traditional examination scores. Second, conduct the evaluation of teaching model effectiveness, assessing the fluency of human-machine collaboration, student participation and teaching satisfaction through questionnaires and teacher-student interviews. Finally, conduct the performance evaluation of machine teachers, regularly analyzing indicators such as feedback accuracy and adaptability of personalized recommendations.

4.5.2 Model Iteration and promotion

At the end of each teaching cycle, hold a review seminar based on evaluation results to optimize the functional design of symbiotic units and the collaborative process of symbiotic models. Refine the mature experience of the Circuit Analysis course into a transferable implementation framework, and gradually promote it to related course groups such as Analog Electronic Technology and Signals and Systems, forming a radiation effect.

5. Practical Paths and Development Challenges

The construction of an effective human-machine collaborative symbiotic system requires collaborative efforts in multiple aspects. In terms of teacher development, it is necessary to strengthen the cultivation of teachers' digital literacy and intelligent education capabilities; in terms of technological development, the research, development and application of artificial intelligence technology dedicated to education should be promoted; in terms of institutional construction, relevant standards, norms and incentive mechanisms need to be improved; in terms of cultural cultivation, an open, inclusive, innovative and collaborative organizational atmosphere should be fostered [9].

Meanwhile, this development process is faced with numerous challenges: algorithm transparency and data security issues at the technical level, responsibility definition and value orientation issues at the ethical level, cost-effectiveness and sustainability issues at the practical level, etc. The resolution of these challenges requires the joint participation of educational researchers, technology developers, policy makers and practitioners [10]. Through continuous exploration and innovation, human-machine collaborative teaching can be driven towards a higher level of development [11].

6. Conclusion

In conclusion, symbiosis theory provides a profound theoretical perspective for human-machine collaborative teaching. By constructing a three-dimensional framework of coordinated symbiotic units, optimized symbiotic models and supportive symbiotic environments, the human-machine relationship can be promoted from mechanical combination to organic integration, ultimately forming a new educational ecology that is people-oriented, technology-empowered and collaboratively innovative. This ecology can not only improve teaching efficiency and quality, but more importantly, promote the all-round development of students and cultivate innovative talents who meet the needs of the intelligent era.

Acknowledgments

This work was supported by 2024 Jilin Provincial Educational Science Planning Project: A Study on the Construction of Human-Computer Collaborative Teaching Model in Colleges and Universities Based on Symbiosis Theory (GH24775).

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