# Constructing an Adult Human-Computer Collaborative Teaching Model from the Perspective of Ecological Systems Theory

Xiaowen Duan

School for Continuing Education, Shanghai International Studies University, Shanghai, China

0233100645@shisu.edu.cn

**Abstract.** In the context of digital transformation, the infiltration of intelligent technologies and products into the learning domain has given rise to human-computer collaborative learning methods. Adult education, however, still faces challenges such as outdated knowledge, monotonous teaching methods, difficulty in meeting personalized needs, and disconnection between technology and teaching. To address these issues, this paper proposes a construction method for an adult human-computer collaborative teaching model based on Bronfenbrenner's ecological systems theory. By analyzing the micro-system, mesosystem, exosystem, macro-system, and chronosystem, the paper explores the interactions between these levels and their impact on adult learners. This study aims to effectively integrate technological tools, teachers, learners, and learning resources through the ecological human-computer collaborative teaching model, providing a more flexible, personalized, and efficient learning experience for adult learners and improving teaching quality. The paper offers robust theoretical support and practical guidance for innovation in teaching models within adult education through theoretical exploration and practical application analysis.

**Keywords:** digital transformation, adult education, ecological systems theory, human-computer collaboration, teaching model

## 1 Introduction

With the rapid development of information technology and the in-depth promotion of digital transformation, various industries around the world are experiencing unprecedented changes. Adult education, as an important part of promoting socio-economic development, has also been profoundly affected. The rapid development of new-generation information technology, such as the Internet of Things, big data, cloud computing and artificial intelligence, has provided new momentum for the implementation of education digitalization strategies. The widespread application of intelligent educational products represented by intelligent guidance systems, educational robots, adaptive learning systems, and intelligent learning machines has changed the representational patterns and practical modes of teaching and learning[1]. Digital transformation not only


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changes the way learners acquire knowledge, but also challenges the traditional education model. Specifically, with the popularization and application of information technology, adult learners can access educational resources and engage in learning activities through a variety of digital means, such as online courses, virtual learning environments and intelligent teaching tools. However, this change has also exposed many deficiencies in adult education in terms of teaching content, teaching methods and the satisfaction of learners' individual needs.

In the current context of digital transformation, how to effectively integrate technology and teaching resources to build a teaching model that adapts to the needs of adult learning has become a hot topic in the field of education research. Learners in adult education generally have rich practical experience and diverse needs, which puts forward highly personalized and flexible requirements for the education model. Traditional teaching models are difficult to cope with these challenges, and the human-computer collaborative teaching model provides a new solution to this problem. The enablement and augmentation of computers is an indispensable key element of future student learning, which can optimize the learning process, change the learning pattern, and promote the transformation and upgrading of the learning mode in the age of intelligence[2]. The binary intelligence field on which future education relies will certainly seek a path of mutual integration between machine intelligence and human intelligence, achieve a reasonable division of labour between humans and machines, and strive to promote a high degree of matching between the instrumental rationality represented by artificial intelligence and the value rationality pursued by education[3]. The six departments of the Ministry of Education and other departments pointed out that new-generation information technologies such as 5G, artificial intelligence, big data, cloud computing, and blockchain should be applied in depth to give full play to the role of data[4]. The 2024 World Conference on Digital Education Artificial Intelligence and Digital Ethics Parallel Session also pointed out that with the rapid development of generative artificial intelligence technology, artificial intelligence will become an important engine to promote the high-quality development of the education cause, and shape a new paradigm and new form of education. The future of education will see the formation of a more open learning environment, with more egalitarian teacher-student relationships and more flexible teaching methods. This new ecosystem will shape a "teacher-machine-student" ternary teaching model, where teachers, machines, and students will work together to promote the development of intelligent education[5].

And the ecological systems theory, as a multi-level and multi-dimensional system analysis method, emphasizes the dynamic balance and interdependence among the elements in the system, which provides a theoretical basis for the construction of human-computer collaborative teaching model in adult education. By introducing the ecological systems theory into adult education, the human-computer collaborative teaching model can be analyzed and designed in a more systematic and comprehensive way, so as to better meet the needs of adult learners and enhance the quality and effectiveness of education. This study aims to explore the human-computer collaborative teaching model in adult education under the background of digital transformation through the perspective of ecological systems theory, and to provide reference for teaching reform and model innovation in the field of adult education.

## 2 Problems in Teaching Adult Education in the Context of Digital Transformation

At the stage of digital transformation of education, the impact, intervention and transformation of smart technologies on the whole process of education have ushered in a profound transformation of teaching methods[6]. Teaching practice in the smart era is beginning to enter the field of intelligent collaboration, which is coexisted, dominated and controlled by teacher intelligence and machine intelligence, triggering changes in the role of teachers, the status of knowledge authority and the paradigm of instructional design[3]. With the accelerated digital transformation of society, the field of adult education is facing unprecedented challenges and opportunities. Although information technology has brought many conveniences and innovative possibilities to adult education, there are still many problems in its practical application, which constrain the quality and effectiveness of adult education.

### 2.1 Late updating of Teaching Content

In the digital age, the pace of knowledge updating has accelerated significantly, and the needs of adult learners have become more diversified and personalized. However, the teaching content of adult education often fails to keep up with the pace of social development and technological progress, showing an obvious lag and making it difficult to reflect the latest industry trends and technological applications in a timely manner. Specifically, many adult education programmes still use traditional teaching materials and resources, which often lack the timely incorporation of the latest technological advances and industry changes, resulting in old and outdated course content. Such curriculum design cannot effectively stimulate adult learners' interest in learning, and it is even more difficult to help them remain competitive in the rapidly changing occupational environment, which makes them often feel that they do not have sufficient knowledge reserves to cope effectively with the challenges of actual work. More importantly, the existing course content generally favors theoretical explanations and neglects practical application guidance. This is particularly inadequate for adult learners with specific vocational background and application needs. Due to the lack of practical application guidance in the course content, learners, after receiving education, find it difficult to transform what they have learned into actionable practical skills, thus failing to achieve desirable results in their work. This situation not only reduces the value of adult education, but also affects learners' career development and quality of life. Therefore, how to speed up the pace of updating teaching content to reflect the latest industry trends in a timely manner and to enhance the practical applicability of course content has become a key issue that needs to be urgently addressed in the field of adult education.

### 2.2 Homogenization of Teaching Methods

The teaching methods of adult education still rely to a large extent on the traditional face-to-face or self-study modes, and the singularity of this approach leads to a lack of flexibility and diversity in teaching, making it difficult to adapt to the actual needs of adult learners[7]. This teacher-centred teaching approach limits learner participation. Learners are often in a passive position in the classroom, lacking sufficient opportunities for interaction and discussion, which not only weakens their interest in learning, but also makes it difficult to stimulate their initiative and creativity. In addition, although digital transformation provides new possibilities for the diversification of teaching methods, many innovative teaching techniques and methods have not been fully utilized due to the conservatism of teaching concepts and the lack of competence of the teaching staff in the application of new technologies[8]. This status quo directly affects the quality and effect of adult education and hinders the modernization and innovation of teaching methods. At present, some digital tools such as online learning platforms and virtual classrooms have been applied to a certain extent in adult education, but in most cases they are only used as auxiliary tools for traditional teaching, and fail to really change the interaction and participation in the teaching process. The use of these tools often stays on the surface of technological application and is not integrated into the design of teaching, with the result that the limitations of the teaching means still exist, failing to effectively enhance the teaching effect. What is more noteworthy is that adult learners often need to squeeze out time for learning in their busy work and life, yet the existing teaching mode lacks flexibility and is difficult to meet their needs for learning anytime, anywhere. Many adult learners are unable to participate in learning at a fixed time and place due to their tight schedules, resulting in a lag in learning progress and a decline in learning quality.

### 2.3 Digital Divide and Neglect of Learners' Individual Needs

Adult learners are significantly different from traditional education targets in that they exhibit a high degree of diversity in terms of age, occupational background, learning goals, and life status. This diversity requires that adult education not only have an adaptive instructional design, but also be able to provide a highly personalized learning experience in order to truly meet the needs of learners. However, most adult education programmes tend to adopt a one-size-fits-all model in their design, lacking differentiated considerations for different groups of learners. Such course design cannot be adjusted to the specific circumstances of learners, resulting in an inability to effectively meet their diverse needs. Due to the imbalance in teacher-student ratios and the limited availability of teaching resources, it is difficult for teachers to take into account the individual needs of each learner in the traditional teaching mode, resulting in learners not being able to get timely help and solutions when they encounter questions and difficulties in learning. The lack of personalized guidance not only makes learners feel isolated in the learning process, but also may lead to unsatisfactory learning results, further weakening their motivation and confidence in learning. In addition, differences

in the level of technology access and digital skills of different learners make their acceptance of personalized learning experiences uneven. Many learners do not have access to the necessary technological tools and Internet services because they live in areas with poor technological infrastructure or due to financial constraints; older learners may lack the ability to use modern digital tools, leading to confusion or exclusion when using online learning platforms[9]. Differences in digital literacy, as well as psychological and cultural resistance to new technologies, further affect learners' acceptance and use of personalized learning resources.

### 2.4 Disconnect Between Technology and Teaching

Despite the fact that some information technologies have been used in adult education, there is still a significant gap between their actual effectiveness and the intended pedagogical goals. This gap creates a clear disconnect between technology and the teaching process, and hinders the realization of the potential of technology in education. Some teachers only regard online devices as a kind of teaching aids, but not as an important carrier for the transformation and upgrading of education and teaching, and fail to deeply integrate into the process of teaching design and implementation, thus failing to truly enhance the teaching effect[10]. Human-computer collaborative teaching is still in its infancy, and there are problems such as the theoretical system of human-computer collaborative teaching needs to be perfected, the ability of technology-enabled teaching change needs to be improved, the mechanism of conflict balance between humans and computers still needs to be explored, and the effectiveness of human-computer collaborative teaching needs to be verified, which hinders the development of human-computer collaborative teaching in adult teaching practice. In many adult education scenarios, the application of machines is a mere formality. For example, although online learning platforms are widely used to publish course content and collect assignments, this application is usually limited to information delivery and fails to make full use of the technology to promote interaction and collaboration among learners. In addition, the existing teaching design often fails to fully consider the advantages and potential of technology, and the application of technology is not truly integrated into the teaching objectives and method. For example, virtual reality technologies can provide learners with an immersive learning experience and deepen their understanding and memory by simulating real-life environments, but due to the lack of matching instructional design and strategies, these technologies have not been able to give full play to their proper roles. The application of technology thus appears disconnected and fails to provide learners with a more efficient learning experience. Inadequate adaptation of technology by faculty is also a key factor contributing to the disconnect between technology and teaching. Many teachers have a shallow understanding of IT and lack the ability to effectively integrate technology with teaching, which makes them face difficulties in applying technology in their teaching. As a result, the introduction of technology not only fails to simplify the teaching and learning process, but also increases the complexity of teaching and the burden on learners.

# 3 The Construction of Adult Human-Computer Collaborative Teaching Model Under the Perspective of Ecological Systems Theory

In order to cope with the problems existing in adult education teaching in the process of digital transformation mentioned above, the optimization and innovation of human-computer collaborative teaching mode on the allocation of educational resources, the organization of activities and the teaching model make it possible to realize the forms of education such as personalized teaching and adaptive learning, which is of great significance for improving the quality of education and increasing its efficiency[11] . However, there is no research in the field of adult education that proposes a comprehensive and holistic framework of human-computer collaborative teaching and describes the future practice pattern and development trend of human-computer collaborative teaching. Deepening the empowerment of technology to the teaching process requires further releasing the potential of human-computer co-teaching and promoting the orderly development of human-computer co-teaching. The ecological systems theory provides a new perspective for constructing the human-computer collaborative teaching mode, emphasizing the dynamic balance and interaction between the elements within the education system. Through the application of ecosystem theory, the adult human-computer collaborative teaching model can be systematically analyzed and designed, aiming to improve the teaching effect and meet the diversified needs of adult learners.

## 3.1 Ecological Systems Theory and its Core Ideas

The American psychologist Bronfenbrenner proposed the Ecological Systems Theory (EST) in the 1970s, which emphasizes that the developing individual is nested within a series of interacting environmental systems in which the system interacts with and influences the individual's development. Bronfenbrenner states that the system is divided into four levels, from the smallest to the largest being the micro system, the mesosystem, the exosystem, and the macro system. These four levels are demarcated by the direct degree of influence of the behavioural system on the development of the individual, from the micro system to the macro system, and the influence on the individual, from direct to indirect, and also include a temporal latitude, or chronosystem, which uses time as a system of reference for the study of psychological change in the growth of the individual[12].

Ecological systems theory emphasizes the interdependence, interaction and dynamic balance between the elements within a system. Applied to the field of education, ecological systems theory provides us with a multi-level and multi-dimensional analytical framework to help understand the complex interactions in the education system. Under the perspective of ecological systems theory, the education system is regarded as an open system containing multiple levels and complex interactions. This system not only includes traditional elements such as teachers, students, and educational content, but also covers a wider range of elements such as technological tools, teaching and learning

environments, and socio-cultural contexts. The relationship between these elements is dynamic and interactive, and together they shape the educational experience and learning effects of adult learners. In the process of digital transformation of adult education, the integrated role of the subsystems is particularly significant. Understanding and optimizing the interaction of these systems is the key to solving the multiple challenges faced by adult education and improving the quality of education. Therefore, when constructing a teaching model, it is necessary to consider how to coordinate the relationship between these elements to ensure the dynamic balance and sustainable development of the whole system.

### 3.2 Components and Connotations of the Adult Human-computer Collaborative Model

The word "synergy" originates from the ancient Greek, and its connotations include cooperation, harmony, coordination, collaboration, etc.[13]. In the 1960s, Licklider first put forward the forward-looking viewpoint of "man-computer symbiosis" to depict the future development direction of close coupling, cooperation and interaction between humans and computers[14], and since then the discussion around the relationship between humans and computers has been constantly updated and iterative. As the relationship between humans and intelligent machines has changed from human-computer coexistence and cooperation to human-computer collaboration, concepts such as human-computer fusion and human-computer co-creation have emerged in recent years[15]. These expressions all reflect the value orientation of humans and computers collaborating with each other to achieve specific practical purposes[16]. Education is a social activity to cultivate human beings purposefully, and human-computer synergy, as a process of human-computer competition and co-operation to create order, refers to the dynamic process in which human beings and computers point to the ideal goal in a consistent manner and develop in an orderly direction , which is more in line with the description of human-computer relationship in teaching practice activities. Therefore, human-computer collaborative teaching can be regarded as a way for human teachers and computers to interact and work together as a whole in multiple educational environments to achieve common goals and improve teaching effectiveness. From the above discussion of related theoretical and practical studies, it can be found that the definition of the connotation of human-computer co-teaching needs to consider the division of functions among teachers, students, and computers.

In the human-computer collaborative teaching model, the computer, the teacher and the student are the three core elements, which work closely together to promote the optimization of the teaching process and the enhancement of the learning effect. Technical tools play an indispensable role in the human-computer cooperative teaching mode. They are not only the medium of information transmission, but also a deep participant in the teaching process. Through these tools, such as Artificial Intelligence (AI) and Virtual Reality (VR) technologies, teachers can design and implement more accurate and personalized teaching activities, help students carry out self-assessment and continuously adjust learning strategies based on feedback. The learner is the core participant of this model. In this environment, students are not only recipients of

knowledge, but also active participants and explorers of learning activities. They use technological tools to select learning paths and resources that suit their learning needs and interests. In this way, students are able to achieve a highly personalized learning experience and, in the process, continuously adjust and optimize their learning strategies. Based on the above key elements, the whole session consists of three major synergistic processes. Firstly, teacher-computer synergy is a key aspect of this model. Teachers make use of the powerful data processing capabilities of machines, including data collection, calculation, storage and analysis, to diagnose students' learning conditions, conduct real-time assessment, and push differentiated learning resources. In this process, teachers not only play a supervisory and review role, but are also responsible for making humane corrections and diversified adjustments to the analyses provided by the machine to ensure that these data can truly serve students' personalized learning. Second, student-computer collaboration is based on teacher-computer collaboration. In this session, the machine takes over some of the tasks that were originally the responsibility of the teacher, such as knowledge transfer and basic instruction, and instead becomes the main object of interaction for the student. Student-computer interactions enable them to learn on their own in an environment surrounded by technology, which requires students to be data literate and capable of applying technology so that they can effectively use it to meet their needs and turn it into a tool for self-development. Finally, teacher-student collaboration is at the heart of the entire model. Despite the increasingly important role of technology in teaching and learning, teachers have not lost their critical position in the process. Teachers not only need to guide students to adapt to a technology-driven learning environment, but they must also continue to take on the role of nurturer, maintaining emotional and spiritual communication between teachers and students. In addition to transferring knowledge and skills, teachers are also tasked with helping students develop the right values and outlook on life. The real challenge of human-computer collaborative teaching lies in how to rationally allocate the functions of teachers and computers, so that they can give full play to their respective strengths and enhance the effectiveness of teaching together.

Overall, the connotation of the adult human-computer collaborative teaching model lies in multiple interactions, dynamic balance and personalized learning. The interaction between teachers, computers, students and the resources of the surrounding learning environment is the core of the model, through which the continuous optimization of the teaching process and the continuous improvement of the learning effect can be achieved. Dynamic balancing is reflected in the flexibility of the teaching model, where teachers and technological tools need to be constantly adapted and optimized according to the learner's individual differences, changing needs and the external environment to ensure that the teaching process is always efficient and adaptable. Personalized learning, on the other hand, is supported by technological tools that provide tailored learning paths and resources to help students learn at their best, ultimately maximizing the effectiveness of teaching and learning.

### 3.3 Ecological Human-computer Collaborative Teaching Model Construction

Under the guidance of ecological systems theory, the construction of adult human-computer collaborative teaching model needs to follow the principles of multiple interactions and continuous optimization to realize frequent interactions among technology tools, teachers, learners and learning resources in the teaching process, which are not only limited to the transmission of teaching content, but also include aspects such as teaching feedback, learning support and collaborative learning.

**The Necessity and Applicability of Establishing a Collaborative Teaching Model for Adults based on Ecological Systems Theory.**

In the current context of digital transformation, learners' individual needs, diverse backgrounds and the complexity of the learning environment make it difficult for traditional teaching models to meet the needs of adult learners. To cope with these challenges, the construction of an adult human-computer collaborative teaching model based on ecosystem theory is of great necessity and applicability. Ecological systems theory provides a multi-level analytical framework for understanding and designing complex educational systems. Adult education involves multiple interacting elements, including teachers, students, technological tools, and learning resources, which interact and change dynamically. By focusing on the relationships and interactions between the various system levels, ecological systems theory can help educational designers construct more integrated and effective teaching models. At the same time, with the popularity of intelligent technology, the synergy between machine intelligence and human intelligence has gradually become possible, and this synergistic relationship is the embodiment of the multi-level interaction emphasized by the ecological systems theory. Therefore, the construction of human-computer collaborative teaching model based on ecological systems theory can effectively deal with the complexity and variability in adult education. The learners in adult education have a high degree of autonomy and practical experience, which is consistent with the dynamic role of learners in various system levels emphasized in the ecological systems theory. By constructing a multi-level teaching model that can adapt to individualized needs, learners' backgrounds, goals and real-world needs can be better integrated. In addition, with the development of intelligent technology, human-computer collaboration in education is no longer a future vision, but a realistic need and trend. Therefore, applying ecological systems theory to the human-computer collaborative teaching model in adult education can not only enhance the efficiency and quality of education, but also promote a better learning experience for adult learners in a technology-driven learning environment.

**The Overall Nested Structure of the Ecological Human-computer Co-teaching Model.**

Based on the ecological systems theory, the adult human-computer collaborative teaching model can be designed as a holistic nested structure covering multiple system levels, including micro system, mesosystem, exosystem, macro system, and chronosystem. Each system level not only has a unique function, but also interacts with other

levels to form a dynamic and balanced educational ecosystem. The specific construction model diagram is shown in Figure 1.

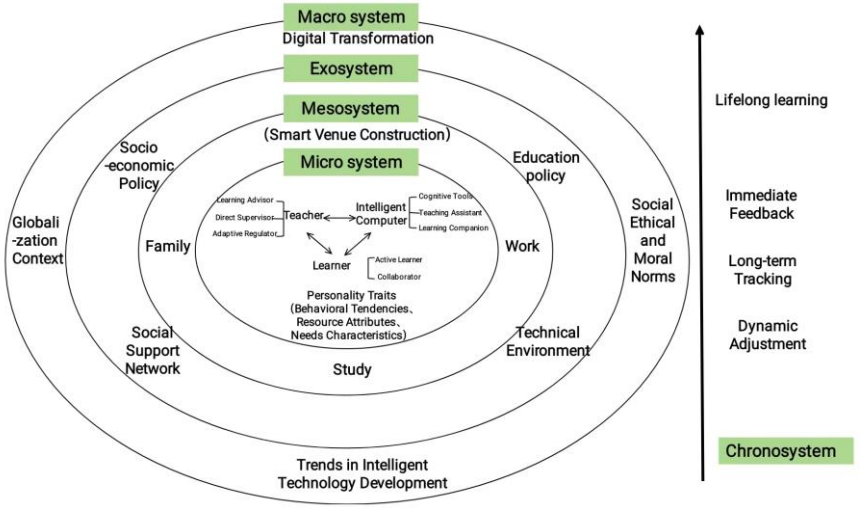


**Fig. 1.** Diagram of the overall nested structure of the ecological human-computer co-teaching model (author's own drawing)

The micro system is the core layer of the model and covers the direct interaction between the teacher, the student and the technological tool. In the micro system, individual elements play different roles, and in particular the personality traits of adult learners (e.g. behavioral tendencies, resource attributes and needs characteristics) need to be taken into account. On this basis, teachers and computers play different roles in the collaborative process with different learners. Teachers are not only knowledge transmitters in the micro system, but also play the roles of learning guides, supervisors and adaptive regulators. For learners with high academic level, strong behavioral tendency and high autonomy, teachers act more as advisors and supporters, helping learners' self-directed learning by providing resources and strategies, while computers provide students with diversified and accurate learning support services, assisting students' personalized independent learning and inquiry learning, cultivating students' exploratory spirit and innovative consciousness, and deepening their independent construction of what they have learned. In this process, the computer mainly acts as a cognitive tool to support, guide and expand students' cognitive process, and help students to construct deep-level meaning with the help of external tools[17]. For learners with weak academic level, lack of resources, and low learning autonomy, the teacher's role is more inclined to direct guidance to help students overcome academic difficulties, improve their academic level, enhance their motivation to learn, and develop good learning habits, while using technological tools for effective learning. The computer, on the other hand, mainly acts as an intelligent assistant teacher, which guides students' learning through learning plan development, learning resource recommendation, learning activity design, learning scaffold construction, etc. It is mainly responsible for data processing, personalized learning path recommendation and real-time feedback. For learners who

are technically proficient, have a clear need for learning and a strong desire for learning exploration, the computer can autonomously undertake most of the learning support tasks, such as automated assessment and resource pushing, in which the teacher only needs to make adaptive adjustments, and the machine acts as an intelligent learning companion, whose goal is to negotiate with the students through dialogue and combine the core strengths of human intelligence and machine intelligence to generate creative problem solutions, exploration and discovery of new knowledge[2]. The role of students in the micro system is that of active learners and collaborators. They interact with the teacher and the computer according to their own learning needs and technical skills, and actively participate in the learning process. For those students with strong motivation and independent learning ability, they may rely more on the computer for personalized learning resources, while for those who need more guidance, they will rely more on the teacher's guidance and support.

The mesosystem connects the micro system and the outer system, and is mainly responsible for coordinating the relationship between teachers, students, and computers and their multiple micro environments, especially in adult education, where adult learners usually face multiple role conflicts between work, family, and learning. The construction of mesosystems needs to focus not only on how to help adult learners balance between these domains, but also consider the construction of wisdom fields to support them to learn more efficiently in their complex life environments. The construction of mesosystems should provide adult learners with personalized learning pathway design, enabling learners to flexibly adjust their learning plans according to their own schedules and priorities. The construction of smart venues, on the other hand, can help learners seamlessly switch roles in different life environments by integrating a variety of smart technology tools, such as smart schedule management, task reminders and virtual collaboration platforms. In this way, adult learners are able to effectively engage in learning and maximize the use of fragmented time without hindering their work and family responsibilities. In addition, teachers can use data analytical tools to monitor learners' performance in different environments in real time and provide personalized advice and support based on the data. For example, by analyzing the difference in learners' performance between weekdays and weekends, teachers can suggest corresponding learning strategy adjustments to help learners better balance multiple roles and ensure that learning outcomes are not interfered by external factors. This kind of support based on smart field construction can significantly enhance the learning experience and outcomes of adult learners, enabling them to effectively achieve their learning goals even in complex life scenarios.

The exosystem plays a key supportive role in the ecological human-computer collaborative teaching model, and although adult learners are not directly involved in these systems, they have a profound effect on the educational process of learners through their indirect influences. The Exosystem encompasses socio-economic policies, educational policies, social support networks, and technological environments that indirectly determine learners' learning opportunities and outcomes by influencing their family, occupational, and community environments. Socio-economic and educational policies directly influence the distribution of resources and access to adult education. For example, funding policies for continuing education or legal guarantees for vocational

training can significantly increase the level of learners' participation in and benefit from education. At the same time, social support networks, including community organizations, vocational associations and family support, provide material and emotional support to learners when they are facing difficult situations, helping them to overcome barriers to learning and maintain motivation. In addition, the prevalence of the technological environment and the development of infrastructure are also important factors in the outer layer system that determine whether learners can access and utilize online education resources smoothly. In order to ensure the effective functioning of the exosystem, educational designers must keenly identify and utilize these socio-economic and technological resources, provide flexible and equitable learning opportunities, and help learners overcome potential external barriers, so as to achieve sustainable development in a complex social environment. Such systematic support not only promotes the equitable distribution of educational resources, but also creates a more stable and stimulating learning environment for adult learners.

The macro system, as the outermost layer of the ecological human-computer collaborative teaching model, covers a wide range of cultural backgrounds, social ethical and moral norms and technological development prospects that affect adult education, and the construction of this system needs to comprehensively reflect and adapt to current and future social development trends. The macro system should deeply reflect the core cultural values of the society, such as equity, tolerance and diversity, which are the foundation of education and determine the design direction and goals of the teaching model. At the same time, the macro system must keenly grasp the current trends of digital transformation and artificial intelligence technology to ensure that the education model not only meets the needs of the moment, but also adapts to future changes. As society enters the digital era and technology rapidly penetrates the education field, educators need to reasonably integrate AI technology into the teaching model, using its powerful data processing capabilities and personalized learning support functions to enhance the teaching effect and learning experience. However, the introduction of such technology must be approached with caution to ensure that its application meets ethical standards and does not deviate from the core values of education. Educators also need to incorporate education on AI literacy in the macro system to help adult learners acquire the necessary digital skills to enable them to learn and work comfortably and responsibly with smart tools in a complex technological environment. By enhancing learners' smart technology literacy, it will not only narrow the gap of the digital divide and enhance their competitiveness in the digital world, but also facilitate their sustainable development in their future careers. In addition, the construction of the macro system should also take into account the educational challenges and opportunities brought about by globalization. Intercultural education and the development of global perspectives have become increasingly important as global connections grow stronger. Educators need to introduce a global perspective into the macro system and design courses and activities that can develop learners' intercultural communication skills and global awareness, helping them to expand their thinking and enhance their adaptability in the context of globalization. They should also pay attention to sustainable development and encourage learners to develop environmental awareness and a sense of social responsibility in the learning process.

The chronosystem emphasizes the influence of the time dimension on the teaching model, focusing on the changing needs of learners at different times and the dynamic adaptability of the education model. For adult education, learners' life status, career development and social roles will change continuously over time, so the teaching model must have the ability of dynamic adjustment and continuous development. This requires educational designers to not only consider current teaching needs, but also anticipate and respond to possible future changes. The chronosystem promotes a high degree of flexibility and adaptability in the instructional model, which can provide appropriate support and resources at different stages of a learner's life. Within the framework of a time-lapse system, teachers and technological tools should be able to provide real-time feedback and long-term tracking, and through continuous data analysis and monitoring of learning behaviour, make timely adjustments to teaching strategies and resource allocation in order to adapt to the changing needs of learners. At the same time, the calendar system also encourages the introduction of the concept of lifelong learning in the teaching process, helping adult learners to maintain the continuity of learning throughout their careers and personal development, and to develop the ability to adapt to social change.

Ecological systems theory provides a scientific and comprehensive theoretical framework and practical guidance for the construction of adult human-computer collaborative teaching models. By integrating technology tools, teachers, learners and other elements, and following the principles of multiple interactions and continuous optimization, ecological systems theory helps to design a flexible, efficient and highly personalized teaching model. Through coordinated operation among different system levels, the ecological human-computer collaborative teaching model ensures the organic integration of technology and education, which enhances the efficiency of learning and guarantees the fairness and inclusiveness of education. In addition, the comprehensive consideration of cultural values, social norms and technological development trends of the macro-system makes this model forward-looking and sustainable for future development, providing solid learning support for adult learners in the ever-changing globalized environment. This model can not only effectively improve the quality of teaching and learning in adult education, but also profoundly adapt and respond to the diverse needs brought about by the digital era.

## 4 Pedagogical Application of the Ecological Human-Computer Collaborative Teaching Model in Adult Education

In adult education, the ecological human-computer collaborative teaching model provides strong theoretical support and practical guidance for the optimization and innovation of the teaching process. The multilevel structure of the model covers all system levels from micro to macro, and through the synergistic operation of the multilevel system, it endows adult education with greater flexibility and personalized potential. It not only provides teachers and students with rich tools and resources in the teaching and learning process, but also realizes the optimization of teaching decisions and the innovation of teaching styles through the deep integration of technology and education.

This section will explore in detail the specific application of this model in adult education, demonstrating its comprehensive practice in teaching process assistance, decision-making optimization, paradigm reshaping, and sustainable development of education.

### 4.1 Optimization of the Teaching and Learning Process Driven by Ecological Human-computer Collaboration

In the ecological human-computer collaborative teaching model, human-computer collaboration can drive the optimization of the teaching process. Continuous collaboration among the three micro systems drives the overall teaching efficiency. The computer is able to provide accurate learning path recommendations and instant feedback services by analyzing student behavior data in real time. For example, through AI technology, the computer is able to automatically identify students' learning bottlenecks and push personalized learning resources. This real-time service upgrade enables teachers to focus on high-level teaching tasks, while computers take on a lot of tedious basic work, thus improving teaching efficiency across the board. In addition, within the micro system, computer intelligence enables real-time tracking and feedback on students' learning status through data analysis and modelling techniques. Teachers can adjust their teaching strategies in a timely manner through the feedback data generated by the computer to achieve dynamic optimization of the teaching process. For example, the machine can analyze students' learning trajectories, discover and provide feedback on knowledge blind spots in the learning process, enabling teachers to make targeted adjustments in the teaching process. This real-time and dynamic feedback mechanism significantly improves the precision and relevance of teaching, and is particularly suitable for educational environments that meet the individual needs of adult learners. Meanwhile, in terms of creating smart teaching venues in mesosystems, computer intelligence provides strong support for teachers and students. Through intelligent processing by computers, teaching is no longer limited to traditional classroom, but can be expanded to a wider learning arena by using tools such as online learning platforms and virtual reality technology. For example, teachers can use computer intelligence to create highly interactive learning scenarios in virtual environments, enabling students to learn at any time and place, thus breaking the constraints of time and space. Therefore, the ecological human-computer collaborative teaching mode not only expands the spatial and temporal boundaries of teaching and the innovative environment through the optimization of human-computer interaction, enhances the efficiency of teaching services and the real-time nature of feedback, but also effectively meets the diversified and flexible learning needs of adult learners.

### 4.2 Optimization of Pedagogical Decision-Making Led by Ecological Human-Computer Integration

The ecological human-computer collaborative teaching model plays an important role in the optimization of teaching decisions led by human-computer integration. Through the deep integration of computer intelligence and teacher wisdom, this model effectively improves the accuracy and efficiency of teaching decisions, providing adult

learners with more accurate and personalized teaching solutions. In this model, computer intelligence is able to effectively mobilize social resources and support networks on the basis of integrating national policies and strategic guidance from the exosystem. With its powerful data processing capabilities, the computer takes on the complex analysis and reasoning tasks traditionally performed by teachers. Through the collection and analysis of a large amount of teaching data, the computer can not only accurately diagnose the teaching effect and analyze the learning situation, but also generate targeted teaching programmes. In this process, the role of the teacher is also extremely critical. Teachers need to adjust and optimize the suggestions provided by the machine according to their own teaching objectives, course content and students' individual needs. For example, the machine can automatically generate personalized teaching plans based on adult learners' behavioral tendencies and learning needs, thus helping teachers to cope with complex and changing teaching situations. At the same time, teachers combine their own teaching experience and deep understanding of their students to adjust the computer-generated teaching plans to ensure that they are accurate and user-friendly. This human-computer collaboration model, which integrates multiple environmental systems and combines computer intelligence with teachers' judgement, enables more scientific and flexible teaching decisions, as well as a higher degree of adaptability in the implementation of teaching and learning.

### 4.3 Remodeling of the teaching Paradigm Driven by Ecological Human-Computer Co-Creation

With the application of the ecological human-computer collaborative teaching model, the teaching pattern will gradually shift from the traditional transmission mode to the co-creative symbiosis and human-centred intelligent classroom. Human-computer co-creation is not only reflected in the innovation of teaching content and form, but also in the change of teacher-student relationship, learning mode and other dimensions. At the core level of the micro system, the joint action of teacher intelligence, computer intelligence and student intelligence contributes to the new smart classroom teaching paradigm. Teachers are not only responsible for transmitting knowledge, but also, through synergy with machines, for providing in-depth guidance on the learning process. Computers, through intelligent analysis and feedback, can promote students' independent learning and personalized development. In this process, students are not merely recipients of knowledge, but also active participants and creators of learning activities. Through this multi-party co-creation, the smart classroom can better meet the individual needs of adult learners and promote teaching innovation. At the same time, the comprehensive macro system of social and cultural norms and educational values emphasizes a teaching paradigm that prioritizes a human-centered approach when implementing AI. This paradigm aims to safeguard the core values of education, accelerate its digital development, and promote educational applications that are both good and useful. It also emphasizes a combination of learning and practical application, seeking innovation within a digital environment of real-world scenarios and real-world practice. Finally, it promotes interoperability of resources and fosters collaborative development through joint efforts and win-win cooperation[18]. Although robotics teachers excel in

the transfer of professional knowledge, they are significantly deficient in professional pedagogical knowledge and moral authority. Teachers remain the irreplaceable core in the ecological human-robot collaborative teaching model, possessing not only the mastery of knowledge, but also the emotional and moral care of educators. Therefore, in the process of reshaping the teaching paradigm, it is still necessary to emphasize the core position of teachers, adhere to the principle of human-centredness, and ensure that the application of technology does not weaken the value of education. Attention should also be paid to the normative application of technology in education and ethical issues, to safeguard the rights of teachers and students, and to ensure that the application of AI contributes to the realization of educational goals rather than replacing education itself. Ensure that the application of machine intelligence is ethical and protects learners' privacy and data security, while avoiding potential threats to educational equity posed by technology. Promote universality and equity in education by enhancing the digital literacy of teachers and students and ensuring that all participants have equitable access to and utilization of smart technologies.

### 4.4 Sustainable Development in Education Promoted by Ecological Human-Computer Co-Creation

In the ecological human-computer collaborative teaching model, the perspective of chronosystems provides strong support for the sustainability of education. Adult learners' needs, life status and career development are constantly changing, and the teaching model must have the ability to adjust dynamically and adapt over time in order to achieve sustainability and long-term effects of education. Chronosystems emphasize that teaching models should have the flexibility to adapt to the changing needs of learners over time. Computer intelligence plays an important role in this process by providing teachers with real-time feedback through continuous data analysis and learning behaviour monitoring. This feedback helps teachers to accurately understand learners' learning status and changing needs, so that they can make timely adjustments to their teaching strategies and resource allocation. For example, the machine can recognize the differences in learners' performance at different learning stages and recommend appropriate learning activities and resources to ensure that the teaching content and methods match the learners' current status and goals. In addition, chronosystems focus on learners' long-term development and lifelong learning needs. Adult learners often need to continuously upgrade their skills and knowledge throughout their professional and personal lives. Therefore, instructional models need to be adaptable over time to support the learning needs of learners at different life stages. Teachers should provide personalized learning advice and support, taking into account students' career development and personal goals. Computer intelligence, on the other hand, can help teachers track learners' progress over time, identify potential developmental opportunities, and provide appropriate learning resources and activities based on learners' long-term goals. This dynamic adaptability not only improves the long-term effectiveness of teaching and learning, but also promotes the sustainable development of education, enabling learners to remain competitive and resilient in an ever-changing social environment.

## 5 Summary

In today's era of digital transformation, adult education faces many challenges and opportunities. With the rapid development of information technology, the traditional teaching model can no longer fully meet the diverse needs of adult learners. Therefore, constructing an adult human-computer collaborative teaching model based on the ecological systems theory is not only a supplement to the current education model, but also a key way to promote the development of adult education. Bronfenbrenner's ecological systems theory provides a systematic analysis framework for adult education. The theory reveals the complex interaction of environmental factors in the process of learner development through the hierarchical division of micro system, mesosystem, exosystem, macro system, and chronosystem. Based on this theory, the adult human-computer collaborative teaching model is able to comprehensively consider and integrate the impact of different environmental systems, making teaching design, implementation and assessment more scientific and systematic.

This paper analyzes the construction and application of the ecological human-computer collaborative teaching model and shows that this model can not only effectively improve the quality and effect of adult education, but also provide adult learners with a more flexible, personalized and efficient learning experience. This model emphasizes the synergy between teachers, technological tools, learners and environmental factors, promotes interaction and feedback in the teaching process, and maximally meets the multiple needs of adult learners in knowledge acquisition, skill enhancement and career development. In the future, with the continuous progress of information technology and the increasing emphasis of society on lifelong learning, the adult human-computer collaborative teaching model based on ecological systems theory is expected to be promoted and applied in a wider range of educational fields. Through further research and practical exploration, this model will be continuously optimized and improved, and ultimately provide strong support for the sustainable development of adult education.

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