Social Science and Management
Print ISSN: 3007-6854
Online ISSN: 3007-6862
DOI: https://doi.org/10.61784/ssm3056

RESHAPING THE COMPETENCY STRUCTURE AND TRANSFORMING THE CULTIVATION MODEL OF SCIENTIFIC AND TECHNOLOGICAL TALENT IN THE ERA OF ARTIFICIAL INTELLIGENCE

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Abstract: Artificial intelligence (AI) is profoundly transforming industries and society, placing new demands on the competency structure of technology professionals. This paper explores the urgent need and pathways for reshaping the competencies of technology professionals and transforming their cultivation models in the AI era. The research indicates that the traditional mono-disciplinary competency structure is no longer suited to the complex innovation environment driven by AI, necessitating the construction of a composite competency system encompassing data thinking, algorithm application, interdisciplinary integration, innovation capability, and lifelong learning. Existing cultivation models exhibit limitations in interdisciplinary focus, innovation cultivation, knowledge update speed, and ethical awareness. To address this, this paper constructs a model comprising six core competency elements: professional technical skills, data processing, innovation, interdisciplinary integration, learning adaptation, and team collaboration. It proposes pathways for competency reshaping from four levels: government, higher education institutions, enterprises, and individuals. Key to transforming the cultivation model are: updating educational philosophies (emphasizing lifelong learning and innovation), innovating teaching methods (e.g., PBL, flipped classrooms), optimizing curriculum systems (integrating cutting-edge knowledge and strengthening interdisciplinary elements), and deepening industry-education integration. Analysis of domestic and international case studies validates the effectiveness of the proposed strategies. Successful transformation is strategically significant for enhancing individual competitiveness and driving national scientific and technological innovation and high-quality development.
Keywords: Artificial intelligence era; Technology professionals; Competency restructuring; Cultivation model transformation; Interdisciplinary integration; Innovation capability

1 INTRODUCTION

With the rapid advancement of technology, the advent of the artificial intelligence era has profoundly reshaped global industrial landscapes and societal lifestyles. As a pivotal force driving future development, AI technology is redefining the core elements of productivity, catalyzing the transformation and upgrading of traditional industries and the emergence of new sectors. Against this backdrop, technology professionals—key agents of scientific progress and innovation—face unprecedented demands to restructure their competencies. Traditional cultivation models for such talent have become inadequate for the new era, necessitating urgent transformation. The imperative to reshape the competency structure of technology professionals and transform their cultivation models lies in the new challenges posed by AI technology regarding knowledge frameworks, skill requirements, and innovation capabilities. Past cultivation models, predominantly focused on specialized knowledge, are insufficient to meet the demand for compound, innovative talent in the AI era. Consequently, reconstructing the competency structure of technology professionals and designing cultivation models aligned with contemporary needs have become focal points for both educational and industrial communities. This paper aims to explore pathways for reshaping the competency structure of technology professionals and strategies for transforming cultivation models in the AI era. By examining existing education and training systems, analyzing their deficiencies, and integrating characteristics of the AI era, it proposes corresponding reform recommendations. This research holds significant theoretical and practical value for enhancing the cultivation and development of China's technology professionals, advancing scientific and technological innovation, and adapting to new dynamics of international competition. Addressing this issue will not only improve the quality of talent cultivation but also provide enduring talent provision and intellectual support for China's long-term scientific and technological advancement.

2 CURRENT STATE OF AI DEVELOPMENT AND EVOLUTION OF COMPETENCY STRUCTURE & CULTIVATION MODELS FOR TECHNOLOGY PROFESSIONALS

2.1 Current State of Artificial Intelligence Development

Since the introduction of the Transformer architecture, it has been widely applied and continuously developed in fields such as natural language processing and computer vision. In recent years, researchers have made numerous improvements and extensions based on the Transformer. For instance, efficient variants suitable for long sequence processing have been proposed. Models like Longformer, by introducing a local attention mechanism, can significantly reduce computational load and enhance processing efficiency when handling ultra-long texts, enabling the processing of texts such as novels and academic papers, thereby expanding the application scenarios of natural language processing. To leverage the strengths of different model architectures, researchers have begun exploring the fusion of multiple architectures. Examples include combining Convolutional Neural Networks (CNN) with Transformers, exploiting CNN's advantage in feature extraction and the Transformer's capability in capturing long-range dependencies. Such hybrid architectures demonstrate superior performance in image and video processing tasks. Large language models represented by GPT-4 are continually setting new parameter records. With massive parameters, these large models can learn richer linguistic knowledge and patterns, exhibiting remarkable capabilities in language understanding, generation, and reasoning. For example, GPT-4 can perform complex text creation, dialogue interaction, and even excel in tests within specialized domains. Beyond the text domain, multimodal large models have become a research hotspot. Multimodal large models can simultaneously process various types of data such as images, text, and audio, enabling more comprehensive information understanding and processing. For instance, some multimodal models can generate descriptive text from images or create relevant images from text. This cross-modal interaction capability endows intelligent systems with more powerful functions and broader application prospects. Deep reinforcement learning has made significant progress in fields like robotics control, gaming, and autonomous driving. By integrating deep learning with reinforcement learning, agents can autonomously learn optimal strategies in complex environments[1]. In robotics, for example, deep reinforcement learning enables robots to navigate autonomously in unknown environments and perform grasping and manipulation tasks. In gaming, reinforcement learning algorithms allow agents to reach the level of top human players in complex game environments. Imitation learning, a branch of reinforcement learning, achieves intelligent decision-making by learning from human expert behavior. Recently, imitation learning has achieved notable results in complex tasks, such as imitating human driver behavior in autonomous driving scenarios, enabling efficient driving while ensuring safety.

Artificial intelligence technology plays a crucial role in medical imaging diagnosis. Deep learning algorithms can analyze medical images such as X-rays, CT scans, and MRIs, assisting doctors in detecting diseases like lung cancer and breast cancer. For example, some AI-based medical imaging diagnosis systems can accurately identify pathological features in images, improving early disease diagnosis rates. AI can predict drug activity and side effects by analyzing vast amounts of biological data and chemical structures, accelerating the drug development process. Through computer simulations and machine learning algorithms, it can rapidly screen potential drug molecules, reducing development cycles and costs. Banks and financial institutions utilize AI algorithms to assess clients' credit risk. By analyzing multi-dimensional data including credit history, financial status, and consumer behavior, they can more accurately predict clients' default probability, lowering credit risk. The application of AI in the investment field is also increasingly widespread. Quantitative investment strategies use machine learning algorithms to analyze market data, uncover investment opportunities, and optimize portfolios. Some robo-advisory platforms can provide personalized investment advice based on investors' risk preferences and financial goals. AI technology can provide personalized learning plans based on students' learning progress, learning style, and knowledge mastery. Intelligent tutoring systems can monitor students' learning processes in real-time, identify their weaknesses, and provide targeted tutoring and exercises. Virtual teaching assistants can answer student questions, provide learning resources, and assist teachers with instructional management. For example, some AI-based chatbots can address common student queries, reducing teachers' workload. AI is the core of autonomous driving technology. Through sensors, cameras, and algorithms, autonomous vehicles can perceive their surroundings, make real-time decisions, and achieve automatic navigation and obstacle avoidance. Currently, many automakers and tech companies are actively developing autonomous driving technology, with testing and pilot applications underway in some cities. Using AI technology to monitor and analyze traffic flow in real-time can optimize traffic signal control and alleviate urban congestion. For instance, some cities employ intelligent traffic systems that dynamically adjust traffic light timing based on flow, improving road efficiency. AI applications in entertainment content creation are becoming increasingly widespread. In music composition, AI can generate melodies and lyrics; in film and television production, it can be used for special effects and scene generation. For example, some AI-generated music works have gained attention online. AI technology can add smarter opponents and richer experiences to games. Non-player characters (NPCs) in games can utilize AI algorithms to exhibit more complex behaviors and decisions, enhancing the game's fun and challenge[2].

2.2 Evolution of the Competency Structure of Technology Professionals

2.2.1 Evolution process of technology professionals' competency structure

In the pre-Industrial Revolution era, technological activities were primarily concentrated in the fields of handicraft and simple mechanical invention. Technology professionals during this period were mostly artisans and craftsmen. Their competency structure emphasized specific manual skills and the use of simple tools. For instance, in the textile industry, artisans possessed proficient weaving techniques and could use simple textile tools to produce various fabrics; in metalworking, artisans mastered skills like forging and casting to create practical metalware. Their knowledge mainly stemmed from long-term practical experience passed down through generations, with relatively less systematic mastery of theoretical knowledge. The competency structure of technology professionals at this time was relatively singular, focused primarily on specific operational skills, with low demand for cross-domain comprehensive abilities. The rise of the Industrial Revolution brought changes to the competency structure of technology professionals[3]. With the emergence of machine production, they needed to master knowledge of mechanical principles, engineering drawing, etc., to design and manufacture machinery. For example, during the steam power era, technology professionals needed to understand thermodynamic principles and master the design and manufacturing techniques of steam engines. They required not only practical operational abilities but also a certain level of theoretical knowledge and innovative capability to improve and innovate upon traditional production methods. During this period, technology professionals began to develop along specialized paths, and the differences in competency structures across various fields became increasingly apparent[4].

2.2.2 Changes in the competency structure of technology professionals in the early stage of the Information Technology Revolution

In the mid-20th century, the Information Technology Revolution quietly emerged, and computer technology began to develop. At this stage, technology professionals needed to master skills like computer programming and algorithm design to develop software and write programs. Early computers were mainly used for scientific computing and data processing, requiring technology professionals to possess solid mathematical foundations and logical thinking skills to write efficient algorithms and programs. For instance, in the early mainframe era, technology professionals needed to be familiar with assembly language, capable of interacting directly with computer hardware, and have a deep understanding of the underlying principles of computer systems. With the initial development of the internet, the competency structure of technology professionals further expanded. In addition to programming skills, knowledge of network technology, database management, etc., became necessary[5]. They needed to be able to build and maintain network systems and manage and process large amounts of data. For example, when e-commerce was just emerging, technology professionals needed to develop and maintain e-commerce platforms. This required them not only to master front-end web design technologies but also to understand back-end database management and server configuration to ensure platform stability and data security.

2.2.3 Transformation of the competency structure of technology professionals during the rapid development period of information technology

Entering the 21st century, with the rapid development of technologies like big data and artificial intelligence, the competency structure of technology professionals underwent significant changes. They now need to possess interdisciplinary knowledge and capabilities, integrating knowledge from computer science, mathematics, statistics, biology, and other disciplines. For example, in the field of bioinformatics, technology professionals need to combine computer technology with biological knowledge, using algorithms and models to analyze and interpret biological data to advance research in genetics, drug development, etc. Faced with rapidly changing technological environments and complex real-world problems, technology professionals need strong innovative capabilities and problem-solving skills. They must be able to quickly adapt to new technological developments and propose novel solutions. For instance, when confronting data privacy and ethical issues in AI algorithms, they require innovative thinking to formulate corresponding technical and management strategies to address these problems. The big data era has generated massive volumes of data, necessitating that technology professionals possess a series of data processing capabilities including data collection, storage, cleaning, analysis, and visualization. They need to be able to use various data analysis tools and techniques to extract valuable information from large datasets to support decision-making[6]. For example, in the financial sector, technology professionals analyze market data to predict trends and provide basis for investment decisions. The advancement of information technology has made technology projects increasingly complex, often requiring collaboration among individuals with diverse professional backgrounds. Technology professionals need strong teamwork and communication skills to interact and collaborate effectively with personnel from different fields. For instance, a large AI project might involve roles such as algorithm engineers, data scientists, and product managers; technology professionals need to work closely with team members to ensure the project proceeds smoothly. The rapid development of information technology has accelerated the pace of knowledge and technology updates, requiring technology professionals to possess awareness and capability for lifelong learning. They must continuously learn new knowledge and skills to adapt to technological changes. For example, with the constant updates to programming languages and development frameworks, technology professionals need to promptly learn and master new technologies to maintain their competitiveness[7].

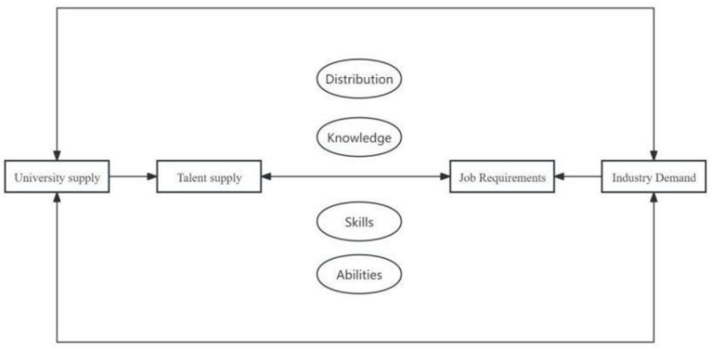

Figure 1 Theoretical Analysis Framework

The industrial demands of the new era are reflected in the job requirements of enterprises and institutions. As a key supplier of high-value-added labor, higher education institutions must cultivate a workforce aligned with these job demands. Such a labor market characterized by supply-demand matching serves as an essential foundation for industrial development. Based on this, the theoretical analytical framework of this study is formed (see Figure 1). This research takes AI talent as the study object, with the supply-demand balance between industrial needs and higher education supply as its logical starting point. It focuses on the matching degree between job requirements and talent supply, using factors such as labor distribution, knowledge, skills, and competencies as analytical elements for evaluating supply-demand matching in the AI labor market[8].

2.2.4 Future development trends of technology professionals' competency structure

With the continuous emergence and integration of emerging technologies such as quantum computing, biotechnology, and new energy, future technology professionals will require more comprehensive competencies. They must not only master foundational knowledge across multiple technical domains but also integrate and innovate with technologies from different fields. For example, in the interdisciplinary area of quantum information technology and biotechnology, technology professionals need to simultaneously understand quantum mechanics, computer science, and biology to develop innovative technologies and applications. The globalization of technology necessitates that technology professionals possess a global perspective, understanding technological developments and cultural contexts across different countries and regions. They must engage in effective communication and collaboration with international peers and participate in global technology projects and competitions. For instance, when addressing global environmental issues and public health crises, technology professionals need to collaborate with research teams worldwide to tackle complex challenges collectively.

2.3 Review of Existing Cultivation Models

2.3.1 Strengths of existing cultivation models for technology professionals

Current cultivation models emphasize building systematic and comprehensive professional knowledge systems during undergraduate and graduate studies. Taking computer science as an example, students systematically study foundational courses such as data structures, computer organization principles, and operating systems during their undergraduate years, while graduate studies delve deeper into cutting-edge fields like artificial intelligence and machine learning. This thorough knowledge transmission enables students to gain profound understanding and mastery of their disciplines, laying a solid theoretical foundation for future research and technical work. To cultivate practical operational and problem-solving abilities, many universities and research institutions have enhanced practical teaching components. For example, electronic information engineering programs include hands-on courses like electronic circuit experiments and microcontroller design, allowing students to consolidate theoretical knowledge and improve practical skills[9]. Additionally, internships and capstone projects provide opportunities to engage with real-world engineering problems, integrating theory with practice and better preparing students for future career demands. Amid globalization, existing cultivation models increasingly prioritize international exchange and collaboration. Through joint programs and academic exchanges with renowned foreign universities and enterprises, higher education institutions offer students broader global exposure. Students access cutting-edge international research and academic ideas and collaborate with top global research teams, fostering innovative thinking and international competitiveness.

2.3.2 Weaknesses of existing cultivation models

In today's rapidly evolving technological landscape, many complex scientific and engineering problems require interdisciplinary knowledge integration. However, existing cultivation models often overemphasize single-discipline knowledge transmission, with limited cross-disciplinary courses, leaving students deficient in interdisciplinary thinking and capabilities. For instance, in the intersection of AI and medicine, there is a severe shortage of professionals proficient in both AI technology and medical knowledge. Under traditional cultivation models, medical students lack AI-related knowledge, while computer science students have minimal medical understanding, failing to meet industry demands. Although practical teaching has been strengthened, innovation cultivation remains inadequate. Current teaching methods predominantly rely on instructor-led lectures, with students passively receiving knowledge and lacking opportunities for active exploration. In experiments and practical courses, students often follow predefined procedures with little room for autonomous innovation. Furthermore, evaluation systems overemphasize exam scores and publication counts, neglecting assessments of innovative thinking and practical skills, which stifles students' creative enthusiasm.

2.3.3 Limitations of existing models in the AI era

The rapid advancement of AI technology sees constant emergence of new algorithms, models, and applications. Knowledge taught in existing cultivation models often lags, with outdated textbooks and curricula failing to reflect the latest technological developments. For example, many current AI courses in universities still focus on traditional machine learning algorithms, with minimal coverage of recent advancements like Transformer architecture and Generative Adversarial Networks (GANs). This disconnect leaves students ill-prepared for the fast-evolving technical demands of the AI era. The widespread application of AI has triggered ethical and social issues—data privacy, algorithmic bias, employment restructuring—yet existing cultivation models prioritize technical knowledge over AI ethics and societal impact education. Students lack deep engagement with these issues, risking oversight of AI's potential risks and negative consequences in future work. In the AI era, human-AI collaboration will become critical. However, current models focus narrowly on professional skills, neglecting training in collaborative capabilities with AI systems. Students lack experience in interacting and co-working with AI, unaware of how to leverage its strengths while compensating for its limitations. For instance, in software development, students may not know how to use AI-assisted programming tools to enhance efficiency or collaborate effectively with AI customer service systems. This hinders future workplace efficacy and productivity[10].

3 RESHAPING THE COMPETENCY STRUCTURE OF TECHNOLOGY PROFESSIONALS IN THE AI ERA

3.1 Analysis of New Competency Requirements

The AI era has triggered unprecedented transformations in technology, demanding a restructured competency framework for professionals. Traditional specialized skills are insufficient for complex, dynamic technological and societal needs. Technology professionals now require new competencies to thrive in an AI-driven innovation landscape. Key emerging competencies are analyzed below.

3.1.1 Data thinking

In the AI era, data is the core resource driving decisions and innovation. Technology professionals need sharp data insight to extract valuable patterns from massive, complex datasets. This requires mastery of data analysis tools (e.g., statistics, machine learning algorithms) and critical thinking to interpret and evaluate data. For example, analyzing clinical data can reveal disease risk factors and treatment efficacy variations, enabling precision medicine. Professionals with data thinking use data—not just intuition—as the basis for decisions. They build data-driven decision models to evaluate options scientifically. In business management, analyzing market data and customer feedback helps optimize product strategies and marketing plans, enhancing competitiveness. With widespread data use, ethical and security concerns intensify. Professionals must uphold data ethics, comply with laws and moral standards, and ensure legal data usage. They also need data security awareness to protect privacy and prevent breaches. For instance, designing AI systems requires anonymization and access controls to safeguard user rights.

3.1.2 Algorithmic understanding and application

AI's core lies in algorithms. Professionals must deeply understand algorithmic principles and applicable scenarios, including machine learning (e.g., neural networks, decision trees) and deep learning algorithms (e.g., CNN, RNN). Mastering principles enables better algorithm selection and optimization. For example, understanding CNN principles improves image classification model design in computer vision. Beyond comprehension, professionals need algorithm design and optimization skills. They must create suitable algorithms for specific problems and refine performance through experimentation. In natural language processing, optimizing machine translation may involve designing new architectures with attention mechanisms. Applying algorithms to real-world scenarios to solve problems and innovate is crucial. For instance, using algorithms for real-time traffic monitoring and prediction enables smart signal control, boosting efficiency. Exploring new application scenarios drives industry transformation.

3.1.3 Interdisciplinary collaboration

AI-era problems are complex and multifaceted, requiring interdisciplinary knowledge integration. Professionals need cross-disciplinary knowledge systems to fuse complementary expertise. For example, smart healthcare demands integration of computer science, medicine, and biology to develop diagnostic systems and personalized treatments. Continuous learning across disciplines broadens perspectives. Interdisciplinary collaboration hinges on teamwork and communication. Professionals must collaborate effectively with diverse experts to achieve project goals. Clear articulation of ideas, understanding others' viewpoints, and leveraging team strengths are essential. Strong communication with team members, clients, and partners ensures project success. Globalization necessitates cross-cultural and cross-domain exchange capabilities. Professionals must engage with international peers, understand global tech trends, and respect cultural differences. Learning from other fields' best practices accelerates innovation.

3.1.4 Innovation and entrepreneurship

The AI era is innovation-driven. Professionals must embrace innovative thinking, break traditional paradigms, and propose novel solutions. Cultivating curiosity and staying abreast of technological frontiers enables exploration of new applications. For example, identifying real-world problems and developing AI-driven products/services meets emerging needs. Innovation requires translating ideas into tangible outcomes. Professionals must validate ideas through experimentation and refine results continuously. In entrepreneurship, launching innovative products to market achieves commercial value. Resilience in overcoming challenges and adapting strategies is vital. Aspiring entrepreneurs need entrepreneurial spirit and competencies. Courage to take risks in uncertain environments, leadership to build and manage teams, and skills in market analysis, business planning, and financial management are essential for venture success.

3.1.5 Lifelong learning

In the rapidly evolving AI era, knowledge and technology constantly renew. Professionals must embrace lifelong learning, recognizing it as an ongoing process to enhance capabilities. Maintaining enthusiasm for new knowledge and proactively acquiring skills ensures adaptability. Effective learning strategies boost efficiency. Diverse approaches—online courses, training programs, professional literature—should be utilized. Structured learning plans, systematic study, and reflective practice optimize outcomes. In the information age, leveraging and integrating resources is key. Professionals must filter and utilize resources from the internet, libraries, and academic databases. Engaging with peers and experts to share resources and experiences fosters collective growth.

In summary, the AI era demands a multifaceted competency structure for technology professionals. Mastery of data thinking, algorithmic expertise, interdisciplinary collaboration, innovation, entrepreneurship, and lifelong learning is essential to adapt to technological and societal shifts. Continuous competency enhancement ensures competitiveness and significant contributions to technological and societal progress[11].

Course content in university AI programs fails to meet industry demands for interdisciplinary and general knowledge. Industry surveys reveal that enterprises require three knowledge types: AI expertise, domain-specific knowledge (e.g., medicine, finance), and general knowledge. However, university curricula focus predominantly on AI expertise (applied, core, tool-based, and foundational courses), with only 22.20% covering interdisciplinary and general knowledge. This gap impedes alignment with industry needs. Constructing interdisciplinary curricula is challenging. Survey results indicate that AI professionals require knowledge spanning diverse fields—management, economics, philosophy, law, education, history, etc. (see Figure 2)—making curriculum design complex.

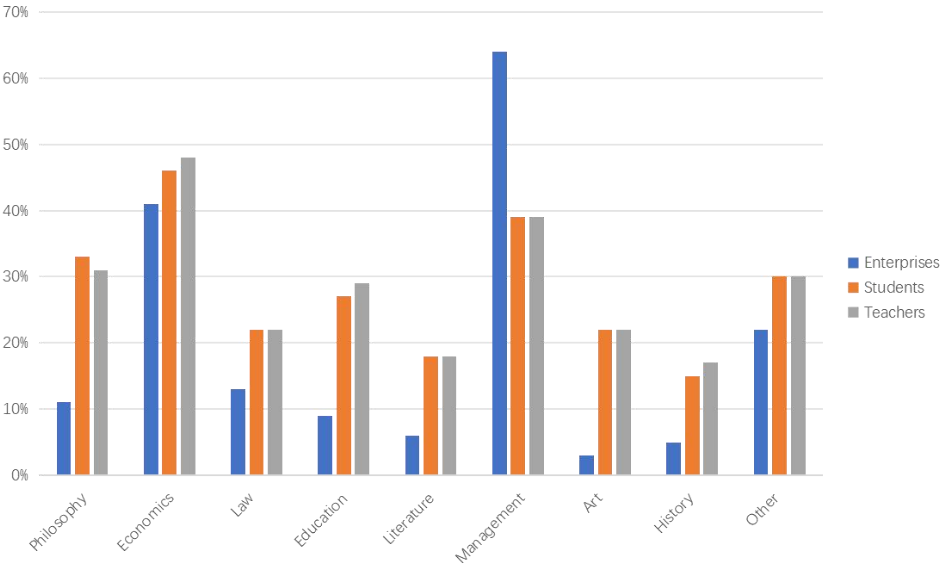

Figure 2 Relevant Subject Knowledge Required by AI Professionals from the Perspectives of Enterprises, Students, and Teachers

3.2 Competency Structure Model Construction

In the artificial intelligence era, technology professionals confront novel challenges and opportunities. Constructing a competency structure model adapted to this epoch is pivotal for cultivating and developing such talent. This section establishes a multidimensional competency structure model for technology professionals and delineates the interrelationships among its constituent elements.

3.2.1 Identification of model elements

Through comprehensive analysis of AI-driven technological trends, industry demands, and requisite competencies, six core elements form the model. Professional technical competency serves as the foundation for innovation and practice within specific domains. In the AI era, professionals must master cutting-edge theoretical knowledge and key technologies in their disciplines—such as algorithm design, programming languages (e.g., Python, Java), and machine/deep learning model construction in computer science; or chip design and circuit principles in electronic engineering. Solid technical expertise enables professionals to play pivotal roles in research and engineering projects. Data, as the core resource of the AI era, necessitates robust data processing and analytical capabilities. This encompasses data collection, cleaning, storage, visualization, and utilization of tools (e.g., SQL, R, Tableau) for mining insights. Extracting actionable intelligence from massive datasets constitutes a critical competitive advantage. The rapid evolution of AI propels continuous technological innovation, demanding innovative thinking and creativity. Innovative thinking—spanning divergent, reverse, and critical thought—breaks conventional constraints to propose novel solutions. Creativity manifests in transforming ideas into products, technologies, or services that advance industries. AI-era challenges often exhibit complexity and multidimensionality, requiring interdisciplinary integration capabilities. For instance, medical AI fuses computer science, medicine, and biology; smart mobility integrates transportation engineering, control science, and AI. This competency dismantles disciplinary barriers, merging resources and methodologies to solve real-world problems[12]. Rapid technological turnover mandates strong learning and adaptability. Professionals must swiftly acquire new knowledge/skills and adapt to evolving technical demands. Continuous learning—through training, academic exchanges, and self-directed study—sustains competitiveness. Collaborative projects increasingly demand teamwork across specialties. Effective collaboration and communication skills—including team ethos, leadership, and conflict resolution—enable professionals to synergize diverse strengths, enhancing project efficacy.

3.2.2 Interrelationships among competency elements

Elements exhibit interdependence: professional technical competency underpins data processing/analysis, as domain expertise ensures accurate data interpretation. Conversely, data analysis informs technical innovation by revealing patterns and improvement opportunities. Mutual reinforcement also exists: innovative thinking fuels learning motivation, enhancing adaptability; improved adaptability enriches knowledge reservoirs, further driving innovation. Similarly, interdisciplinary integration fosters collaboration skills in diverse teams, while strong collaboration facilitates cross-disciplinary knowledge synthesis[13]. The competency structure constitutes a dynamic system: elements evolve with technological progress and individual growth. As AI proliferates, professionals must continuously recalibrate their competencies—e.g., intensifying data analysis and innovation capabilities to meet emergent demands. This model elucidates competency interrelationships, offering theoretical and practical guidance for cultivating, developing, and evaluating technology professionals. Enhancing these competencies elevates holistic quality and competitiveness, propelling technological advancement in the AI era.

3.3 Pathways for Competency Restructuring

Reshaping the competency structure of technology professionals in the AI era demands a systemic, multi-stakeholder approach. Governments, universities, enterprises, and individuals must collaborate through policy guidance, educational reform, practical training, and self-improvement.

3.3.1 Government level: policy guidance and resource support

Governments should formulate policies aligned with AI-driven technological trends. Policies should encourage interdisciplinary learning and research—for instance, establishing dedicated funds for cross-domain projects to dismantle disciplinary silos. Concurrently, talent recruitment and retention policies must attract overseas experts while enhancing domestic professionals' development environments to curb brain drain. Increased fiscal investment in education—particularly AI-related disciplines—is essential. Supporting universities and vocational institutions in launching cutting-edge programs (e.g., AI, big data, machine learning) and upgrading infrastructure is critical. Dedicated training funds should incentivize enterprises and institutions to deliver continuing education for upskilling professionals. Governments must actively foster industry-academia-research integration by organizing international/domestic conferences, seminars, and innovation contests to facilitate knowledge exchange. Establishing talent-sharing mechanisms will promote mobility and collaboration across regions, enterprises, and research entities.

3.3.2 University level: educational reform and innovative cultivation

Universities must optimize curricula to build interdisciplinary structures aligned with AI-era demands. Beyond traditional courses, integrating AI, information technology, and data analytics across disciplines cultivates interdisciplinary thinking—e.g., embedding AI algorithms in STEM fields and data mining in humanities programs. Strengthening practical pedagogy enhances hands-on and innovative capacities. Partnerships with enterprises and research institutes to co-establish internships and innovation platforms provide real-world project exposure. Encouraging participation in academic competitions and entrepreneurial activities hones teamwork and problem-solving skills[14]. Faculty competence—particularly in AI application—requires enhancement through training, interdisciplinary research incentives, and recruiting industry-experienced adjunct professors. Leveraging prevailing AI technologies (e.g., intelligent platforms, AI teaching assistants, machine learning) to reform pedagogical methods can effectively address these gaps. Fundamentally, the future "AI + education" model should evolve toward personalization, intelligence, accessibility, and timeliness (Figure 3).

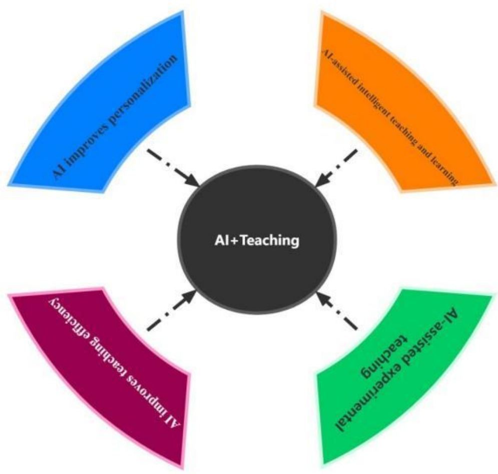

Figure 3 The Integration Direction of AI Technology and College Chemistry Teaching

3.3.3 Enterprise level: practical training and incentive mechanisms

Enterprises should actively provide technology professionals with practical training opportunities by involving them in actual projects and R&D initiatives. Establishing a project mentorship system where experienced technical experts guide new hires facilitates rapid growth. Concurrently, professionals should be encouraged to participate in technological and managerial innovation, contributing insights to corporate development. Robust incentive mechanisms must be instituted to stimulate innovation motivation. Innovation reward funds should offer material and recognition-based incentives for outstanding achievements in technological innovation, product development, and management improvement. Furthermore, clear career progression paths should enable professionals to realize their value within the organization. Enterprises must enhance internal training by conducting tailored programs aligned with professional needs and roles—e.g., AI workshops and data analytics seminars—to elevate technical and holistic competencies. Support for self-directed learning through resource provision is equally critical.

3.3.4 Individual level: self-improvement and lifelong learning

Technology professionals must embrace lifelong learning, recognizing that accelerated knowledge and technological obsolescence in the AI era necessitates continuous self-upgrading. Maintaining learning enthusiasm and proactively tracking industry trends is essential. Personalized learning plans should address career goals and competency gaps, prioritizing frontier technologies (e.g., AI, big data, cloud computing) and interdisciplinary knowledge acquisition through courses, online platforms, and literature. Cultivating innovative thinking requires breaking conventional paradigms and experimenting with novel approaches[15]. Engaging in cross-domain collaboration sparks creative inspiration, while critical thinking enables deep analysis of knowledge and techniques. Collectively, competency restructuring demands concerted efforts from governments, universities, enterprises, and individuals. Implementing these pathways will optimize talent capabilities, providing robust human capital for AI-driven technological advancement.

4 TRANSFORMATION STRATEGIES FOR CULTIVATION MODELS

4.1 Updating Educational Philosophies

To align education with contemporary demands and cultivate talent suited to societal needs, updating educational philosophies is imperative. AI-era education must prioritize lifelong learning and innovation as core pillars of a restructured system. Traditional models emphasizing knowledge transmission and memorization are obsolete amid rapid knowledge turnover. New philosophies should focus on cultivating comprehensive competencies for navigating complex challenges. Education must foster critical thinking and problem-solving abilities. While AI excels at data processing, human judgment remains irreplaceable for creative problem-solving. Guiding students to critically evaluate information, pose questions, and devise solutions—e.g., through case-based group discussions—enhances independent thinking and practical problem-solving. Cross-disciplinary integration is equally vital. AI's multidisciplinary nature (spanning computer science, mathematics, statistics, psychology) demands interdisciplinary vision. Universities should offer cross-disciplinary courses and projects to facilitate knowledge synthesis.

Lifelong learning is non-negotiable. Frequent career transitions necessitate continuous skill renewal. Education must instill lifelong learning awareness beyond formal schooling. Educators should cultivate growth mindsets by illustrating technological and occupational shifts. Providing diverse resources—open libraries, labs, lectures, and training—encourages self-directed exploration. Teaching learning strategies (e.g., time management, digital resource utilization, self-assessment) sustains post-graduation upskilling. Innovation constitutes the core competitiveness in the AI era. Educational environments must stimulate creativity through innovation courses, competitions, and design challenges. Recognizing individual strengths enables personalized development—e.g., nurturing artistic talent or scientific curiosity. Ultimately, an educational philosophy centered on lifelong learning and innovation empowers individuals to thrive and drive societal progress.

4.2 Innovative Teaching Methods

4.2.1 Application of Project-Based Learning (PBL) in cultivating technology professionals

Project-Based Learning (PBL), a student-centered approach, engages learners in authentic projects to acquire knowledge and skills. In technical education, PBL simulates real-world scenarios, enhancing comprehensive abilities through problem-solving. Instructors should select challenging, interdisciplinary project themes—e.g., developing mobile applications in computer science programs—encompassing requirements analysis, design, coding, and testing. Students form diverse teams to foster complementary collaboration. Instructors act as facilitators, providing guidance while encouraging autonomy. Post-project evaluation includes teacher/peer reviews and presentations to hone communication skills. PBL bridges theory and practice, elevating technical, collaborative, and innovative capacities. Implementation requires experienced instructors, institutional resources, and strategies to ensure universal engagement.

4.2.2 Application of flipped classrooms in cultivating technology professionals

The flipped classroom inverts traditional teaching: students self-learn theory before class via videos/materials, while class time focuses on discussion, practice, and Q&A. Instructors prepare concise video lectures highlighting key concepts and provide online support. In-class activities include peer discussions, project implementation, and individualized guidance. Post-class assignments (e.g., reports, summaries) consolidate learning, supplemented by recommended resources for deeper exploration. This model enhances flexibility and engagement, fostering collaboration and personalized instruction. Success depends on students' self-discipline and instructors' technological and pedagogical proficiency[16].

4.2.3 Integration and practice of innovative teaching methods

Blending methods like PBL and flipped classrooms maximizes educational outcomes. For instance, pre-class flipped learning delivers theoretical foundations for in-class PBL implementation, optimizing efficiency. A case in electronic information engineering demonstrates this synergy: students studied project theory online before class, then executed team projects in supervised sessions with peer discussions. This hybrid approach boosted engagement and output quality. Successful integration requires institutional investment in digital platforms and practical facilities, continuous teacher training in pedagogy and technology, and evaluative mechanisms for iterative refinement.In addition,AI enterprises demand not only specialized knowledge and technical skills but also exhibit strong requirements for versatile competencies. Consequently, higher education institutions should prioritize integrating general education courses into AI curricula to cultivate students' transferable skills.

5 CASE ANALYSIS

5.1 Successful Cases Domestically and Internationally

Germany's traditional manufacturing industry holds significant global advantages. However, with the advancement of the technological revolution, particularly the introduction of the Industry 4.0 concept, the demand for scientific and technological talents has shifted from purely skill-based to compound talents equipped with digital and intelligent technology application capabilities. The traditional vocational education model exhibits deficiencies in cultivating students' ability to address emerging technological challenges, prompting Germany to transform its dual-system vocational education model. Building upon the original integration of practice and theory, emerging technology courses such as digital technology, industrial Internet of Things, and big data analytics have been added. For example, in the mechanical manufacturing major, students are required not only to learn traditional machining techniques but also to master programming and operation of CNC machine tools, application and maintenance of industrial robots, and other knowledge. Enterprises deeply participate in school curriculum development and teaching processes. Based on their production needs and industry development trends, enterprises collaborate with schools to formulate syllabi and practical projects. Simultaneously, enterprises provide schools with advanced production equipment and internship bases, while schools supply enterprises with high-quality talents meeting their development needs. Training for vocational education teachers has been strengthened, requiring teachers to possess not only solid theoretical knowledge but also extensive practical enterprise experience. Teachers regularly engage in practical training at enterprises to understand the latest industry technologies and production processes, enabling them to integrate real-world cases into teaching. Through the transformation of the dual-system vocational education model, Germany has cultivated a large number of scientific and technological talents adapted to Industry 4.0 development, maintaining its leading position in high-end manufacturing. Graduates are in high demand in the job market, and enterprises have seen significant improvements in production efficiency and innovation capabilities. Emphasizing industry-education integration is key to cultivating scientific and technological talents. Close collaboration between enterprises and schools ensures that talent cultivation aligns closely with market demands. Meanwhile, the curriculum system should keep pace with technological development trends, updating teaching content promptly to cultivate students' innovation and adaptability. As a frontier city of technological innovation in China, Shenzhen has experienced rapid industrial development, with demand for scientific and technological talents characterized by diversification and high-end specialization. In its early stages, the Shenzhen Research Institute of Tsinghua University primarily focused on transforming scientific research achievements. However, recognizing shifting market demands, it has consciously transformed into a comprehensive innovation talent cultivation platform integrating scientific research, education, and industrial incubation. An innovation and entrepreneurship curriculum system has been established, covering technological innovation, business model innovation, management innovation, and other aspects. Through teaching methods such as case analysis, project practice, and entrepreneurship simulation, students' innovative thinking and entrepreneurial capabilities are cultivated. The institute integrates Tsinghua University's scientific research resources with Shenzhen's industrial resources to establish multiple industry-university-research collaboration bases. Researchers, teachers, and students can conduct scientific research projects within these bases, engaging in deep cooperation with enterprises to accelerate the transformation and application of research achievements. Active international exchanges and collaborations have been carried out, establishing partnerships with renowned foreign universities and research institutions. International experts are invited to deliver lectures and guide student projects, while students are selected for exchange programs and internships abroad, broadening their international perspectives. Through the transformation of its talent cultivation model, the Shenzhen Research Institute of Tsinghua University has cultivated a large number of scientific and technological talents with innovative spirit and practical abilities, incubated numerous high-tech enterprises, and promoted industrial upgrading and innovative development in the Shenzhen region. Domestic scientific and technological talent cultivation should emphasize innovation education to foster students' innovation and entrepreneurship capabilities. Simultaneously, the resource advantages of universities and local regions should be fully utilized to build deeply integrated industry-university-research platforms that facilitate the transformation and application of scientific and technological achievements. Furthermore, creating an internationalized talent cultivation environment helps enhance students' global competitiveness.

5.2 Experience and Insights

The educational institution in this case has achieved remarkable results in operations and educational teaching. Its successful experience offers multifaceted reference value for other educational institutions. This institution has established a scientific and comprehensive curriculum system. Based on the cognitive characteristics and learning abilities of students of different age groups, courses are subdivided into multiple levels, each with clear teaching objectives and content. For example, for younger students, courses emphasize fun and foundational knowledge transmission, employing gamified and interactive teaching methods; for older students, theoretical depth and practical application content are increased. Simultaneously, the institution continuously updates course content to keep pace with educational frontiers and industry development trends. Regarding teacher training, it regularly organizes professional training and academic exchange activities for teachers, encouraging them to engage in teaching research and innovation. Other educational institutions should prioritize curriculum system development, implementing stratified teaching according to students' actual situations to meet the learning needs of different stages. Concurrently, they should monitor educational developments, promptly updating course content to ensure teaching timeliness and practicality. Additionally, strengthening teachers' professional development by providing training and exchange opportunities helps enhance teaching quality. This institution adopts a flat management model, reducing hierarchical layers to improve decision-making and execution efficiency. In resource allocation, human, material, and financial resources are reasonably distributed based on the actual needs of departments and projects, avoiding resource waste. Simultaneously, a comprehensive supervision and evaluation mechanism has been established, conducting regular assessments of teaching quality and employee performance to ensure the smooth implementation of all tasks. Educational institutions can optimize management structures, streamline processes, and improve operational efficiency[17]. Rational resource allocation and effective supervision and evaluation mechanisms ensure orderly execution of institutional tasks, enhancing overall operational standards. Other educational institutions may learn from this management model, adjusting and optimizing it according to their actual conditions.

Regarding enrollment, this educational institution employs diversified recruitment strategies, such as combining online and offline promotion methods, utilizing social media and offline events to attract potential students and parents. It also emphasizes communication and interaction with parents, regularly organizing parent meetings and open days to keep parents informed about students' progress and institutional developments. In student care, it provides personalized services such as psychological counseling and academic tutoring to enhance students' motivation and sense of belonging. Other educational institutions can adopt diversified enrollment strategies to broaden recruitment channels. Strengthening communication and interaction with parents establishes positive home-school cooperation relationships. Addressing students' personalized needs and providing attentive care services helps improve satisfaction and loyalty among students and parents. This educational institution focuses on shaping its brand image, building a strong brand reputation through unique educational philosophies and culture. In market promotion, it utilizes multiple channels for publicity, such as participating in education exhibitions and publishing high-quality educational content, thereby increasing its visibility and influence. Educational institutions should prioritize brand building, clarify their educational philosophies and characteristics, and conduct brand promotion through various channels to enhance brand recognition and reputation. A favorable brand image attracts more students and parents, laying a foundation for long-term institutional development.

6 CONCLUSION

This study systematically explores the objective inevitability and urgency of reshaping the competency structure of scientific and technological talents and transforming cultivation models in the era of artificial intelligence. The research finds that the AI era demands scientific and technological talents break through traditional disciplinary boundaries to construct a new competency structure centered on interdisciplinary knowledge integration, high-order innovation capabilities, continuous learning abilities, and critical and systemic thinking. Correspondingly, the cultivation model for scientific and technological talents urgently requires transformation toward content frontierization (integrating AI, data science, etc.), teaching practicization (project-based and inquiry-based learning), and diversified evaluation. Looking ahead, this study anticipates four major trends in scientific and technological talent cultivation: deep interdisciplinary integration, equal emphasis on practice and innovation, expansion of international perspectives, and personalized pathway customization. Key challenges requiring resolution include constructing interdisciplinary models, deepening AI-empowered education, optimizing internationalization strategies, and scientifically evaluating innovation capabilities. To address these, collaborative advancement is recommended through policy guidance and support, deepened school-enterprise collaboration, strengthened faculty development, and fostering an innovation culture. This study contends that successfully reshaping the competency structure of scientific and technological talents and realizing the transformation of cultivation models hold crucial strategic significance for enhancing individuals' competitiveness in the AI wave, driving national scientific and technological innovation and high-quality development, and ultimately achieving scientific and technological self-reliance while contributing to human progress.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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