Article

Construction and Practice of a Triple Helix Model for Cultivating Technological Ethics Literacy in Emerging Engineering Talents in Higher Vocational Education

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Abstract: With the rapid development of disruptive technologies such as artificial intelligence, technological ethics literacy has become a core competency for emerging engineering talents. However, higher vocational engineering education currently faces structural contradictions such as emphasizing technology over ethics and valuing knowledge over innovation. The three elements of values education, professional education, and innovation and entrepreneurship education are often separated, leading to difficulties in cultivating students' technological ethics literacy. Based on the Triple Helix theory, this study constructs a deeply integrated model for cultivating technological ethics literacy through values guidance, knowledge transmission, and capability building. The model reveals the spiral and synergistic evolution mechanism among these three elements, with values anchoring, knowledge embedding, and capability transformation as its core logic. Through three pathways of curriculum system reconstruction, teaching scenario reengineering, and evaluation mechanism innovation, the model achieves deep coupling of values education, professional education, and innovation and entrepreneurship education. This research provides a theoretical framework and practical paradigm for cultivating technological ethics literacy in emerging engineering talents within higher vocational institutions.

Keywords: triple helix model; emerging engineering talents; technological ethics literacy; higher vocational education; values-education-entrepreneurship integration

1. Introduction

The current wave of technological revolution and industrial transformation is advancing rapidly, with emerging technologies such as artificial intelligence, big data, and biotechnology reshaping social operational logic while simultaneously bringing increasingly complex ethical risks. Issues such as algorithmic discrimination, data privacy breaches, and compliance boundaries of generative AI frequently emerge, posing severe challenges to the ethical literacy of technology practitioners. In October 2025, the Standing Committee of the National People's Congress passed the Decision on Amending the Cybersecurity Law of the People's Republic of China, explicitly requiring the improvement of artificial intelligence ethical norms and strengthening of risk monitoring, assessment, and safety supervision [1]. This legislative amendment marks a new stage in China's technology ethics governance, moving from macro-level policy advocacy to specific legal regulation.

In this context, cultivating responsible innovation talents who possess both technological innovation capability and ethical awareness has become a core issue in global engineering education reform. The international academic community has increasingly focused on incorporating ethical dimensions into the Triple Helix model. James et al. introduced ethical theory to the Triple Helix model, revealing the crucial role

of supererogatory acts in micro-level individual relationships during innovation processes [2]. For higher vocational institutions oriented toward industry, cultivating high-quality technical talents who understand both technology and ethics is a key element in serving the digital transformation of manufacturing and supporting high-quality regional industrial development. Notably, the philosophical wisdom embedded in China's excellent traditional culture provides unique intellectual resources for modern technology ethics education. The Huxiang practical learning tradition, particularly Wang Fuzhi's epistemology of mutual support of knowledge and action, emphasizes the interdependence and mutual promotion of knowledge and practice. This idea resonates profoundly with the contemporary pursuit of unifying value cognition and ethical practice in technology ethics education, offering a philosophical foundation for constructing a technology ethics education model with Chinese cultural subjectivity.

However, current higher vocational engineering education faces multiple dilemmas in cultivating technological ethics literacy. Research indicates that engineering talent cultivation suffers from structural contradictions characterized by emphasizing technology over ethics and valuing knowledge over innovation [3]. Against the backdrop of digital transformation, the excessive expansion of technological rationality has led to an ontological crisis in values education, with the disciplinary logic gap between engineering education and values education creating a physical splicing phenomenon. Curriculum design follows technology-based quantitative logic, with credit weights for hardcore technology courses such as artificial intelligence and digital twins far exceeding those for humanities courses such as engineering ethics and philosophy of technology. Evaluation systems emphasize technical capability achievement indicators, while value dimensions such as engineering ethics and social responsibility are often blurred or marginalized.

More notably, values education, professional education, and innovation and entrepreneurship education are often disconnected, failing to form a synergistic educational force. The fundamental reason lies in the fundamental differences in disciplinary logic: engineering education is an applied discipline dominated by instrumental rationality and driven by data-models, while values education is a theoretical discipline centered on value rationality, and innovation and entrepreneurship education emphasizes commercial value and market logic. This divergence in pathways leads to curriculum designs where value elements are superficially embedded in professional courses, lacking organic integration.

This study introduces the Triple Helix theory into the cultivation of technological ethics literacy, integrating the philosophical wisdom of the unity of knowledge and action from China's excellent traditional culture, to construct a model of values guidance, knowledge transmission, and capability building. It systematically explains the coupling mechanisms and collaborative evolution paths among the three elements, aiming to provide a theoretical framework and practical guidance for cultivating technological ethics literacy in emerging engineering talents within higher vocational institutions.

2. Theoretical framework and research hypotheses

2.1. The Triple Helix theory and its ethical dimension expansion

The Triple Helix theory, proposed by Etzkowitz and Leydesdorff in the 1990s, initially described the interactive relationships among universities, industry, and government in the knowledge economy era, emphasizing that the three parties maintain their independent identities and functions while forming spiraling innovative forces through interaction [4]. This independent yet collaborative thinking paradigm provides a powerful tool for understanding the synergistic relationships among multiple elements in complex educational systems.

In terms of ethical dimension expansion, the research by James et al. has groundbreaking significance. Through case studies of three medical device innovation

projects during the COVID-19 pandemic, they found that the Triple Helix exhibited lasting interoperability under crisis conditions, with micro-level relationships among individual actors facilitating the conception of new devices, identification of resources, and minimization of bureaucratic obstacles. More importantly, these micro-relational behaviors manifested as supererogatory acts, moral actions exceeding duty requirements, between individuals [5]. This discovery reveals the core role of the ethical dimension in the micro-operation of the Triple Helix. The IEEE Transactions on Technology and Society recently dedicated a special issue to ethics in the global innovation helix, covering topics such as AI ethics education and responsible innovation [6].

It is worth noting that China's excellent traditional culture contains rich philosophical wisdom regarding the unity of knowledge and action. Wang Fuzhi, in his commentary on the Book of Rites, proposed the idea that knowledge and action mutually support each other [7]. This idea emphasizes the dialectical relationship of interdependence and mutual promotion between knowing and doing. This philosophical insight resonates across time and space with the core concept of synergistic evolution among elements in the Triple Helix theory, providing a unique philosophical foundation for constructing a model of technological ethics cultivation in the Chinese context. Furthermore, international scholarship has long recognized the practical orientation of Chinese thought; de Bary's seminal work on the liberal tradition in China highlights the enduring emphasis on practical learning and its emphasis on applying knowledge to real-world affairs [8].

2.2. Dimensions of technological ethics literacy

Technological ethics literacy refers to an individual's comprehensive ability to identify ethical issues, make ethical judgments, and make responsible decisions in technological activities. For emerging engineering talents, this literacy comprises three core dimensions.

Ethical cognition: understanding basic concepts, principles, and norms of technology ethics, as well as sensitivity to and foresight regarding potential ethical risks of technology. With the implementation of the amended Cybersecurity Law, algorithm fairness and data compliance have become basic norms that practitioners must master [9].

Ethical judgment: the ability to analyze, weigh, and make decisions using ethical principles in complex technological contexts, balancing technical feasibility with social value.

Ethical practice: the ability to translate ethical considerations into responsible technological behavior, consciously embedding ethical reflection throughout the entire process of technological innovation [6]. This dimension is highly consistent with the central role of practice emphasized in the unity of knowledge and action philosophical tradition [9].

2.3. The logic of values-education-entrepreneurship integration

Values education, professional education, and innovation and entrepreneurship education, while having different emphases, possess inherent complementarity and synergy in cultivating technological ethics literacy.

Values education provides the value foundation by focusing on people's thoughts, values, moral norms, and social relationships. It answers the fundamental questions of why innovate and for whom to innovate.

Professional education provides the knowledge carrier by enabling students to master scientific and technological knowledge and methods, helping them identify ethical issues and assess ethical risks in specific technological contexts.

Innovation and entrepreneurship education provides the practice field by cultivating the ability to solve complex problems in real or simulated innovation practices, transforming ethical cognition into responsible innovation behavior.

Based on this logic, and drawing on the philosophical wisdom of mutual support of knowledge and action from Chinese tradition, we propose the following hypotheses.

H1:Values guidance positively affects the cultivation of technological ethics literacy in emerging engineering talents.

H2: Knowledge transmission positively affects the cultivation of technological ethics literacy.

H3: Capability building through innovation and entrepreneurship practice positively affects the cultivation of technological ethics literacy.

H4:The synergistic interaction among values guidance, knowledge transmission, and capability building forms a triple helix that enhances technological ethics literacy beyond the sum of individual contributions.

3. Model construction

3.1. Basic architecture of the Triple Helix model

Based on the Triple Helix theory and drawing on the philosophical wisdom of the unity of knowledge and action from China's excellent traditional culture, this study constructs a model of values guidance, knowledge transmission, and capability building for cultivating technological ethics literacy, explaining the coupling mechanisms and evolutionary paths.

The values guidance helix takes fostering virtue through education as its fundamental task, placing value concepts such as technology for good, patriotism, and human welfare as the soul of technological ethics literacy cultivation. This helix, through the bidirectional penetration of values courses and values-integrated professional courses, implants value anchor points in professional teaching and innovation-entrepreneurship practice, guiding students to form an ethical consciousness of guiding technology with ethics. This helix aligns with the traditional practical learning pursuit of applying knowledge to meet the needs of society [10].

The knowledge transmission helix uses professional knowledge and engineering ethics knowledge as carriers, embedding technological ethics principles within the technical knowledge system. This helix, through reconstructing professional curriculum content, establishes a three-dimensional mapping of professional knowledge points, value elements, and innovation-entrepreneurship capabilities, enabling students to understand the ethical implications behind technology while mastering technical knowledge.

The capability building helix uses innovation-entrepreneurship projects as platforms, cultivating ethical decision-making abilities in authentic innovation practice. This helix, through embedding ethical risk assessment into the project incubation process, guides students to engage in ethical reflection throughout the entire process of concept conception, technology development, and product iteration, forming a practical paradigm of comprehending ethics in creation and leading innovation through ethics. This helix represents a modern interpretation and practical transformation of the philosophical idea of the unity of knowledge and action [9].

The three helices maintain their independent functional positions while forming a synergistic mechanism of values anchoring, knowledge embedding, and capability transformation through interaction. The values guidance helix provides direction for knowledge and capability, preventing technological innovation from deviating from the track of human welfare. The knowledge transmission helix provides the cognitive foundation for values and capability, enabling ethical reflection to be based on professional understanding. The capability building helix tests and deepens value cognition and knowledge mastery in practice, forming a closed loop of literacy generation through unity of knowledge and action.

3.2. Coupling mechanisms of the Triple Helix

Drawing on international research on micro-relationships in the Triple Helix and incorporating the philosophical wisdom of mutual support of knowledge and action from Chinese tradition, this study summarizes the coupling mechanisms of the Triple Helix into four levels.

Coupling mechanism 1: goal coupling from fragmentation to value consensus. The three elements achieve organic unity at the level of talent cultivation goals. Values education goals evolve to specifically cultivating responsible innovation emerging engineering talents. Professional education goals elevate to possessing the ability to apply technology with ethical consciousness. Innovation and entrepreneurship education goals deepen to developing practical abilities for responsible innovation. Together, they point to the talent cultivation positioning of combining virtue and skill, ethics for good. This positioning aligns closely with the value orientation of applying knowledge to meet the needs of society in the Huxiang practical learning tradition [9,10].

Coupling mechanism 2: content coupling from physical splicing to chemical integration. At the curriculum content level, three-dimensional mapping of professional knowledge points, value elements, and innovation-entrepreneurship capabilities is achieved. Drawing on evaluation frameworks, a content framework integrating technical effectiveness, value orientation, and social benefit is constructed, enabling students to simultaneously complete the construction of ethical cognition and the cultivation of innovation capabilities while learning professional knowledge.

Coupling mechanism 3: process coupling from linear progression to spiral ascent. In the teaching process, the linear model of theoretical learning first, practical innovation later is broken, constructing a spiral cycle of learning by creating, creating while learning. Students encounter ethical issues in professional learning, deepen ethical cognition in project practice, and bring ethical dilemmas from practice back to the classroom for theoretical reflection, forming a reinforcement loop of theoretical grounding, cognitive conflict, and practice verification. This mechanism echoes the internal logic of mutual promotion and cyclical progression emphasized in Wang Fuzhi's idea of mutual support of knowledge and action [9].

Coupling mechanism 4: evaluation coupling from single dimension to systematic architecture. Technical indicators and ethical dimensions are integrated within the evaluation system. Drawing on international multidimensional evaluation frameworks for ethics education, a diverse evaluation framework covering technical feasibility, value orientation, and social benefit is constructed. Process evaluation records students' ethical decision-making behaviors in project practice, and qualitative assessment analyzes their ability to resolve value conflicts in technology application scenarios, forming a comprehensive portrait of students' technological ethics literacy.

3.3. Dynamic mechanisms and evolutionary paths of the model

The dynamic forces of the Triple Helix model originate from the synergistic effects of policy traction, technical support, and value internal drive. Policy traction comes from policy guidance such as national emerging engineering construction, curriculum values integration reform, and technology ethics governance, particularly the newly amended Cybersecurity Law incorporating improving artificial intelligence ethical norms into legal provisions [1]. Technical support comes from the empowerment of digital technology in educational scenarios, with virtual simulation, big data analysis, and artificial intelligence providing tools for deep integration of the Triple Helix. Value internal drive originates from the era's call for engineer core competencies and the spiritual heritage of applying knowledge to meet the needs of society from China's excellent traditional culture [10], driving educational subjects to consciously shift from knowledge transmission to value shaping.

The evolution of the Triple Helix follows the path of coupling, collaboration, and emergence. The initial stage achieves preliminary coupling of the three elements, forming

a framework consensus of values, knowledge, and capability. The middle stage enters collaborative operation, achieving deep interaction in curriculum, projects, and evaluation. The mature stage manifests the overall effect, forming a new ecological environment for technological ethics cultivation that transcends the simple sum of the three elements, enabling students to autonomously make ethical decisions and engage in responsible innovation in complex technological contexts.

4. Practical paths based on the Triple Helix model

4.1. Curriculum system reconstruction: establishing three-dimensional mapping integrated courses

The curriculum is the main carrier for values-education-entrepreneurship integration. It is necessary to construct an integrated curriculum system characterized by horizontal coverage and vertical articulation. Horizontal coverage refers to the synergistic exertion of three types of courses: public basic courses teach general ethical principles, such as basic norms of technology ethics; professional courses teach position-specific ethical requirements, such as engineering ethics criteria; innovation and entrepreneurship courses teach innovation ethics practice, such as process design for responsible innovation. Vertical articulation refers to progression from freshman to junior years: lower grades establish ethical cognitive foundations through general education courses; middle grades embed ethical issues in professional courses; upper grades engage in ethical practice through innovation-entrepreneurship projects.

The key lies in establishing three-dimensional mapping of professional knowledge points, value elements, and innovation-entrepreneurship capabilities. Taking electrical majors as an example, when teaching smart grid technology, the ethical issue of energy equity is embedded simultaneously, and students are guided to design low-cost smart grid solutions for remote areas. Through this approach, students naturally acquire ethical cognition and innovation capabilities while mastering professional knowledge.

In AI-related courses, drawing on the dual-track four-dimensional framework, a parallel nested teaching model of technical capability cultivation track and values shaping track can be constructed. The technical capability cultivation track follows technological development laws, setting up the technical chain of data collection, feature engineering, model training, and application deployment. The values shaping track simultaneously sets up the ethical review chain of privacy risk assessment, data ethics review, algorithm fairness testing, and social impact prediction, enabling students to complete ethical assessment while accomplishing technical tasks [6]. The design of this teaching model embodies the concrete application of the mutual support of knowledge and action philosophy in modern curriculum development [9].

4.2. Teaching scenario reengineering: creating blended virtual-real ethical practice fields

Reengineering teaching scenarios is key to achieving deep values-education-entrepreneurship integration. It is necessary to break through the spatiotemporal limitations of traditional classrooms and construct blended virtual-real ethical practice fields.

Virtual simulation experiments utilize technologies such as digital twins and VR to create immersive ethical education scenarios. For example, developing a self-driving car ethical dilemma virtual simulation experiment allows students to face trolley problem-style ethical choices in simulated environments, experiencing value conflicts in technological decision-making. This echoes the international academic advocacy for cultivating ethical decision-making abilities through role-playing teaching methods, and also resonates across time with the epistemology of investigating things to extend knowledge in the traditional practical learning tradition [10].

Project-based learning embeds ethical considerations throughout the entire process of innovation-entrepreneurship projects. Drawing on James et al.'s research on micro-

relationships in the Triple Helix [2], students are required to complete ethical risk assessment reports at the project initiation stage, identifying potential ethical risks. Ethical reflection sessions are set up during project implementation, regularly discussing ethical issues arising during project progress. Ethical compliance is incorporated into evaluation indicators at the project conclusion stage. This responds to the legal requirements of the amended Cybersecurity Law regarding improving artificial intelligence ethical norms and strengthening risk monitoring and assessment [1].

University-industry collaborative ethical makerspaces are established in partnership with enterprises based on platforms such as makerspaces. Enterprises provide real technological ethics cases such as algorithmic bias and data privacy disputes, and students, while solving real problems, exercise both technological innovation capabilities and enhance ethical decision-making abilities. Through university-industry collaboration, students experience and understand the ethical dimensions of Triple Helix operations in real contexts. The design of this practical platform can draw inspiration from the valuable explorations of local vocational colleges in Hunan in inheriting the Huxiang practical learning tradition [9].

4.3. Evaluation mechanism innovation: constructing a multi-dimensional literacy evaluation system

Evaluation serves as the baton, requiring the construction of a literacy evaluation system compatible with the Triple Helix model.

Process evaluation records students' ethics-related behaviors in professional learning and project practice through smart teaching platforms. For example, recording students' participation levels in ethical issues during group discussions, the depth of ethical reflection in project reports, and the degree of consideration of ethical factors in technical solutions.

Capability evaluation develops technological ethics decision-making simulation tests, setting up multiple technological ethics dilemma scenarios to examine students' ethical identification, analysis, and decision-making abilities. Drawing on international cutting-edge research on ethics education evaluation frameworks, student project proposals are evaluated from three dimensions: technical feasibility, value orientation, and social benefit.

Developmental evaluation establishes student technological ethics literacy growth files, linking the literacy enhancement process with career development. In collaboration with enterprises, students' ethics literacy evaluation results are used as reference bases for internship and employment recommendations, forming a closed loop of cultivation, evaluation, and incentive. The design of this evaluation system reflects a comprehensive consideration of the practical effectiveness of the unity of knowledge and action [9].

5. Conclusion and prospects

This study, based on the Triple Helix theory and drawing on the philosophical wisdom of the unity of knowledge and action from China's excellent traditional culture, constructs a deeply integrated model for cultivating technological ethics literacy through values guidance, knowledge transmission, and capability building. The model takes values anchoring, knowledge embedding, and capability transformation as its core logic, revealing the coupling mechanisms of the three helices at four levels of goals, content, process, and evaluation, as well as the synergistic evolutionary paths driven by the triple forces of policy, technology, and value. The research provides a systematic theoretical framework and practical paradigm for solving the real dilemmas of fragmentation among values education, professional education, and innovation and entrepreneurship education in higher vocational engineering education and the weakness in cultivating technological ethics literacy.

The main contributions of this research are as follows.

First, at the theoretical level, it expands the application of Triple Helix theory in internal reform of engineering education, responding to the international academic frontier of introducing ethical dimensions into the Triple Helix model. Simultaneously, it integrates the philosophical wisdom of mutual support of knowledge and action from China's excellent traditional culture into the model construction, providing a theoretical foundation with Chinese cultural subjectivity for cultivating technological ethics literacy [9,10].

Second, at the practical level, it designs the Triple Helix structure of values guidance, knowledge transmission, and capability building and the four-stage progressive model of courses, projects, competitions, and incubation, particularly the creation of ethical makerspaces, providing a practical template for higher vocational institutions to carry out technology ethics education.

Third, at the policy level, it responds to policy requirements such as the amendment to the Cybersecurity Law and the Outline of the Plan for Building a Strong Education Country, addressing the institutional concerns of the amended Cybersecurity Law regarding improving artificial intelligence ethical norms, providing talent support solutions for local institutions to serve high-quality regional industrial development.

Looking forward, deepening research on the Triple Helix model can proceed in the following directions. First, conducting empirical research to test the model's effectiveness in specific majors and institutions, exploring differentiated implementation paths for different types of institutions and professional fields. Second, developing supporting teaching resources and tools, such as technology ethics teaching case libraries, ethical risk assessment toolkits, and literacy assessment scales, providing practical support for model implementation. Third, further exploring the contemporary educational value of intellectual resources such as applying knowledge to meet the needs of society and seeking truth from facts from China's excellent traditional culture [9,10], deeply integrating local cultural traditions with technology ethics education, for example, combining the philosophical wisdom of mutual support of knowledge and action from the Huxiang practical learning tradition to explore models of technological ethics cultivation with regional characteristics. Fourth, tracking new challenges brought by disruptive technologies such as artificial intelligence to technology ethics education, dynamically optimizing the content structure and operational mechanisms of the Triple Helix, cultivating more emerging engineering technical talents with technological capabilities, innovation spirit, and ethical bottom lines under the AI governance framework of developing and ensuring safety in parallel.

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