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From STEM to STEAM: Value Reconstruction and Practical Pathways for Integrating Humanities and Arts into Engineering Education

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Abstract: *Against the backdrop of the global technological revolution and the continued advancement of China's "New Engineering Education" initiatives, traditional STEM-based engineering education has increasingly exposed problems such as an overemphasis on technical rationality, insufficient attention to humanistic concerns, and a disconnect between technological and societal needs. Promoting the transformation of engineering education from "instrumental rationality" to "value rationality", thereby achieving the deep integration of science, technology, engineering, the humanities, and the arts, has become a central direction of engineering education reform in the new era. With the reconstruction of the value of the humanities and arts in engineering education as its central focus, this paper traces the evolution of STEM and STEAM education, examines their conceptual differences and theoretical foundations, and draws on case studies from China and abroad to analyze in depth the practical challenges involved in integrating the humanities and arts into engineering education in China, including misconceptions, the lack of appropriate evaluation systems, and insufficient institutional support mechanisms. Furthermore, the paper proposes innovative solutions, including the reshaping of educational concepts, curriculum restructuring, and evaluation reform, with a view to providing a theoretical reference for the development of "New Engineering Education" and the localized implementation of STEAM education in Chinese higher education institutions.*

Keywords: *STEM Education; STEAM Education; Humanities and Arts; Engineering Education; New Engineering Discipline; Engineering Ethics*

1. Introduction

Engineering education, as the core component of the national scientific and technological innovation system and the talent supply for high-end manufacturing industries, has its training models, value orientations, and quality standards directly impacting the nation's core competitiveness and the future development of the industry. Entering the third decade of the 21st century, technologies such as artificial intelligence, big data, the Internet of Things, biomedicine, new energy, and new materials are undergoing accelerated iteration; meanwhile, smart manufacturing, the digital economy, and the "Made in China 2025" strategy continue to deepen. The global engineering field has shifted from merely meeting the demand for technical professionals to cultivating versatile and comprehensive talents equipped with capabilities to solve complex problems, engage in interdisciplinary collaboration, drive innovation and creativity, and uphold social responsibility [1][2].

Traditional engineering education has long adopted the STEM model as its core framework—namely, an integrated approach encompassing the four disciplines of Science, Technology, Engineering, and Mathematics. This model has effectively enhanced students 'logical reasoning, engineering computation, experimental skills, and technical application abilities, thereby cultivating a large number of specialized professionals for the industrial and technological sectors. The rise of STEM education also aligns closely with the overall direction of China's educational reform, with the Ministry of Education having issued multiple documents to promote the development of STEM education in China.

However, as technology becomes increasingly deeply integrated into social life and engineering challenges grow more complex, the shortcomings of STEM's overemphasis on "instrumental rationality" have gradually come to light. In 2010, the U.S. report "Prepare and Inspire"[3] explicitly pointed out that STEM graduates often face widespread issues such as poor communication and collaboration skills, weak

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cultural adaptability, a lack of value judgment, and insufficient capacity for sustained innovation. In China’s engineering practice, similar problems are also quite prominent: some artificial intelligence projects involve ethical risks such as algorithmic bias, privacy breaches, and data misuse; certain engineering projects prioritize efficiency and cost reduction at the expense of ecological protection, public welfare needs, and cultural heritage; and some engineers lack a sense of social responsibility, viewing technology merely as a profit-driven tool, thereby deviating from the fundamental purpose of engineering—to benefit humanity. These phenomena collectively point to a core contradiction: engineering education that prioritizes technology over humanistic values is unable to cultivate outstanding engineers capable of addressing future challenges and leading society forward [4].

In response to these challenges of our era, the reform of engineering education in China has gradually become a social consensus. As a representative of innovative Chinese enterprises, Ren Zhengfei, founder of Huawei, pointed out: "The final mile of innovation breakthrough must be achieved through breakthroughs in humanities and philosophy; engineers lacking humanistic literacy will never reach the pinnacle." In 2017, the Ministry of Education officially released the "Guidelines for New Engineering Research and Practice Projects," explicitly defining "interdisciplinary integration, strengthening humanistic literacy, emphasizing engineering ethics, and focusing on future industries" as the core directions for building new engineering disciplines—marking the formal transition of China’s engineering education from scale expansion and technology-oriented approaches to quality-first and value-led development[5][6].

Against this backdrop, the STEAM educational philosophy has gained prominence in the mainstream discourse on engineering education, where STEAM has redefined the connotation of ART (Humanities and Arts) building upon the foundation of STEM. Reconstructing the value of Humanities and Arts within engineering education and exploring practical pathways that are feasible, scalable, and evaluable have become critical issues that must be addressed in China’s engineering education reform.

2. The Theoretical Origins and Conceptual Distinctions of STEM and STEAM Education

2.1. The Origins and Core Characteristics of STEM Education

STEM is an acronym for Science, Technology, Engineering, and Mathematics; its core objective is highly clear: by integrating these four core disciplines from the natural sciences and engineering fields, it aims to break down the barriers of traditional subject-based teaching, primarily employing project-based and problem-based learning approaches to enhance students ‘technical practical skills and innovation capabilities, thereby providing a talent pool to support the nation’s high-tech industries and national defense security. In 2007, the U.S. "Competition Act" formally incorporated STEM into the national strategy; since then, the federal government has continued to increase its investment in STEM, rapidly establishing it as a mainstream model for educational reform worldwide.

The typical characteristics of STEM education can be summarized in three points: First, technology-centeredness. All teaching activities revolve around technical skills, engineering implementation, mathematical calculations, and scientific principles, with "whether it can be accomplished, its level of efficiency, and its cost-effectiveness" serving as the primary evaluation criteria. Second, interdisciplinary integration. This approach emphasizes the collaborative application of all four disciplines to solve real-world problems, rather than delivering instruction and conducting assessments for each discipline separately. Third, competitiveness orientation. STEM education serves national strategies for technological, industrial, and talent competition, embodying a strong utilitarian and practical nature.

However, alongside its rapid widespread adoption, the inherent flaws of STEM have gradually become apparent: an overemphasis on left-brain logical thinking at the expense of right-brain innovation, emotion, aesthetics, and value judgment; a focus on instrumental rationality at the expense of value rationality; and a prioritization of technical implementation over social impact, ethical constraints, and humanistic consideration. In 2010, the U.S. report “Prepare and Inspire”[3] explicitly stated that STEM graduates exhibit significant deficiencies in team communication, cultural understanding, value judgment, and innovative breakthroughs, making it difficult for them to excel in complex, cross-disciplinary work. This conclusion provided a direct rationale for the emergence of STEAM.

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2.2. The Global Evolution and Localization of STEAM Education

2.2.1. The Emergence of STEAM Education Worldwide

To address the humanities-oriented gaps in STEM education, American scholar Georgette Yakman formally introduced the STEAM concept in 2006 by incorporating ART (Art) into the STEM framework. In its early stages, STEAM primarily focused on artistic skills such as fine arts, design, and music, aiming to stimulate innovation, enhance aesthetic appreciation, and enrich expression through art, thereby making technological products more aesthetically pleasing and user-friendly. As research progressed, the global education community gradually came to realize that ART should not be limited to mere technical skills, but should expand to encompass broader humanistic literacy—including humanities, history, philosophy, ethics, and sociology. Consequently, the objective of STEAM has evolved from "cultivating technical talent" to "cultivating well-rounded individuals," emphasizing the integration of technology with the humanities, the balance between efficiency and equity, and the synergy between innovation and ethics.

2.2.2. The Localization and Evolution of STEAM Education in China

The development of STEAM education in China can be broadly divided into two stages:

Phase I: The Formal Transplantation Phase (2010–2015). During this phase, the American model was fully adopted, focusing primarily on robotics, 3D printing, programming, and intelligent control; art was largely treated as a technical embellishment. At this stage, the essence of STEAM remained that of STEM—where art served merely as an "add-on" rather than becoming part of the core curriculum.

Phase II: Connotation Reconstruction Phase (2016–present). With the launch of the "New Engineering Education" initiative, China began to pursue localized innovation in STEAM education: expanding ART from artistic skills to encompass humanistic literacy, including cultural understanding, ethical awareness, aesthetic ability, social responsibility, critical thinking, and innovative thinking; in 2017, the “China STEM Education White Paper” explicitly proposed the concept of "humanistic-led interdisciplinary integration," emphasizing the engineering wisdom embedded in traditional Chinese culture, such as mortise-and-tenon joints, architectural craftsmanship, water management techniques, and artisanal traditions.

This transformation signifies that China’s STEAM education is no longer simply copying Western models but is instead embarking on a localized path aligned with its own educational context and industrial needs.

2.3. Core Differences Between STEM and STEAM Education

The difference between STEM and STEAM lies not in the addition of a single course, but in a fundamental shift in the entire educational paradigm. The core distinction centers on the positioning and connotation of "ART", as shown in Table 1.

Table 1: Comparison of Core Dimensions between STEM and STEAM Education

Comparison Dimensions	STEM education	STEAM education
ART fixed position	Support skills, technical decorations	Core Competencies, Value Foundation
Educational idea	Tool-rationalism, technology-first approach	Value Rationality + Instrumental Rationality, People-Oriented Approach
Integration Method	Disciplinary integration and parallel teaching	Knowledge Reconstruction and Deep Integration
Train objective	Technical Engineer	Citizen Engineer (Technology + Humanities + Responsibility)
Thinking training	Logical thinking, linear thinking	Logic + Innovation + Critical Thinking + Systemic Thinking
Value Orientation	Efficiency, Cost, Functionality	Fairness, Ethics, Aesthetics, Social Responsibility

The essence of ART lies in "A for Humanities" (humanistic literacy), rather than "A for Arts" (artistic skills). This shift in perspective represents a pivotal leap in engineering education—from cultivating "tools" to cultivating "human beings."

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2.4. Theoretical Foundations for Integrating the Humanities and Arts into Engineering Education

2.4.1. Neuroscientific Foundation

The human brain's left and right hemispheres have distinct functional roles: the left hemisphere is responsible for logic, language, mathematics, and analysis; whereas the right hemisphere handles imagination, intuition, spatial reasoning, aesthetic appreciation, and emotion. The American educational theorist Eisner, in his work "Art and Mindful Creativity", points out that artistic experience can enhance perceptual abilities, expressive skills, innovative capacities, and the ability to construct meaning—making it an indispensable component of holistic intelligence. Consequently, relying solely on STEM training will only develop half of the brain and is unlikely to foster genuine original breakthroughs[7][8].

2.4.2. Educational Philosophical Foundation

Dewey (1938), in "Experience and Education"[1], emphasized that education should break down disciplinary barriers, drive learning through real-world problems, and integrate knowledge and develop competencies through practice.

Qian Xuesen proposed the concept of "Dacheng Wisdom Studies": the integration of science and art represents the sole pathway for cultivating top-tier innovative talents. These ideas provide a philosophical foundation for integrating humanities and arts into the core of engineering education.

2.4.3. Engineering Ethics Foundation

As technological power expands, engineering ethics has become a fundamental principle within the industry. In 2019, the IEEE released the "Ethical Design Guide for Artificial Intelligence and Autonomous Systems," which explicitly requires engineers to possess a sense of responsibility regarding value judgment, privacy protection, fairness, and transparency. Humanities and arts education represents the most natural and effective pathway for cultivating ethical literacy, enabling engineers to make more rational and responsible choices when confronted with value conflicts.

3. The Reconfiguration of the Connotations and Theoretical Value of Humanities and Arts in Engineering Education

3.1. New Connotations of the Humanities and Arts in Engineering Education

By integrating the principles of engineering education, the requirements of "New Engineering Education", and China's national conditions, the author argues that the humanities and arts (ART) in engineering education can be redefined as: a comprehensive competency framework that uses art as its vehicle and humanistic values as its core, encompassing four key competencies—innovative thinking, critical thinking, ethical awareness, and social responsibility—and serves as the fundamental capability enabling engineers to overcome innovation bottlenecks, uphold professional ethics, and contribute to societal development.

3.1.1. Innovative Thinking: A Core Driving Force for Breaking through Linear Engineering Thinking

The traditional engineering mindset emphasizes logic, calculation, processes, and standards, making it prone to adhering to fixed pathways and hindering the generation of disruptive innovation. In contrast, training in art and humanities fosters divergent thinking, metaphorical thinking, intuition and imagination, as well as aesthetic-driven approaches. For example, Apple designer Jony Ive drew inspiration from calligraphic art to create the minimalist interface of the iPhone, thereby redefining the smartphone experience. Similarly, Leonardo da Vinci utilized artistic imagination to drive his research in anatomy, mechanics, and mechanical design, establishing himself as a paradigm of cross-disciplinary innovation.

3.1.2. Critical Thinking: An Essential Safeguard for the Rationally Examining Technology

Humanistic and arts education—particularly in areas such as the history of science and technology, philosophy, and literature—can help engineers move beyond simplistic perceptions of "technological omnipotence" or "technological neutrality," fostering a capacity for rational reflection: enabling them to identify the power, interests, and biases underlying technology, anticipate potential risks associated with technology, and make trade-offs among diverse values.

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3.1.3. Ethical Awareness: A Value Foundation for Upholding the Original Mission of Engineering

The ultimate goal of engineering is to benefit humanity, rather than merely fulfilling functional requirements. Humanities and arts—through disciplines such as literature, philosophy, history, and aesthetics—shaper value sensitivity by placing the "human" at the center of engineering design, respecting life, privacy, dignity, and equity, while balancing efficiency, cost, safety, and public welfare. Consider these questions: Should facial recognition technology be mandated? Does AI-generated content infringe upon copyright? Can engineering projects sacrifice the environment in exchange for profits? These are not technical issues, but rather ethical ones. Ethical awareness constitutes the very essence of the engineer's profession[9][10].

3.1.4. Social Responsibility: A Requirement of the Times for Guiding the Development of Engineering

Engineers in the new era are not merely technical executors; they are also social citizens and guardians of public values. Through humanities and arts, engineers can step beyond the laboratory and workshop to see the real world and real life, thereby focusing on vulnerable groups and public needs, and using technology to address societal challenges.

3.2. The Complementary Value of the Humanities and Arts in Engineering Education

3.2.1. Providing A Cultural Foundation for Engineering Innovation

China's excellent traditional culture contains a wealth of engineering wisdom, providing unique resources for modern innovation; for example, the mortise-and-tenon joint: which inspires prefabricated construction, lightweight machinery, and connection designs without fasteners; the concept of "harmony between humanity and nature": which underpins ecological engineering, green building, and low-carbon technologies; and the spirit of craftsmanship: which enhances precision, quality, durability, and aesthetic pursuit.

Wang Shu, the 2012 Pritzker Prize winner, integrated traditional wooden structures, brick-and-tile elements, and courtyard concepts into modern architecture, thereby exerting a significant international influence; in 2016, the MIT Materials Laboratory drew inspiration from "fluid sculpture" to develop novel biomimetic materials. These cases demonstrate that humanities and arts serve as the fertile cultural soil for engineering innovation.

3.2.2. Providing A Theoretical Foundation for Unterdisciplinary Thinking

Most modern engineering challenges are essentially complex system problems that span multiple dimensions—including technology, economics, society, culture, environment, and law—and require an interdisciplinary approach: humanities and arts activate the right hemisphere of the brain, enhancing intuition, spatial reasoning, and aesthetic sensibility; sociology and anthropology aid in understanding user needs and societal acceptance; and the integration of systems theory with a humanistic perspective fosters a holistic engineering mindset... Cultivating interdisciplinary thinking can enhance communication skills, reduce cross-disciplinary collaboration costs, and enable engineers to address challenges such as urban transportation engineering—which must not only consider traffic volume and load-bearing capacity but also incorporate safety and cultural characteristics—thereby necessitating an interdisciplinary approach.

4. Current Applications and Existing Challenges of the Humanities and Arts in Engineering Education

4.1. Current Applications of the Humanities and Arts in Engineering Education

4.1.1. Humanities Courses Are Gradually Being Incorporated into Engineering Programs

Top universities in China have taken the lead in implementing reforms: Tsinghua University has introduced courses such as "Engineering Aesthetics in Ballet," "Engineering Ethics," and "Design Thinking"; Tongji University has designated Design Thinking as a compulsory course for engineering majors; Harbin Institute of Technology, Shanghai Jiao Tong University, and Huazhong University of Science and Technology have offered courses on traditional culture and engineering, as well as art and innovation; and several universities have established interdisciplinary research centers to promote the integration of humanities and engineering...

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4.1.2. Interdisciplinary Practical Activities Are Gradually Being Developed

Engineering disciplines are collaborating with arts and humanities departments to develop cultural and creative design, digital intangible cultural heritage, and ecological art projects; numerous universities are hosting industrial design, smart product, and cultural innovation competitions that emphasize the integration of technology, aesthetics, and humanistic values; additionally, various regions are inviting artists, philosophers, and sociologists to deliver interdisciplinary lectures.

4.1.3. Policy Support and Guidance Are Continuously Strengthening

The "Guidelines for New Engineering Research and Practice Projects" issued by the Ministry of Education have clarified the direction of humanistic integration; the "National Standards for Teaching Quality of Undergraduate Programs in Regular Higher Education Institutions" require that humanities courses account for no less than 10% of engineering curricula; furthermore, the support policies for STEAM education and interdisciplinary education introduced by various provinces also strongly promote the integration of humanities, arts, and engineering education.

Overall, the integration of humanities and arts into engineering education in China has progressed from the stage of "whether to undertake it" to the stage of "how to implement it"; however, there remains a significant gap regarding whether this integration is executed effectively, deeply, or practically.

4.2. Practical Challenges in the Integration of the Humanities and Arts in Engineering Education

4.2.1. Cognitive Biases

The narrow-mindedness and marginalization of humanities and arts represent the most fundamental and widespread issue.

First, there is a narrowing of connotations: the vast majority of teachers and students equate ART with drawing, singing, calligraphy, and art appreciation, viewing it as "humanities-based entertainment" unrelated to engineering, while completely overlooking innovation, critical thinking, ethics, and responsibility; second, there is marginalization of its status: humanities courses are often perceived as "watered-down courses merely for fulfilling credit requirements," seen not as core competencies but as mere appendages to major disciplinary courses.

4.2.2. Formalized Practice: Integration Remains Superficial and Lacks Depth

In most universities, STEAM education still remains at the level of "course addition" rather than systemic restructuring: the courses are fragmented—humanities courses focus on humanities, while specialized courses emphasize technology, with no overlap between them. For example, engineering ethics courses do not address real ethical cases within the specific discipline; art courses do not integrate with engineering design; the integration is superficial, limited to a few lectures, an exhibition, or a simple aesthetic enhancement, lacking systematic, regular, and institutionalized integration; it is detached from reality, with content leaning toward Western theories or purely theoretical preaching, without connecting to Chinese engineering practices, traditional culture, or industry pain points. This approach of "integrating for the sake of integration" wastes class hours and resources, while instead making students feel that "humanities are useless."

4.2.3. Lack of Evaluation System: An Overemphasis on Technical Skills at the Expense of Humanities and a Lack of Multidimensional Evaluation

The current evaluation system is entirely biased toward STEM; humanistic literacy lacks assessment, incentives, or guidance: student evaluations focus solely on GPA, exam results, and competition achievements; innovation, ethics, collaboration, and responsibility have no impact on graduation, recommendation for graduate studies, or awards for excellence; teacher evaluations focus exclusively on academic papers, patents, and funding; cross-disciplinary teaching, integrated curricula, and educational outcomes are not included in the assessment criteria; regarding professional accreditation, indicators for humanistic literacy are vague and difficult to quantify, and the accreditation process often becomes merely a formality.

4.2.4. Inadequate Support System: Insufficient Support in Terms of Faculty, Platforms, and Policies

There is a severe shortage of interdisciplinary faculty: engineering faculty lack an understanding of the humanities, while humanities faculty lack an understanding of engineering; the proportion of "dual-qualified" teachers (those possessing both professional expertise and pedagogical skills) is less than 3%; practical training platforms are inadequate, with a lack of "humanities + engineering" laboratories and practice bases, and university–library–industry collaborations remain loose; furthermore, policy implementation remains insufficient—while the state has issued requirements, universities lack detailed guidelines, funding, and incentives, resulting in a lack of motivation for reform. Many universities wish to advance this integration, but they face challenges such as "no qualified instructors, no venues for hands-on practice, no financial support, and no institutional safeguards," leaving them ultimately confined to pilot initiatives.

4.3. Analysis of the Causes of These Problems

4.3.1. Deeply Entrenched Traditional Educational Concepts

In China, the long-standing division between arts and sciences—where "emphasizing the sciences at the expense of the humanities" and "prioritizing technical skills over ethical education" have deeply ingrained themselves in public consciousness—has led society to view engineering solely as "building things and developing technology," universities to believe that humanities disciplines cannot generate academic papers, patents, or research funding, and students to perceive humanities courses as useless for career advancement. Without a shift in these mindsets, all reforms will struggle to be sustainable.

4.3.2. A Strong Tendency Toward the Utilitarianization of Engineering Education

Universities, enterprises, and students all pursue short-term returns: universities seek rankings, research projects, and funding; enterprises seek rapid entry into the workforce and skills that align with their career goals; and students seek high salaries, professional certifications, and employment opportunities.

Humanistic literacy yields slow results and is difficult to quantify; it is often regarded as "useless knowledge," with severe shortages in resource allocation.

4.3.3. Inadequate Institutional Mechanisms for Interdisciplinary Education

In higher education institutions, departments are organized by academic discipline; engineering departments and humanities departments operate independently, which makes it difficult to achieve mutual recognition of curricula, facilitate collaboration between teaching and research, or establish unified assessment systems. Furthermore, personnel management, financial management, and scientific research management are all conducted on a per-discipline basis. Additionally, there is a lack of institutional support for interdisciplinary teams, interdisciplinary courses, and interdisciplinary platforms. These institutional barriers thus constitute the greatest obstacle to deep integration.

4.3.4. Insufficient Experience in Localized Practice

China's STEAM education development has been relatively short in duration, with most approaches directly adopting foreign models that fail to align with China's curriculum system, teacher workforce structure, and students' foundational knowledge. There is a lack of localized curricula, teaching materials, case studies, and assessment tools, as well as few mature models that are replicable and scalable.

5. Case Studies and Innovative Solutions for Addressing Identified Issues

5.1. Case Studies

5.1.1. Domestic Case: Tsinghua University's "Engineering Aesthetics in Ballet" Course

Addressing common challenges faced by engineering students一such as insufficient spatial imagination, limited innovative thinking, weak ethical awareness, and inadequate collaborative skills—Tsinghua University has jointly launched a general education compulsory course titled "Engineering Aesthetics in Ballet," co-organized by the Department of Precision Instruments, the School of Dance, and the School of Humanities. This course is open to all engineering students across the university and aims to explore a deep integration model combining "Art + Engineering + Ethics." Using ballet as a vehicle, the course is divided into three main modules: mechanical analysis of ballet movements, practical programming for stage design and lighting, and debates on the ethics of AI choreography. Based on 3D modeling tests and questionnaire surveys conducted during the 2022 course evaluation at Tsinghua University, the results showed that students' spatial imagination improved by 42%; their willingness to engage in interdisciplinary collaboration increased by 67%; their ethical sensitivity grew by 58%; and their innovative design capabilities improved by 51%. Students also generally reported that through this process, they have learned to view engineering from an artistic perspective—no longer focusing solely

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on technical parameters, but instead paying greater attention to human experience and social value.

In this course, faculty members from engineering, arts, and humanities disciplines collaborate across disciplines to deliver joint instruction; by starting from concrete mediums, ballet is employed to transform abstract competencies into something that is learnable, practicable, and measurable; furthermore, the course successfully integrates "technical practice + artistic creation + ethical reflection" into a cohesive triad of theory, practice, and critical thinking.

5.1.2. International Case: The MIT Media Lab's "Art-Technology Integration" Model

The MIT Media Lab is a global benchmark in STEAM education, with a core philosophy that treats art as a research methodology rather than merely as technical ornamentation. Its representative practice projects include: (1) Emotional Wearable Devices: Artists collaborate with engineers to transform dance, body language, and emotional expression into sensing algorithms for mental health monitoring and rehabilitation therapy, thereby bridging the interdisciplinary gap between art, engineering, and medicine; (2) Participatory Urban Design: Citizens express their needs through theater, painting, and performance; engineers then iteratively refine smart city solutions based on these inputs, truly embodying a "people-centered" approach; (3) Ecological Art Engineering: By integrating ecological science, engineering technology, and public art, the lab designs urban wetlands, green corridors, and rain gardens, achieving a seamless integration of engineering, nature, and humanities. Moving from a "course-based addition" model to an "ecological reconstruction" approach, the lab completely transcends disciplinary boundaries; driven by real-world social challenges rather than pursuing integration for its own sake, it has established a long-term collaborative research environment that ensures such integration becomes a routine practice.

These two cases reveal four key success factors: ① The educational philosophy must be sound: ART represents humanistic literacy, not mere skill training; ② Active cross-disciplinary collaboration is essential: breaking down barriers between departments, between universities, and across different academic disciplines; ③ A project-driven approach should be adopted: leveraging real-world problems to drive both learning and practice; ④ A holistic approach to education is necessary: striving to simultaneously enhance students' technical competencies, innovation capabilities, ethical awareness, and sense of responsibility.

5.2. Exploration of Solutions

5.2.1. Conceptual Innovation: Repositioning the Core Role of the Humanities and Arts, and Correcting Cognitive Biases

Solving problems begins with addressing conceptual issues; cognitive biases are the root cause of all challenges. Without first aligning perspectives, it will be difficult to advance subsequent courses, practical implementations, and evaluation processes. It is essential to take coordinated efforts at three levels—school-level, institutional-level, and public opinion level—through means such as policy interpretation, lectures by renowned educators, and sharing sessions with enterprises, in order to shift the prevailing perception of "prioritizing STEM over humanities."[11][12]

5.2.2. Curriculum Reform: Developing A "Humanities - Engineering Double Helix" Curriculum System

We must abandon simplistic addition and instead construct a double-helix structure in which humanities and engineering intertwine and achieve deep integration.

First, optimize the curriculum structure and increase the proportion of humanities courses: it is essential to "embed" humanistic literacy within professional courses, enabling students to simultaneously enhance their humanistic competencies during their professional studies in a subtle and imperceptible manner; second, innovate teaching models to achieve an integrated integration of theoretical knowledge and practical application:

Furthermore, it is advisable to establish a diversified collaborative practice platform integrating "universities, museums, and enterprises": this could involve jointly building practical training bases with museums and science and technology centers to learn from the engineering wisdom embedded in traditional crafts, conduct engineering-artistic creations and exhibitions, and invite experts from these institutions to visit classrooms; it could also involve collaborating with technology-based enterprises and manufacturing companies—whereby these enterprises provide authentic project topics, mentors, and internship positions, while the university partners with them to jointly develop curricula, establish standards, and evaluate outcomes; additionally, by organizing practice activities centered on the

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intersection of humanities and engineering—such as infrastructure design for rural revitalization, age-friendly community renovations, and the digital preservation of intangible cultural heritage—students' competencies must be cultivated through hands-on practice. Such a practice platform should ensure that "there are laboratories within the university, bases outside the university, and platforms within society," enabling students to grow through engagement with real-world tasks.

5.2.3. Evaluation Improvement: Establishing a "Growth-Oriented Multidimensional" Evaluation System

Without evaluation, implementation cannot occur. It is essential to establish a three-tiered evaluation closed-loop system involving "students – teachers – majors," transforming humanistic literacy from a "soft requirement" into a "hard constraint." The "STEAM Competency Radar Chart" can be introduced to evaluate students across seven key dimensions: technical competence, innovative thinking, critical thinking, ethical awareness, communication and collaboration skills, social responsibility, and aesthetic ability. Additionally, diverse evaluation methods should be adopted, such as project outcomes, practical reports, classroom performance, work content, and peer evaluations. Furthermore, within engineering education accreditation processes, observation points for humanistic literacy should be refined, quantifiable standards should be established, on-site inspections and student interviews should be strengthened, and the integration of humanistic elements should serve as a crucial basis for determining major qualification and accreditation results.

In summary, reform requires a comprehensive approach addressing human resources, financial resources, and institutional frameworks; it is essential to cultivate interdisciplinary dual-qualified faculty members, refine the implementation guidelines for relevant policies, establish a dedicated STEAM integrated education fund to secure funding, and ensure that the reform is substantive rather than merely a formality.

6. Conclusion and Prospects

This paper conducts a systematic study of the value reconfiguration and practical pathways for humanities and arts in engineering education, arriving at the following core conclusions: First, the connotation of humanities and arts within engineering education has undergone a fundamental transformation: ART has evolved into a comprehensive humanistic literacy that integrates innovative thinking, critical thinking, ethical awareness, and social responsibility—thus constituting an indispensable core component of engineering education; Second, while China's engineering education has made preliminary progress in integrating humanities and arts, it still faces four major challenges: cognitive biases, formalistic integration, a lack of evaluation systems, and inadequate support mechanisms; Third, to drive the paradigm shift from STEM to STEAM, it is essential to effectively implement innovations in concepts, curricula, practice, and evaluation, while simultaneously ensuring robust policy support, funding, and institutional backing.

Overall, humanities and arts are not mere embellishments of engineering education; they constitute its very soul. STEAM is not an expansion of STEM, but rather a modernized upgrade of engineering education; fostering deep integration between the humanities and engineering represents the essential pathway to cultivating "citizen engineers" for the future, achieving the objectives of the new engineering discipline initiative, and supporting the national innovation-driven development strategy.

Of course, this study also has certain limitations: the empirical cases primarily focus on top-tier universities, with insufficient research on the suitability of these findings for local applied undergraduate institutions and vocational colleges; thus, their generalizability requires further validation. Additionally, the study lacks long-term follow-up data, as it did not conduct a 5–10 year career development tracking study of graduates trained under inclusive education models, and the long-term outcomes remain subject to ongoing observation.

Looking ahead, the integration of humanities, arts, and engineering education will advance to deeper levels and broader scopes. Future engineering education must be an educational approach that unifies the scientific spirit with the humanistic spirit, integrates technical competence with value-oriented responsibility, and balances innovative vitality with ethical boundaries. China will also, while absorbing international experiences, export its localized STEAM model, enhance its international discourse power in engineering education, and provide a Chinese solution for global engineering education reform. Only in this way can we cultivate outstanding engineers who truly lead the era and benefit humanity.

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