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Research on the Mental Model, Core Values and Teaching Transformation of Craftsmanship Spirit in the Digital Age

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Abstract: The industrial transformation in the digital age imposes new requirements on the cognitive patterns and professional qualities of technical personnel. Consequently, the inheritance and development of the craftsmanship spirit urgently require a transition from value advocacy to practical teaching application. This paper adopts the "mental model" as a core analytical perspective to systematically deconstruct the internal and external manifestations of the craftsmanship spirit within a digital context, focusing on its transformation path and injection mechanism in engineering education. Research indicates that the contemporary craftsmanship spirit functions as a mental model integrating the willpower of dedication, meticulous behavioral orientation, and complex cognitive abilities like defect insight and parameter optimization. Its core value lies in converting traditional perceptual knowledge, intuitive judgment, and experiential tricks into a systematic thinking framework suitable for intelligent production environments. Furthermore, this study constructs a dual-wheel-driven teaching transformation model. First, experiential knowledge is visualized and structured through an educational transformation path emphasizing craftsmanship experience and rigorous spirit. Second, spiritual heritage—such as rigorous calculation paradigms and responsibility ethics—is integrated with modern concepts like zero-defect management and full life cycle analysis. These elements are systematically transformed into teaching objectives, case designs, and skill evaluation standards. Ultimately, this paper provides an operational theoretical framework and teaching design principles for higher engineering education, aiming to achieve the collaborative advancement of spiritual inheritance and professional ability cultivation.

Keywords: craftsmanship; mental models; digitalization; engineering education; pedagogy

1. Introduction: The Teaching Theory Shift in the Study of Digital Transformation and Craftsmanship Spirit

The craftsmanship spirit serves as a foundational cultural force driving the high-quality development of China's manufacturing industry. Over time, its role has evolved from a focus on promoting its inherent values and virtues to a more integrated approach that combines these principles with specific industrial practices and technological advancements. The advent of transformative technologies such as intelligent manufacturing, digital twin systems, and artificial intelligence has fundamentally altered the knowledge dynamics within production environments [1]. Tacit knowledge, which was traditionally embedded in human expertise, is increasingly being codified into explicit data formats, enabling algorithmic optimization to take over complex decision-making processes. However, this technological evolution has also introduced new systemic challenges and technical bottlenecks across domains, requiring innovative solutions. Against this backdrop, a critical educational question arises: In a highly digitalized industrial landscape, how does the craftsmanship spirit, characterized by "dedication and meticulousness," manifest and operate as a mental model? Furthermore, how can its unique cognitive and cultural value be effectively identified, analyzed, and conveyed to students in a way that aligns with modern educational practices and technological realities?

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Previous research has predominantly explored the craftsmanship spirit through the lenses of management, ethics, and cultural studies, emphasizing its significance but often neglecting the practical aspects of instructional design. These studies have largely failed to address the "how to teach" and "how to learn" dimensions, which are essential for translating abstract concepts into actionable educational strategies. This paper posits that a paradigm shift in teaching theory is necessary to bridge this gap. By conceptualizing the craftsmanship spirit as a professional mental model that is comprehensible, transformable, and cultivable, it becomes possible to approach it not merely as an attitude but as a structured cognitive framework and a strategic approach to problem-solving. This framework is particularly relevant in addressing the complexities of modern industrial processes and fostering a pursuit of excellence. To achieve this, the paper leverages a logical framework diagram provided by users to explore two core areas: "Mental Model and Value Manifestation Analysis" and "Teaching Transformation Path and Mechanism Construction." These sections aim to establish a direct connection between the spiritual attributes of craftsmanship and practical educational methodologies. By doing so, the paper seeks to offer a clear and actionable pathway for cultivating outstanding engineers who are equipped to thrive in the digital era, ensuring that the craftsmanship spirit remains a vital component of professional development and innovation.

2. Mental Model Deconstruction: Spiritual Traits and Core Value Manifestation in Digital Practice

Digitalization has not eradicated the craftsmanship spirit; rather, it has transformed the ways in which this enduring quality is expressed and adapted to modern contexts [2]. The integration of digital tools and platforms has led to a reconfiguration of traditional practices, enabling the craftsmanship spirit to evolve and thrive in new domains. This transformation reflects a dynamic interplay between technological innovation and human creativity, where the mental model of craftsmanship is redefined to accommodate the demands of a digital era. The essence of craftsmanship, characterized by meticulous attention to detail, dedication to quality, and a commitment to continuous improvement, remains intact but is now manifested through digital mediums such as software development, digital art, and virtual design. These fields exemplify how the core values of craftsmanship are preserved and adapted, showcasing the resilience and adaptability of this spirit in the face of technological change. By embracing digitalization, practitioners are able to expand their creative horizons while maintaining the foundational principles that define their work.

2.1. Deepening of Spiritual Traits: The Cognitive Dimensions of "Persistent Concentration" and "Excellence Pursuit"

In the digital era, the concept of "persistent concentration" transcends the traditional understanding of sustained effort over time. It represents a profound level of immersion and unwavering focus on critical problem domains, even amidst the overwhelming influx of information and the challenges posed by multitasking. Engineers are required to maintain a clear and consistent cognitive framework, seamlessly navigating between simulation interfaces, data streams, and physical systems. This cognitive clarity ensures that their focus remains unbroken, enabling them to address complex challenges with precision and efficiency. Similarly, the notion of "excellence pursuit" has evolved significantly. It no longer pertains solely to the refinement of manual craftsmanship but has expanded into a continuous process of optimizing parameters, refining control logic, and enhancing algorithmic performance. This iterative process is deeply rooted in data-driven methodologies, where the ultimate goal is to achieve the Pareto optimal solution within multi-dimensional objective functions. Such optimization embodies a harmonious blend of rational analysis and a commitment to perfection. By striving for these ideals, engineers engage in a relentless pursuit of improvement, pushing the boundaries of what is achievable. This process not only reflects technical mastery but also underscores the

importance of adaptability and innovation in addressing the dynamic demands of modern technological landscapes [3]. The interplay between these cognitive dimensions highlights the critical role of mental discipline and analytical rigor in achieving excellence in the digital age.

2.2. Contemporary Manifestation of Core Values: From "Sensory Experience" to "System Insight"

Traditional craftsmen relied on sensory knowledge, intuitive judgment, and accumulated tricks and experiences. These forms of tacit knowledge are deeply personal and context-dependent, often passed down through generations in a highly individualized manner. In the era of digital intelligent systems, however, these traditional values have found new expressions and applications [4]. The transition from manual craftsmanship to digital intelligence has not diminished the importance of these skills but has instead transformed them into a foundation for advanced technological processes. The nuanced understanding and experiential insights of traditional craftsmen now serve as a critical bridge in adapting to the complexities of modern intelligent systems. This evolution underscores the enduring relevance of human intuition and experience, even in the face of rapid technological advancements.

The spiritual essence in optimizing complex process parameters lies in the ability to navigate the intricate interplay of variables within a system. When confronted with thousands of potential combinations of process parameters, optimization transcends the simplistic trial-and-error approach. Engineers must synthesize their understanding of physical mechanisms, historical data, and intelligent optimization algorithms to design experiments, interpret outcomes, and refine strategies. This process demands a collaborative synergy between human expertise and machine intelligence, where engineers develop acute insights into the underlying physical principles suggested by algorithmic outputs. The ability to discern subtle correlations and identify optimal solutions reflects the enduring spirit of craftsmanship, characterized by a relentless pursuit of precision and excellence. This human-machine collaboration not only enhances efficiency but also fosters a deeper understanding of the systems being optimized, ensuring that the integration of technology remains grounded in human ingenuity and creativity.

The spiritual manifestation of insight into intelligent system defects highlights the evolving role of engineers as systemic detectives. Unlike traditional methods that relied on sensory perception to identify surface-level flaws, modern approaches involve diagnosing deeper issues through advanced techniques such as monitoring system logs, analyzing performance metrics, and tracing data lineage. These defects often exhibit hidden, interconnected, and emergent properties, requiring engineers to adopt a meticulous and detail-oriented mindset. By paying close attention to subtle anomalies and persisting in uncovering root causes, engineers embody the principles of precision and zero tolerance for errors. This approach not only ensures the reliability and robustness of intelligent systems but also reflects the timeless values of thoroughness and dedication [1, 5]. The transition from sensory-based detection to data-driven diagnostics signifies a profound shift in the engineering discipline, where traditional craftsmanship is reimagined within the digital realm to address the challenges of modern technological systems.

3. Transformation Path Research: The Reconstruction of Teaching through Craft Experience and Rigorous Spirit

Transforming this mindset into teachable content requires a deliberate approach to making implicit knowledge explicit and organizing fragmented knowledge into coherent systems. The process involves identifying the underlying principles that govern tacit understanding and translating them into structured frameworks that can be effectively communicated and taught. This study emphasizes the importance of bridging the gap

between experiential learning and formal education by integrating practical insights with theoretical rigor. By systematically reconstructing fragmented knowledge, educators can create pathways that not only enhance comprehension but also foster critical thinking and innovation. Furthermore, the transformation paths proposed in this research aim to cultivate a deeper appreciation for the interconnectedness of craft experience and intellectual discipline [6]. This approach underscores the necessity of aligning pedagogical strategies with the evolving demands of contemporary education, ensuring that learners are equipped with both practical skills and analytical capabilities. Ultimately, the goal is to establish a dynamic and adaptable teaching model that resonates with diverse learning contexts and promotes lifelong intellectual growth.

3.1. Path One: The Migration of "Perceptual Knowledge" through Embodiment and Simulation

"Perceptual knowledge" refers to the understanding gained through sensory experiences, which is often challenging to convey through traditional educational methods. However, advancements in modern educational technologies have made it possible to simulate such experiences, creating what can be described as a "pseudo-perceptual" learning environment. By leveraging high-fidelity physical simulation software and virtual reality (VR) technology, educators can construct highly realistic environments that mimic real-world scenarios, such as processing, assembly, or debugging tasks. These environments allow students to engage with complex sensory feedback systems. For instance, they can visually observe the effects of varying cutting force parameters, listen to simulated abnormal sounds that may arise from improper assembly techniques, and detect subtle changes in fluid dynamics. While these simulations do not entirely replicate the tactile and sensory nuances of real-world experiences, they serve as an effective tool for visualizing and structurally presenting critical sensory correlation patterns. This approach significantly accelerates the development of students' physical intuition by providing them with a structured framework to understand and internalize these patterns. Such immersive learning experiences are particularly valuable in technical and engineering education, where hands-on practice is essential but often limited by logistical constraints [7, 8]. By bridging the gap between theoretical knowledge and practical application, these technologies enhance the overall learning process, enabling students to build a more comprehensive and intuitive understanding of complex physical systems.

3.2. Path Two: The Modeling and Case-Based Inheritance of the "Rigorous Calculation" Paradigm

The "rigorous calculation" paradigm, which was developed and refined through significant projects such as the "Two Bombs and One Satellite," represents the pinnacle of scientific rationality and the spirit of meticulous craftsmanship [9, 10]. To effectively integrate this paradigm into educational practices, it is essential to move beyond merely recounting historical events and instead focus on its methodological essence. For instance, educators can recreate scenarios from that era, such as "hand-operated calculations" and "multiple verification processes," and juxtapose these with modern Computer-Aided Engineering (CAE) analysis techniques. This approach allows students to gain a profound understanding of how "calculation credibility" is established, the origins of potential errors, and the strategies for their mitigation. By engaging in such comparative analyses, learners can appreciate the evolution of engineering methodologies and the enduring importance of precision and verification. Furthermore, this paradigm should be framed as a universal model in contemporary engineering education. It is crucial to instill in students a mindset that prioritizes critical thinking and independent verification, particularly when assessing input conditions, boundary assumptions, and the interpretation of results. This mindset remains vital even in the context of advanced digital tools, which, while powerful, are not immune to errors or misapplication. By emphasizing these principles, the "rigorous calculation" paradigm can serve as a foundational

framework for cultivating a new generation of engineers who are not only technically proficient but also deeply committed to accuracy, reliability, and the scientific method. This educational approach ensures that the lessons of the past are effectively adapted to meet the challenges of modern engineering practices.

3.3. Path Three: The Scenarioization and Modernization of Responsibility Ethics

The profound sense of responsibility and the ethic of selfless dedication embodied in the "Iron Man Spirit" must be contextualized within the framework of contemporary engineering practices. To achieve this, educational strategies should emphasize creating a meaningful connection between the "Iron Man Spirit" and modern engineering principles such as "zero defect management" and "full life cycle responsibility." For instance, students can analyze real-world cases, such as a space mission failure caused by a minor weld defect, to understand the critical importance of precision and accountability in engineering. Similarly, discussions on environmental responsibility, such as incorporating recycling considerations during the initial stages of product design, can illustrate how ethical responsibility extends beyond the immediate scope of a project. By grounding the abstract concept of "dedication" in tangible examples, students can appreciate how the spirit of craftsmanship in the digital age demands a holistic ethical commitment. This commitment spans the entire lifecycle of a product, from conceptual design to eventual recycling or disposal. Furthermore, this approach fosters systemic thinking and a forward-looking perspective, encouraging students to view their work as part of a broader, interconnected system. Such an understanding not only enhances their technical competence but also instills a sense of lifelong responsibility for the outcomes of their work. Ultimately, this integration of ethical principles with practical scenarios equips future engineers with the mindset and skills necessary to address complex challenges in a rapidly evolving technological landscape.

4. Injection Mechanism Research: The Integration of Spiritual Elements and Professional Teaching

The transformation paths must be operationalized through well-defined teaching mechanisms to achieve a seamless integration of spiritual elements and professional teaching, akin to the metaphorical "dissolution of salt into water." This approach emphasizes the harmonious blending of intangible values with tangible skills, ensuring that both dimensions are interwoven into the educational process rather than treated as separate or incidental components [9].

Mechanism One involves the dual encoding and transformation of teaching objectives. In this approach, course designs and teaching objectives are structured to incorporate two distinct yet interconnected dimensions. On one hand, there are clearly defined knowledge and skill goals, such as mastering specific technical processes or methodologies. On the other hand, there are equally explicit goals related to cultivating the spirit of craftsmanship [6, 11]. For instance, alongside learning technical simulations, students are encouraged to develop habits of meticulous verification, such as rigorously checking simulation boundary conditions. By embedding spiritual cultivation as a visible and measurable aspect of teaching design, this mechanism ensures that such values are not relegated to incidental mentions but are instead integral to the learning experience.

In the design of courses and teaching objectives, the concept of dual encoding ensures that both technical proficiency and spiritual growth are given equal importance. For example, while students may be tasked with mastering the simulation process of a specific engineering procedure, they are simultaneously guided to adopt a mindset of precision and thoroughness. This dual focus transforms spiritual cultivation into a tangible and assessable dimension of education, fostering a holistic approach to learning that aligns technical expertise with personal and professional values.

1. Mechanism Two emphasizes the deep development and narrative reconstruction of teaching cases. Professional course case libraries should be systematically enriched

with cases that highlight the decision-making processes embodying the spirit of craftsmanship. These cases should go beyond merely showcasing technical successes to delve into the cognitive and emotional journeys of professionals. For instance, a case study on the development of a high-performance material heat treatment process could detail how an engineer identified and analyzed abnormal metallographic structures, fine-tuned interacting parameters, and conducted numerous experiments to stabilize the process. By reconstructing these narratives, students are provided with a window into the mental frameworks and problem-solving strategies of professionals, enabling them to grasp how spiritual traits such as perseverance, critical thinking, and adaptability manifest in technical decision-making.

2. Mechanism Three focuses on integrating skill evaluation standards with an emphasis on the learning process. In this approach, assessment criteria are expanded to include dimensions that reflect the craftsmanship spirit. For example, in evaluating experimental reports, additional scoring items could be introduced to assess the authenticity of data verification and the analysis of anomalies. Similarly, project-based evaluations could include criteria such as the extent of self-assessed defect improvements or the thoroughness and precision of design documentation. This shift from a purely results-oriented evaluation to one that values the exploration process, critical thinking, and quality awareness encourages students to adopt deeper and more reflective learning behaviors. By aligning evaluation standards with these broader dimensions, this mechanism fosters a more comprehensive development of both technical skills and professional values.

In skill assessment and evaluation, the integration of craftsmanship-related dimensions ensures a more holistic approach to student development. For instance, when assessing experimental reports, evaluators could include criteria that reward meticulous data verification and the ability to identify and analyze anomalies. Similarly, project evaluations could prioritize the degree of improvement in self-identified weaknesses or the rigor and completeness of submitted design documents. This approach shifts the focus from merely achieving end results to valuing the intellectual and procedural rigor involved in the learning process. By doing so, students are guided to internalize values such as precision, persistence, and a commitment to quality, which are essential for both academic and professional success.

5. Conclusion: Towards a New Synergistic and Progressive Engineering Education Paradigm

The digital age necessitates a transformative approach to engineering education, one that transcends the mere transmission of technical expertise to cultivate the mental frameworks and professional character essential for technological innovation and excellence. This study proposes a comprehensive pathway for integrating cultural spiritual heritage into modern engineering education by deconstructing the mental model of craftsmanship spirit and systematically constructing its teaching transformation mechanisms. The "dual-wheel drive" model, which combines experience transformation and teaching injection, is designed to harmonize the inheritance of spiritual values with the cultivation of professional competencies. Educators are envisioned as both interpreters of the craftsmanship spirit and architects of dynamic learning environments, leveraging technology-driven teaching methodologies and interactive pedagogical designs to instill traits such as dedication, precision, and resilience as intrinsic cognitive and ethical responses in students. By embedding these values deeply within the cognitive and emotional fabric of future engineers, the craftsmanship spirit can flourish, equipping them with the wisdom and moral foundation necessary to tackle complex global technological challenges and drive sustainable innovation. The implications of this paradigm extend beyond individual development, offering a blueprint for fostering a generation of engineers capable of addressing multifaceted issues in diverse professional contexts. Future research should delve into the tailored design of transformation

pathways for specific engineering disciplines, exploring how these frameworks can be adapted to the unique demands and challenges of various fields. Additionally, empirical studies grounded in learning science are essential to evaluate the effectiveness of these transformation mechanisms, ensuring that the proposed model achieves its intended outcomes. By systematically refining and expanding these approaches, the engineering education community can contribute to the creation of a robust, globally relevant educational paradigm that not only advances technical proficiency but also nurtures the ethical and intellectual capacities required for sustainable progress in the digital era.

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