

Research on the Construction of Core Competency Framework and Training Quality Evaluation System for Industrial Design Talents in the Intelligent Era

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Abstract

Against the backdrop of intelligent technologies such as artificial intelligence (AI) and big data driving revolutionary industrial transformations, this study aims to address the fundamental restructuring of industrial design paradigms and talent roles in the AI era by constructing a dynamic competency model centered on "value-system-collaboration" and its enabling evaluation system. The research first demonstrates the paradigmatic shift of industrial design from a "tool for creating objects" to a "definer of intelligent ecosystems," clarifying the upgrading of designers' roles to "ecosystem architects." Based on this, a three-tier competency ecosystem framework is proposed, with value ethics as the guide, systems thinking as the backbone, and human-machine collaboration as the lifeblood. To implement this framework, an intelligent evaluation closed-loop is designed, shifting from "summative assessment" to "formative empowerment." Through full-process data perception and diagnostic feedback, teaching is driven to accurately align with competency objectives. This study provides a systematic discussion from theoretical model to evaluation system for cultivating the core competencies of industrial design talents facing the intelligent era.

Keywords

Intelligent Era; Industrial Design; Core Competency Framework; Quality Evaluation System; Human-Machine Collaboration; Ecosystem Architect

1. Introduction

1.1. Research Background and Practical Dilemmas

We are in a new era where intelligent technologies such as AI, big data, and the Internet of Things (IoT) are profoundly reshaping the world. Industrial design, as a creative activity connecting user needs, technological possibilities, and commercial

value, is undergoing a paradigmatic leap in its connotation and extension. Design objects have expanded from tangible physical products to intangible services, experiences, systems, and even digital ecosystems; the design process has evolved from linear and closed to agile, open, and data-driven; and designers' roles have transformed from traditional creative implementers and form givers to "intelligent design builders" and "human-machine collaboration hubs" who master intelligent tools, integrate diverse resources, and define complex problems. This transformation poses unprecedented challenges and requirements for the training of industrial design talents.

However, the current training system and evaluation mechanism for industrial design talents in China face significant dilemmas. Firstly, the competency structure is outdated: the curriculum systems of many universities still focus on traditional modeling, hand-drawing, and CAD skills, lacking sufficient training in emerging core competencies such as AI-generated content (AIGC)-assisted design, data thinking, system architecture, and technological ethics. Secondly, the evaluation system is disconnected: existing evaluations mostly focus on coursework and final outcomes, with homogenized standards, lacking multi-dimensional and full-process monitoring of design thinking processes, human-machine collaboration efficiency, the value of innovative strategies, and actual industrial contributions. This dual lag in "training" and "evaluation" has led to a "structural mismatch" between talent supply and the industrial upgrading needs of the intelligent era. Therefore, systematically answering "what kind of industrial design talents are needed in the intelligent era" and "how to scientifically evaluate the training quality of such talents" has become an urgent task for the reform of design education.

1.2. Review of Domestic and Foreign Research Status

Internationally, research on the transformation of design competencies in the intelligent era has become a hot topic. Scholars generally agree that designers need to shift from "tool users" to "strategists" and "AI trainers." Some studies have proposed the "Design Futures Literacy Competency Wheel," emphasizing seven key competencies including acute perception, systematic planning, and hybrid computing; in terms of teaching methods, a "generation-evaluation" double-diamond model teaching framework integrating Generative AI (GenAI) and Machine Learning (ML) has emerged to cultivate students' ability to use AI for creative divergence and convergent evaluation. These studies provide important references for competency construction but mostly focus on listing competency elements or innovating teaching methods, lacking in-depth analysis of the internal logical hierarchy and systematic connections of competencies.

Domestically, Lu Xiaobo (2025) prospectively pointed out that design education needs to transform from "professional type" to an "ecological innovation system" and systematically elaborated on the core literacy required for future designers.[1] The

concept of "Beyond Designer" proposed by Zhejiang University prospectively outlines the compound role of designers as the core of the tripartite structure of business, technology, and design, whose connotation includes strategic architecture, resource integration, and human-AI collaboration. In terms of evaluation systems, the "Three-Dimensional and Five-Stage" graduate training quality monitoring system pioneered by Jinan University is a milestone. By integrating multi-stakeholder perspectives, covering the entire training cycle, and utilizing mathematical models and intelligent platforms, it has achieved a paradigmatic shift from qualitative and static assessment to quantitative and dynamic monitoring. These achievements provide valuable top-level ideas and methodological references for this study. However, existing research either focuses on macro role transformation or general evaluation models, and no study has systematically decomposed the "core competencies of industrial design talents for the intelligent era" into a framework, and based on this, tailored a deeply coupled, operable, and iterable training quality evaluation system. This research gap is the key that this paper attempts to fill.

2. New Paradigm of Industrial Design: From "Tool for Creating Objects" to "Human-AI Collaborative Ecosystem Definer"

Intelligent technologies have triggered a paradigmatic transformation in industrial design. This transformation is far more than a simple addition of tools; it is an overall restructuring of design ontology, thinking, and processes, resulting in a fundamental upgrading of designers' roles—from shapers of material forms to "ecosystem architects" who navigate complex relationships and define intelligent experiences.

2.1. Ontological Restructuring: Design Objects Evolve from "Static Artifacts" to "Dynamic Relational Interfaces"

The objects of traditional industrial design are "artifacts" with clear physical and functional boundaries. The integration of intelligent technologies has completely eliminated this certainty. The core value of a product is no longer fixed in its material form but lies in the dynamic relationships it carries as an interactive interface for continuous data flows and service ecosystems. For example, in the design of an intelligent car, the physical shape is merely a carrier; the real design object is the real-time, multi-modal communication and collaborative relationships between the vehicle, drivers, passengers, other road users, and even urban infrastructure, enabled by data and algorithms. The goal of design has shifted from "shaping a perfect object" to "defining a trustworthy, smooth, and inspiring relational field." This requires designers to confront a system with blurred boundaries, continuous evolution, and inherent uncertainty, and their core work has transformed into architecting and orchestrating complex "relationships" rather than simple "entities." This shift profoundly confirms the classic paradigmatic transition in interaction design from "physical logic" to "behavioral logic," where the focus of design moves from physical

attributes to the shaping of behaviors and relationships.[2]

2.2. Integration of Epistemology and Methodology: Design Activities Upgrade to Evidence-Based Systematic Intervention

Faced with the aforementioned "relational systems," traditional problem-solving thinking based on intuition and inspiration is insufficient. Design thinking and practice in the intelligent era are merging into an evidence-based, systematic intervention methodology. Epistemologically, designers need to shift from "solving problems for users" to "jointly defining problem domains with multiple stakeholders." For example, designing a home energy management system is not about creating an aesthetic control panel but about collaboratively framing the complex issue of "home energy well-being" with users, power companies, environmental policies, and hardware suppliers, finding a dynamic balance between efficiency, cost, comfort, and sustainability.

Methodologically, this process is manifested as "human-machine collaborative agile co-creation." Artificial intelligence (such as generative design tools) assumes the role of a "super co-pilot" in generating massive solutions, multi-dimensional simulations, and pattern recognition, greatly expanding the exploration space of solutions; while designers upgrade to "curators and referees," responsible for setting value frameworks, providing key intuitions, conducting ethical reviews and aesthetic refinement, and making strategic choices and refinements of AI outputs. Meanwhile, digital twin technology provides a "sandbox" for this collaboration, enabling real-time integration and iterative verification of design, engineering, manufacturing, and user feedback in the virtual world, forming a continuous learning loop from physical to digital and back to physical. Design thus evolves from a project-based linear activity to a governance process of continuously defining, intervening in, and optimizing an intelligent system.

3. Core Competency Restructuring: From "Professional Skill List" to "Dynamically Evolving Competency Ecosystem"

The paradigmatic transformation of industrial design in the intelligent era poses fundamental challenges to the competency structure of designers. The list of skills taught in traditional education—such as hand-drawing, modeling, and ergonomics—are certainly necessary foundations but are far from sufficient to define the core competitiveness of future designers. The new competency structure should be understood as a dynamic ecosystem centered on value judgment as the guide, systems thinking as the backbone, and human-machine collaboration as the lifeblood. This ecosystem is not a simple accumulation of skills but an integrated "wisdom" that is activated, integrated, and continuously evolved in complex contexts.

At the top of this competency ecosystem is a profound and conscious ability of value shaping and ethical decision-making. When designers' roles upgrade to system de-

finers, every choice they make—from AI training data to product interaction logic, and to material life cycles—embeds value orientations and ethical consequences. This means designers must go beyond the traditional focus on function and aesthetics to develop an "ethical imagination." They need to anticipate and critically examine potential biases, privacy infringements, social divisions, or environmental costs brought by technology, and make prudent trade-offs between commercial goals, user experience, and social well-being. This competency requires designers to not only understand technological principles but also possess philosophical, sociological, and ethical thinking frameworks, thereby infusing intelligent systems with values of goodness at the source.

The middle layer of the competency ecosystem is the ability of systems thinking and strategic architecture to navigate complexity. Faced with the dynamic object of "product-service-system," designers' core task shifts from solving isolated problems to understanding and intervening in networks of interrelated elements. This requires designers to conduct system modeling, identify key leverage points, feedback loops, and potential emergent behaviors within the system. For example, designing a ride-sharing platform is not only about the App interface but also about considering how it changes urban traffic flow, energy consumption, community relationships, and even employment patterns. This thinking elevates design from a tactical modeling activity to a strategic architectural activity. Designers need to think like architects, constructing clear and flexible system blueprints, defining interfaces and protocols for each module, and ensuring the resilience, inclusiveness, and sustainable evolutionary potential of the entire ecosystem.

The operational layer of the competency ecosystem is the ability of human-machine collaborative innovation and data storytelling to coexist with machines. As noted in relevant research, "human-machine collaboration" competency in the intelligent era has been concretized into a system framework including "prompt engineering" and "AI output evaluation," which constitute the key competency elements of the "collaborative innovation layer" in this model.[4] This is by no means merely learning to operate several AI software but fundamentally restructuring designers' cognition and workflow. Designers need to master "prompt engineering" to guide AI in high-quality creative divergence with precise language; understand the basic logic of machine learning to convert design constraints into computable parameters and effectively evaluate and iterate AI outputs. More importantly, designers must become interpreters of data and storytellers. In the data-driven design closed-loop, massive amounts of user behavior data, market feedback, and environmental information need to be transformed into warm, insightful "stories" to define problems, verify solutions, and persuade stakeholders. This competency makes designers indispensable translators and curators between humans and machines, and between data and meaning. The "three-tier and nine-dimensional" model constructed in this study draws on systematic methods of competency model construction, aiming to go beyond traditional skill

lists and form a hierarchical and structured competency ecosystem.[3]

4. Evaluation System Transformation: From "Summative Assessment" to "Formative Empowerment" Intelligent Closed-Loop

Matching the dynamic competency ecosystem, the traditional training quality evaluation system—focused on final works, relying on teachers' subjective scoring, and aiming for grade identification—has become ineffective. The new evaluation system must achieve a paradigmatic shift: its purpose should not be to "judge past achievements" but to "promote future growth"; its form should not be a static transcript but a continuous, formative empowerment system embedded in the entire training process. Through data perception, intelligent diagnosis, and precise feedback, this system forms an intelligent closed-loop that drives the continuous evolution of the competency ecosystem. The design of this "formative empowerment system" benefits from the theoretical development of "learning analytics-based formative evaluation" in the field of educational technology, which provides a feasible path for process data-driven teaching improvement.[5]

The cornerstone of this system lies in the ubiquitous collection and integration of multi-dimensional, process-based evidence. Evaluation data will far exceed a final design report or model. It should penetrate the entire learning journey: students' discussion records and contribution levels on interdisciplinary project collaboration platforms reflect their systems thinking and leadership; the prompt iteration history and AI output selection logic in their human-machine collaborative design processes directly map their collaborative innovation capabilities; the program adjustment and simulation test data in digital twin sandboxes demonstrate their technological integration and evidence-based decision-making levels; even their ethical reflection journals on their own design decisions are key evidence of value judgment capabilities. Through IoT, learning analytics technology, natural language processing, and other means, these structured and unstructured behavioral data, process data, and outcome data are collected in real time and unobtrusively, jointly weaving a three-dimensional "digital twin" of learners' competency development.

Based on this, the core function of the system lies in data-driven dynamic diagnosis and personalized competency profile generation. With the help of machine learning models, the system can analyze massive process data to identify the development trajectory, strengths, and bottlenecks of each student in core competency dimensions such as "value-ethics," "system-strategy," and "collaboration-data." For example, the system may diagnose that a student is good at generating creative solutions (strong collaborative innovation ability) but weak in demonstrating their social impact (needing improvement in the value-ethics dimension); another student may excel in technical implementation but show shortcomings in cross-team communication. The resulting competency profile is no longer a general score but a "learning physical examination report" revealing internal structures and dynamic relationships, accu-

rately locating key obstacles to growth and the next development zone. Ultimately, the value closed-loop of the system is reflected in precise feedback, resource adaptation, and teaching optimization based on diagnosis. For students, the system can automatically push personalized learning resources—such as recommending relevant case libraries and ethics micro-courses for students with weak ethical reflection, or suggesting participation in specific collaborative workshops for students with insufficient team collaboration. For teachers and teaching managers, the group competency map and early warning mechanism provided by the system (such as discovering that a cohort of students is generally weak in "system modeling" ability) provide a scientific basis for real-time adjustments to the curriculum system and teaching methods. Evaluation thus transforms from a measurement tool external to the teaching process into an empowerment engine embedded in the learning process, continuously driving "teaching" and "learning" to accurately align and dynamically adapt to the core competencies required by the intelligent era.

5. Future Challenges and Paradigm Outlook: Constructing a New Ecosystem of Design Education in Tension

Constructing the aforementioned competency framework and evaluation system is not merely an educational technology reform but a profound restructuring of the organizational form of industrial design education and even higher education. This process will inevitably be accompanied by a series of severe and profound challenges, and addressing these tensions is a prerequisite for the paradigm to take root.

The primary tension lies in the conflict between the rigidity of disciplinary systems and the fluidity of the competency ecosystem. The current tree-like organizational structure of universities based on faculties and majors is a product of the era of knowledge compartmentalization. Its rigid resource allocation, evaluation standards, and faculty affiliation are incompatible with the in-depth interdisciplinary integration (integrating engineering, ethics, data science, business) required to cultivate "system definers." Future design schools may need to evolve into a "hub" or "platform," whose core is no longer having fixed faculty teaching fixed courses but building an "innovation network" that can flexibly allocate multi-disciplinary experts, industrial mentors, and AI agents inside and outside the university, and dynamically organize teaching around complex real-world projects. This requires a shift in the management philosophy of higher education from "managing disciplines" to "managing innovation ecosystems."

Secondly, the balance between data empowerment and academic ethics has become a new focus. Formative evaluation systems rely on comprehensive data tracking of the learning process, which inevitably touches on ethical boundaries such as privacy, autonomy, and "digital panopticon surveillance." Should every attempt, hesitation, and conflict in collaboration of students be recorded and analyzed? How to define the ownership and use rights of data? How to prevent evaluation algorithms themselves

from solidifying or even exacerbating social biases? Constructing a transparent, auditable ethical framework that endows students with data autonomy is equally important as developing the technical system itself. Future design educators must themselves be practitioners and role models of digital ethics.

Finally, and most fundamentally, the challenge lies in redefining "what makes an excellent teacher." In classrooms where "human-machine collaboration" has become the norm, teachers' authority no longer stems from exclusive knowledge or skills. Their core roles will shift to: designers of complex learning contexts—designing real-world projects that stimulate systems thinking and value debates; coaches of human-machine collaboration—guiding students on how to engage in high-level dialogue and critical cooperation with AI tools; mentors of growth journeys—providing emotional support, life wisdom, and value guidance that machines cannot replace based on intelligent diagnostic reports. This requires a revolutionary transformation in faculty training and evaluation systems, whose professionalism will be re-evaluated and reshaped.

6. Conclusion

In summary, the reform of industrial design education facing the intelligent era is a paradigmatic revolution from "creating objects" to "managing affairs" and from "imparting skills" to "cultivating ecosystems." The "dynamic competency ecosystem" model and "formative empowerment closed-loop" system constructed in this study aim to respond to the inherent requirements of this revolution. It attempts to shift the goal of education from cultivating "craftsmen" proficient in tools of the old paradigm to nurturing "creators of new knowledge and responsible innovators" who can navigate uncertainty, define complex systems, and shoulder ethical responsibilities. This path is not smooth, full of institutional, ethical, and cognitive tensions. However, it is precisely in the continuous response to and creative resolution of these tensions that a new ecosystem of design education truly oriented towards the future and nurturing the source of new-quality productive forces can be nurtured and grown. This is not only a way forward for the single discipline of industrial design but may also provide a profound pioneering model for the overall transformation of higher education in the intelligent era.

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