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Analysis on the Depth of Integrated Development and Curriculum Reform of 《Engineering Structure》 Driven by AI

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Abstract: *In the wave of engineering education reform, civil engineering education needs to be transformed urgently because of the lag of learning mode, insufficient interdisciplinary integration, and the dislocation of objectives and industry needs. Its uniqueness lies in the large-scale artificial system design, diverse practical needs and deep system thinking requirements, and it needs to take a differentiated path: reconstructing the PBL curriculum system to integrate interdisciplinary knowledge, strengthening the practice and innovation ability of "Industry-University-Research", and innovating the teacher structure and project-based evaluation. The international "integrated design studio" model and personalized learning path can be used for reference. The research points out that only by building a system of "system integration-practice innovation-cross-domain collaboration" can we train new civil engineers who can adapt to complex challenges.*
Keywords: Engineering Structure; Educational reform; Systematic thinking; Differentiated path

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I. The core practical challenges faced by civil engineering education

At a time when the field of engineering education is undergoing structural changes [1], civil engineering education is obviously lagging behind, exposing three deep-seated contradictions:

(1) The fault between learning paradigm and technical iteration

The cognitive habits of a new generation of learners have changed from passive acceptance to active inquiry and digital tool-driven. However, traditional civil engineering teaching still relies on theoretical teaching and standardized process training, and it is difficult to adapt to the demand for reshaping engineering thinking by new technologies such as AI, BIM and Internet of Things. Taking artificial intelligence technology as an example, its application in the field of civil engineering has extended from data processing to intelligent decision-making, such as optimizing foundation pit support scheme by machine learning algorithm and identifying construction quality defects by computer vision. This requires learners to have algorithmic thinking, be able to transform engineering problems into data models, and seek the optimal solution through parameter adjustment and model training. However, in traditional teaching, students have limited access to AI tools, and their understanding of the algorithm only stays at the level of mathematical formulas, so it is difficult to combine it with engineering practice. The application of BIM technology also exposes the shortcomings of traditional teaching: a complete BIM process needs to establish a multi-dimensional model including geometric information, material properties and schedule in the design stage, and continuously update it in the construction and operation and maintenance stages to form a digital main line running through the whole life cycle of the project. However, BIM teaching in most colleges and universities is still limited to software operation training, which is not integrated into the whole process teaching of design, construction and management. As a result, students only master modeling skills, but cannot use BIM to realize multi-disciplinary collaboration, construction simulation and operation and maintenance data integration. To solve this contradiction, the teaching of civil engineering needs to be reformed from three aspects: first, the learning scene should be reconstructed, and technologies such as AI, BIM and Internet of Things should be deeply integrated into the course, for example, the generative design algorithm should be introduced into the teaching of structural design to guide students to automatically generate multiple alternatives by adjusting design objectives such as cost, carbon emission and aesthetics; Secondly, innovate the practice system and build an intelligent construction laboratory, so that students can operate sensors, drones, construction robots and other equipment in a simulated real construction site environment; Finally, we should strengthen the cultivation of composite ability, pay attention to thinking training in the dimensions of technology, data and management while teaching technical tools, for example, analyze the chain effect of construction schedule delay on carbon emissions through BIM model, and cultivate the ability of life cycle system optimization.

(2) The dual deficiency of interdisciplinary integration and systematic thinking.

The current curriculum system is mostly limited to imparting knowledge in a single subject (such as structural mechanics and materials engineering), but the practice of civil engineering essentially needs to integrate knowledge in many fields such as environmental science, urban planning and economics. Although the industry continues to call for strengthening systematic thinking, the education level fails to pay enough attention to the unique needs such as large-scale artificial system construction and life cycle management, which leads to students being stretched to meet the challenges of complex systems such as resilient cities, carbon-neutral infrastructure and so on. At present, the curriculum system of civil engineering presents obvious characteristics of subject separation, and knowledge transfer is still based on the in-depth development of a single field. The course of structural mechanics focuses on the stress analysis and structural design of building load-bearing system, while the course of material engineering focuses on the optimization of concrete ratio and the performance test of steel. Although this interdisciplinary teaching mode helps students master a solid professional foundation, it invisibly cuts engineering knowledge into fragmented modules. However, the practice of civil engineering in reality is a highly complex systematic project in essence. From the planning and design of urban subway network to the construction and operation of cross-sea bridge, it is necessary to integrate the knowledge of environmental science, urban planning, economics and other fields. For example, in the construction project of sponge city, it is necessary not only to use the knowledge of fluid mechanics to design the drainage pipe network, but also to combine the ecological principles to build the rainwater garden, and at the same time, to use the economic method to evaluate the balance between the reconstruction cost and the environmental benefits. This interdisciplinary knowledge is the key to solve practical engineering problems. Although the industry has long emphasized the importance of systematic thinking and called for the cultivation of engineering talents with comprehensive ability, there are still obvious shortcomings in implementing this concept at the educational level. The current curriculum fails to fully consider the unique needs in the field of civil engineering, especially the construction of large-scale artificial systems and life cycle management. The design, construction, operation and demolition of large-scale artificial systems, such as urban infrastructure networks, involve multiple stakeholders and complex technical links, which requires engineers to have overall coordination ability and long-term planning vision; Life-cycle management requires systematic and sustainable thinking from pre-planning to post-maintenance. However, due to the lack of in-depth integration of these core contents in the curriculum system, students often lack effective coping strategies and problem-solving ability when facing complex system challenges such as resilient city construction, carbon neutral infrastructure transformation. For example, when dealing with the problem of urban waterlogging, students may only propose solutions from the perspective of drainage engineering, ignoring the synergy of urban planning, ecological protection and other aspects, resulting in the lack of systematicness and feasibility of the solutions. This disconnect between theory and practice not only affects students' career development, but also restricts the innovation and progress of civil engineering industry [2].

(3) The structural dislocation between the educational goal and the industry demand

Technological innovation forces engineers to change their roles from specification executors to innovative solution designers. However, at present, civil engineering education still focuses on specification compliance and project management, ignoring the cultivation of basic abilities such as problem definition, model construction, experimental verification and innovation. As Thomas Friedman said, the industry pays more attention to the ability of knowledge transformation and application than the static knowledge stock [3].

II. The mirror of international experience and localization enlightenment

Foreign research shows that some universities in Australia have tried the mode of "integrated design studio", which integrates courses such as structural engineering, geotechnical engineering and traffic engineering into interdisciplinary design projects, and requires students to solve comprehensive engineering problems in a team-work way. The educational concept of "individuation, system orientation and interaction" advocated by foreign scholars can be implemented through blended learning (online theory+offline practice) and personalized learning path (such as setting the professional direction of "sustainable design" and "intelligent construction") [4].

III. Conclusion

An Irreversible Revolution of Educational Paradigm

The reform of civil engineering education is by no means simply following the existing engineering education revolution, but needs to build a unique system of "system integration, practice innovation and cross-domain collaboration" based on the characteristics of disciplines. As Friedman said, the core competitiveness in the future lies in "knowledge application efficiency", and the particularity of civil engineering determines that its talent training must focus on "value creation ability in complex systems". Only by breaking the discipline barrier and reconstructing the educational paradigm centered on "solving real-world problems" can we cultivate new civil engineers who can meet the multiple challenges in the 21st century.

Standing at the time node of the 21st century, civil engineering education is facing the transition from "industrial age training mode" to "digital age training mode". The core of this reform is to shift from "standardization talent replication" to "cultivation of complex problem solvers". Only by building a new educational ecology based on the characteristics of disciplines, in which system integration breaks down knowledge barriers, practical innovation drives capacity growth, and cross-domain collaborative response to multi-dimensional needs, can civil engineers become system architects who can control complex systems and create multiple values in the tide of intelligent construction, green development and urban renewal, rather than "technical executors" confined to a single field. This is not only the innovation of education mode, but also the return to the essence of civil engineering. Because from the pyramids to the Hong Kong-Zhuhai-Macao Bridge, the greatest civil masterpiece of mankind has always been the crystallization of systematic thinking and innovative ability.

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