

A Holistic Educational Framework for Water Transport Engineering: A Mega-Project-Driven Pedagogical Model

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Abstract

This paper proposes a holistic pedagogical model for Water Transport Engineering that addresses three persistent challenges in civil engineering education: weakened professional identity, fragmented knowledge structures, and a persistent theory-practice gap. Anchored in the concept of the "Mega-Project," the model integrates three dimensions—Value Shaping, Knowledge Integration, and Ability Cultivation. Major national infrastructure projects provide the narrative and context for cultivating professional mission and craftsmanship; project-based knowledge scaffolding fosters systems thinking; and authentic problem-based learning develops advanced engineering judgment. This reform embeds value guidance throughout the curriculum to cultivate engineers with technical excellence, innovative capacity, and a deep sense of social responsibility.

Keywords

Water Transport Engineering; Mega-Projects; Curriculum Ideology and Politics; Holistic Education; Teaching Reform.

1. Introduction

A central challenge in contemporary engineering education worldwide is transcending purely technical training to cultivate engineers with a profound sense of social responsibility, professional ethics, and holistic problem-solving capabilities [1]. In response to this global imperative, the Chinese higher education system has systematically advanced a comprehensive educational philosophy known as "Curriculum Ideology and Politics," which aims to seamlessly integrate values education into professional coursework [2]. This approach reframes engineering courses not merely as platforms for imparting technical knowledge, but as crucial environments for shaping students' professional identity and civic values. This paper explores an innovative application of this philosophy within a civil engineering context, arguing that it offers a powerful model for holistic engineering education.

The international literature reflects a consistent movement towards integrating broader societal contexts into engineering curricula. Accreditation bodies like ABET have long emphasized that graduates must understand the impact of engineering solutions in global, economic, environmental, and societal contexts, a mandate that continues to shape modern pedagogical approaches [3]. Recent studies have advanced this by advocating for the integration of socio-technical systems thinking, which equips students to analyze the complex interplay between technology and society [4]. Pedagogical models such as Project-Based Learning (PBL) have been shown to be highly effective in developing students' critical thinking and practical competencies by engaging them with complex, real-world problems [5]. Furthermore, research increasingly highlights the use of large-scale, authentic case studies to

foster students' motivation and systems thinking, connecting classroom theory to tangible, impactful engineering practice [6].

Building on these global trends, Chinese educators have extensively implemented the "Curriculum Ideology and Politics" framework across various disciplines. These efforts have demonstrated significant success in enhancing students' professional identity, learning motivation, and sense of social responsibility [7]. However, a research gap persists in applying these principles systematically to courses centered on large-scale, practical infrastructure projects, such as Water Transport Engineering Construction. While case-based learning is common, the potential of using mega-projects of national significance as holistic educational environments—simultaneously cultivating values, knowledge, and abilities—remains underexplored [8].

This paper addresses this gap by proposing and evaluating a novel pedagogical framework centered on "Mega-Projects." We argue that these complex, socio-technical endeavors serve as a unique and powerful vehicle for achieving a synergistic integration of professional values, systematic knowledge, and practical skills. By situating learning within the context of nationally significant engineering feats, this approach aims to provide a replicable and effective model for cultivating the next generation of socially responsible and technically proficient engineers.

2. Pain Point Analysis in Professional Courses for Curriculum Ideology and Politics

A holistic educational model seeks to integrate value formation, knowledge acquisition, and competency development in a unified framework. In practice, however, traditional engineering courses—exemplified by "Water Transport Engineering Construction"—face multiple entrenched challenges. These pain points not only limit the enhancement of teaching quality but also undermine the effective cultivation of highly capable engineering professionals.

2.1. Erosion of Professional Identity: The Absence of a Grand Narrative

Civil and hydraulic engineering disciplines, as represented by the "Water Transport Engineering Construction" course, are often perceived in public discourse as "traditional," "arduous," or "low-tech." This perception contributes to a weakened professional identity and a sense of purposelessness among students. The underlying cause is a pedagogy that overemphasizes granular technical details while lacking a unifying, compelling narrative—one that situates the curriculum within broader national strategies and societal development goals. Students may acquire the technical expertise required to construct world-class harbors, yet fail to appreciate the societal and strategic significance of their work. This absence of a "grand narrative" compromises the curriculum's value-shaping function, limiting its capacity to instill professional pride, motivation, and a sense of mission. It represents the primary barrier to fulfilling the "value guidance" component of holistic education.

2.2. Knowledge Fragmentation: A Siloed Curriculum and the Lack of Systems Thinking

The "Water Transport Engineering Construction" curriculum spans diverse modules, including waterway, port, and coastal protection engineering. Traditional instruction typically follows a linear, siloed approach, teaching topics—such as caisson installation, channel dredging, and breakwater construction—as discrete, independent units. This structure results in fragmented knowledge, where students can master individual "trees" but fail to comprehend the "forest." While technical proficiency in specific tasks may be achieved, students often lack the systems thinking necessary to integrate these elements into complex, dynamic projects. They are unable to adopt the macro-perspective of a chief project engineer, which requires understanding interdependencies, constraints, and spatiotemporal relationships across construction phases.

Knowledge fragmentation, therefore, obstructs the development of a holistic problem-solving framework and represents a key impediment to achieving the "knowledge imparting" goal of a holistic educational model.

2.3. The Theory-Practice Gap: Suspended Competence and Inert Knowledge

The ultimate aim of the curriculum is to cultivate the capacity to solve real-world engineering problems. However, reliance on simplified, idealized textbook cases often results in "inert knowledge"—information that can be recalled but not applied in novel, complex scenarios. Students may demonstrate proficiency in theoretical models, yet struggle to address unstructured, on-site challenges, such as unexpected geological shifts or extreme weather events. This gap stems from the absence of an authentic, integrative learning environment that mirrors the complexity and conflicts inherent in real-world practice. Consequently, students' competence remains "suspended," disconnected from theory and devoid of rigorous training in higher-order cognitive skills such as analysis, evaluation, and creation. This suspended competence represents the critical shortcoming in fulfilling the "ability cultivation" mandate of holistic education.

The pain points identified—erosion of professional identity, fragmented knowledge, and the theory-practice gap—are systematically mapped to the corresponding reform strategies, as illustrated in Fig. 1. This deliberate alignment ensures that every component of the proposed pedagogical framework directly addresses a fundamental limitation of traditional curricula, establishing a robust foundation for the holistic, mega-project-centered model detailed in the subsequent section.

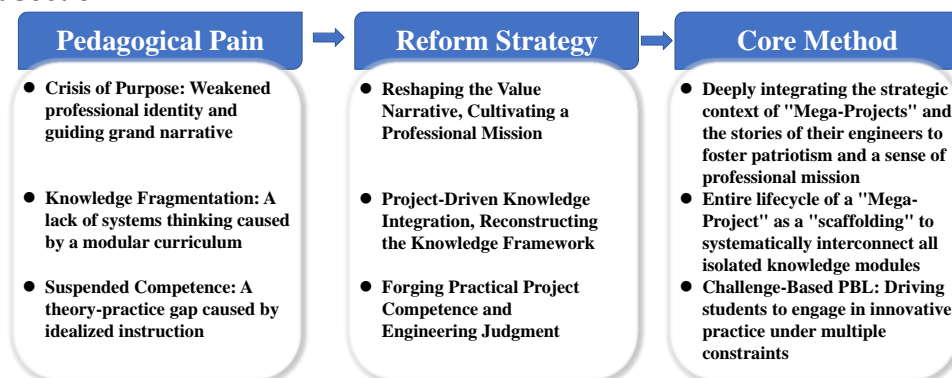


Figure 1. Pedagogical pain points and reform strategies

3. A Holistic Educational Framework Integrating Mega-Projects

To systematically address the pedagogical challenges identified previously, this study proposes a holistic educational framework centered on "Mega-Projects." This framework integrates value formation, knowledge acquisition, and competency development, transforming the course from a conduit of technical instruction into a comprehensive educational experience that cultivates professional mission, systematic understanding, and practical capability [5]. The overarching structure, linking objectives, core concepts, and learning activities, is illustrated in Fig. 2.

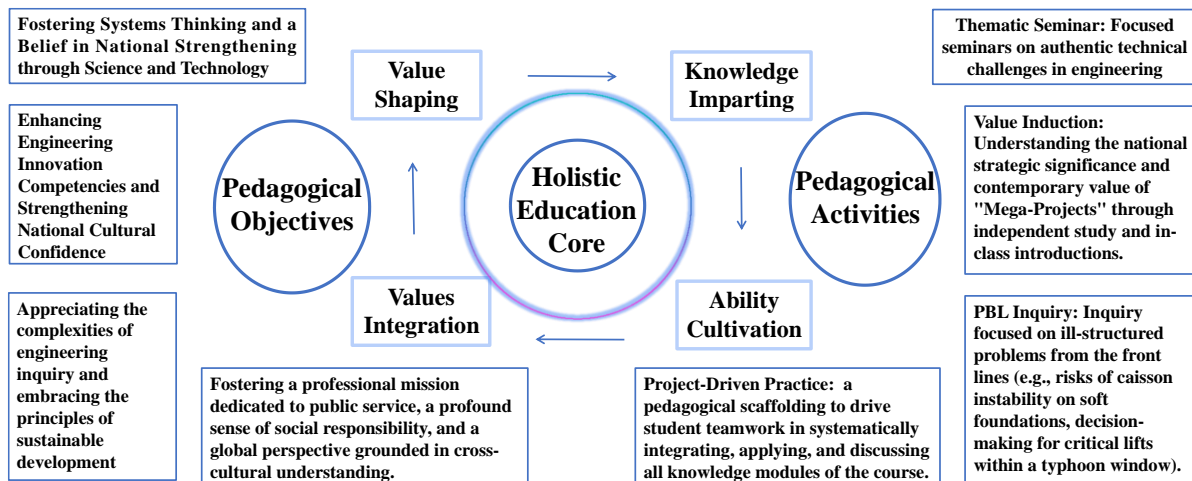


Figure 2. The holistic educational framework from the mega-projects perspective

3.1. Reshaping the Value Narrative to Foster Professional Mission and Civic Responsibility

To counter weakened professional identity, the framework positions "Mega-Projects" as living case studies embodying national development and societal responsibility. Through in-depth analysis of flagship projects—such as the Yangshan Port Automated Terminal and the Hong Kong–Zhuhai–Macao Bridge—the strategic context, construction history, and societal impact of these projects are woven into the curriculum. Instruction extends beyond technical explanations to guide students in understanding how such projects advance global initiatives and national technological leadership [7]. Biographical narratives of chief engineers further highlight responsibility, innovation, and resilience in overcoming extreme challenges. This approach internalizes values of professional mission, craftsmanship, and innovative confidence, allowing students to appreciate the honor and societal significance of engineering while mastering technical knowledge, thereby addressing the crisis of purpose.

3.2. Project-Driven Knowledge Integration: Reconstructing the Cognitive Framework

To address the problem of knowledge fragmentation, this framework adopts the core principles of Project-Based Learning (PBL), reconstructing the traditional linear pedagogical structure by using the entire lifecycle of a typical mega-project as a pedagogical scaffolding. For instance, using a large-scale immersed tube tunnel project as the central case, the course content is no longer delivered in discrete chapters. Instead, knowledge points such as foundation treatment, cofferdam construction, and tube segment prefabrication and installation are systematically integrated according to the authentic logic of project progression. Digital tools like BIM (Building Information Modeling) are introduced to enable students to intuitively grasp the complex spatio-temporal and technical relationships between various construction phases within a 3D visualized environment. This approach, which scaffolds learning around the entirety of a project, guides students to actively construct their own knowledge. It is designed to help them synthesize fragmented information into a coherent whole, thereby developing the macroscopic, systems-thinking capabilities essential for overcoming the bottleneck of a fragmented knowledge base.

3.3. Forging Engineering Judgment and a Spirit of Excellence through Authentic Challenges

To bridge the gap between theory and practice, this framework transforms the real technical challenges and complex decision-making scenarios encountered in "Mega-Projects" into a series of Authentic Problem-Based Learning (PBL) cases. The pedagogical focus shifts from

unidirectional knowledge transmission to placing students in the authentic role of project engineers. They engage in inquiry-based learning and team discussions centered on ill-structured problems drawn from the front lines, such as, "How can the stability of a massive caisson on soft soil foundation be guaranteed?" or "How can a critical crane lift be completed within a narrow typhoon window?" By guiding students to make trade-offs and decisions under multiple constraints—technical, economic, safety, and environmental—this approach systematically forges their engineering judgment. This immersive environment transforms students from passive recipients into active problem-solvers. Repeated engagement with authentic engineering scenarios fosters craftsmanship, systems analysis, and innovative application, thereby bridging the persistent theory–practice gap.

4. Effectiveness, Challenges, and Future Directions

4.1. Value Realization and Pedagogical Effectiveness

The value of this pedagogical reform is demonstrated through a tripartite enhancement of student competencies, with its effectiveness verified via a multi-dimensional evaluation. In the dimension of Value Shaping, the introduction of a grand national narrative through "Mega-Projects" successfully elevated students' professional perspective from a technical focus to a sense of civic identity; qualitative and quantitative feedback data (from surveys and reflective essays) indicate a significant activation of their professional pride and sense of mission. In the dimension of Knowledge Imparting, the project-driven model effectively overcame the challenge of knowledge fragmentation; holistic portfolio assessments show that students developed the ability to integrate discrete knowledge points and construct a systems-thinking framework. In the dimension of Ability Cultivation, the PBL approach, rooted in authentic engineering challenges, markedly improved students' knowledge transfer and innovative application skills. The "near-professional" competency in solving complex problems that students exhibited in their project defenses earned high praise from external industry expert evaluators.

4.2. Challenges and Future Directions for Sustainable Implementation

While affirming the effectiveness of the reform, ensuring its sustainability and scalability requires addressing several practical challenges, which in turn outline a clear agenda for future work. First, the reform demands a more versatile, hybrid set of competencies from instructors; the future direction lies in cultivating cross-disciplinary teaching teams that integrate academic and industry expertise. Second, the dynamic development and updating of the "Mega-Projects" case library is critical for maintaining curricular relevance, which necessitates the establishment of sustainable university-industry partnerships. Furthermore, a continual effort is needed to strike an optimal balance between the depth of a single case study and the breadth of knowledge coverage, making the refinement of a modular "mainline-branchline" case structure a key optimization path. Finally, the inherent difficulty in assessing "soft" value-based outcomes calls for the development of a multi-faceted assessment framework that incorporates qualitative and quantitative, as well as formative and summative, methods. This represents a core research challenge to ensure the holistic educational goals are fully realized and robustly evaluated.

5. Conclusion

This study demonstrates that a holistic, mega-project-centered paradigm can effectively address longstanding challenges in engineering education, including fragmented knowledge, weak value guidance, and the persistent theory-practice gap. By integrating national strategic priorities, systematic disciplinary knowledge, and authentic problem-solving experiences,

mega-projects serve as powerful platforms for the simultaneous cultivation of professional values, systems thinking, and practical competencies.

The core contribution of this research lies in validating an educational model that restores engineering education to its fundamental mission: fostering holistic development. The "Mega-Projects" approach transforms curricula from narrowly focused technical training into comprehensive learning experiences that produce engineers with strong social responsibility, advanced systems-thinking capabilities, and heightened innovative potential. Beyond offering a replicable framework for reforming practice-intensive courses, this paradigm has broader implications: it provides a scalable model for cultivating globally competitive leaders and innovators capable of driving critical infrastructure development and societal progress. In doing so, it not only addresses immediate pedagogical challenges but also charts a strategic path for the future of engineering education.

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