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Exploration of Innovative Practical Abilities in Environmental Design Based on the CDIO Concept

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Abstract: To ameliorate prevalent issues in environmental design education, such as the gap between theoretical instruction and practical application, a dearth of team collaboration ethos, and inadequate process assessment, we have developed an application-oriented pedagogical system. This system is grounded in the Conceive, Design, Implement, Operate (CDIO) paradigm, a contemporary educational approach for the creation of adept engineers.Our system embraces a modular course structure, championing experiential, project-based pedagogy to direct course design. To generate research outcomes, we utilised qualitative research methodologies, gathering data through thorough interviews and systematic observational techniques.Our research indicates that the establishment of a collaborative and communicative interface linking academic institutions and industries effectively broadens the scope of practical teaching environments. This can be further fortified by the assimilation of the CDIO engineering education philosophy. By tailoring teaching training programs to meet industrial talent needs, reinforcing course reform, and enhancing process assessment procedures, we can better accustom ourselves to the dynamic requirements of the industry.Moreover, endorsing the cultivation of design thinking patterns among learners has proven to be an efficacious method for nurturing applied skills. This approach fosters inventive problem-solving capabilities and a flexible mindset, both of which are indispensable for successful environmental design practice.

1. Introduction

In the wake of rapid socio-economic development and ceaseless technological advancements, there is an escalating demand for talents endowed with practical innovation capabilities in the realm of engineering technology. Environmental design, a discipline characterized by strong applicability and high integration, is in critical need of fostering individuals equipped with innovative thought and pragmatic competencies.

To better acclimate to this demand, the educational sphere has initiated endeavors to incorporate a novel pedagogical paradigm: Conceive-Design-Implement-Operate (CDIO). Emerging in the 1990s, the CDIO concept is an education model underpinned by engineering practice, emphasizing the cultivation of students' holistic qualities and practical innovation capabilities. It stratifies the educational process into four stages: conception, design, implementation, and operation, with the aim of nurturing students' end-to-end capabilities from project needs analysis to product realization.

In recent years, the CDIO concept has been globally adopted and is perceived as an instrumental educational reform ideology. In the context of environmental design, the assimilation of the CDIO concept will aid in promoting educational model reform and in fostering pragmatic talents poised to tackle future challenges.

The cultivation of practical innovation capabilities in environmental design under the CDIO paradigm necessitates reforms and innovations in course arrangements, pedagogical methods, and assessment systems. By constructing a curriculum structure that is intimately connected to actual engineering projects, guiding students to actively partake in practical activities, and nurturing their capacities for independent thinking, team collaboration, and innovative design, the practical innovation competencies of environmental design can be substantially enhanced.

2. Interpretation of the CDIO Concept

Internationally recognized, the Conceive-Design-Implement-Operate (CDIO) represents a sophisticated philosophy in engineering education. Its central objective is to employ the C-D-I-O product life cycle as the core of the pedagogical process (Figure 1: CDIO educational concept), with engineering practice serving as the integral medium.

The CDIO approach is designed to facilitate students' proficiency in fundamental engineering technical knowledge, foster hands-on operational competencies, and inspire innovation in the development process of new products. There is a significant emphasis on cultivating undergraduate students' engineering capabilities and qualities. This is primarily achieved through the completion of projects that encapsulate the "Conceive-Design-Implement-Operate" product life cycle process, thus instilling in learners a comprehensive understanding of the end-to-end engineering design and development processes[1](wang wanting,2023).

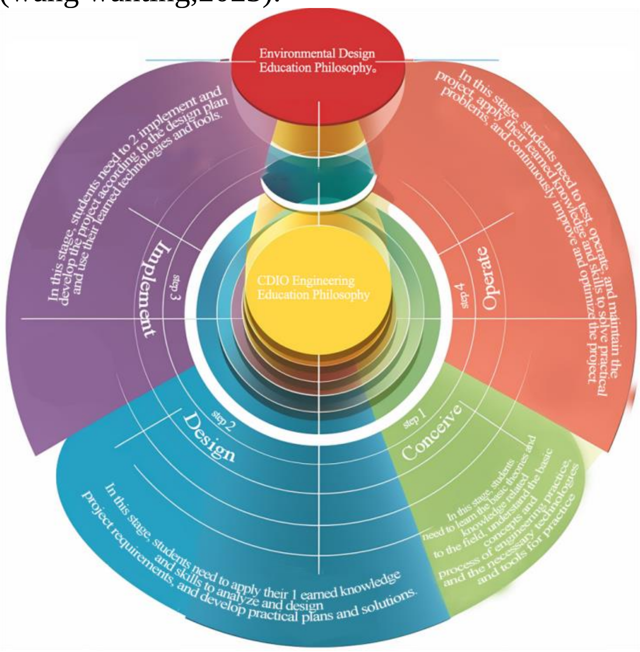

Figure 1: CDIO educational concept

3. New Challenges Faced by Practical Innovation in Environmental Design

In an era characterized by an increasingly refined societal division of labor, the expectations for professional qualities and comprehensive literacy of environmental design talents have been heightened. However, in recent years, an underemphasis on practical application in university environmental art specialization curricula has resulted in graduates struggling to meet the demands of the real-world engineering design field. This has precipitated a steep decline in the employment rate of these graduates[2](George, Chen Simeng, 2023).

Concurrently, numerous large design corporations have itemized the essential qualities required for their urgently needed engineers. To reconcile the discrepancy between the talent demands of design production in companies and university education, an urgent recalibration of the talent development program in university environmental design is imperative (Figure 2: Factors affecting environmental design education).

Against this backdrop, the critical mission of professional teaching in environmental design and the cultivation of innovative practical ability in talent training is unequivocally apparent. Only by reevaluating and reforming past methodologies can we discover novel approaches to cultivate talents for the environmental design specialization[3](Zeng Fangping, 2023).

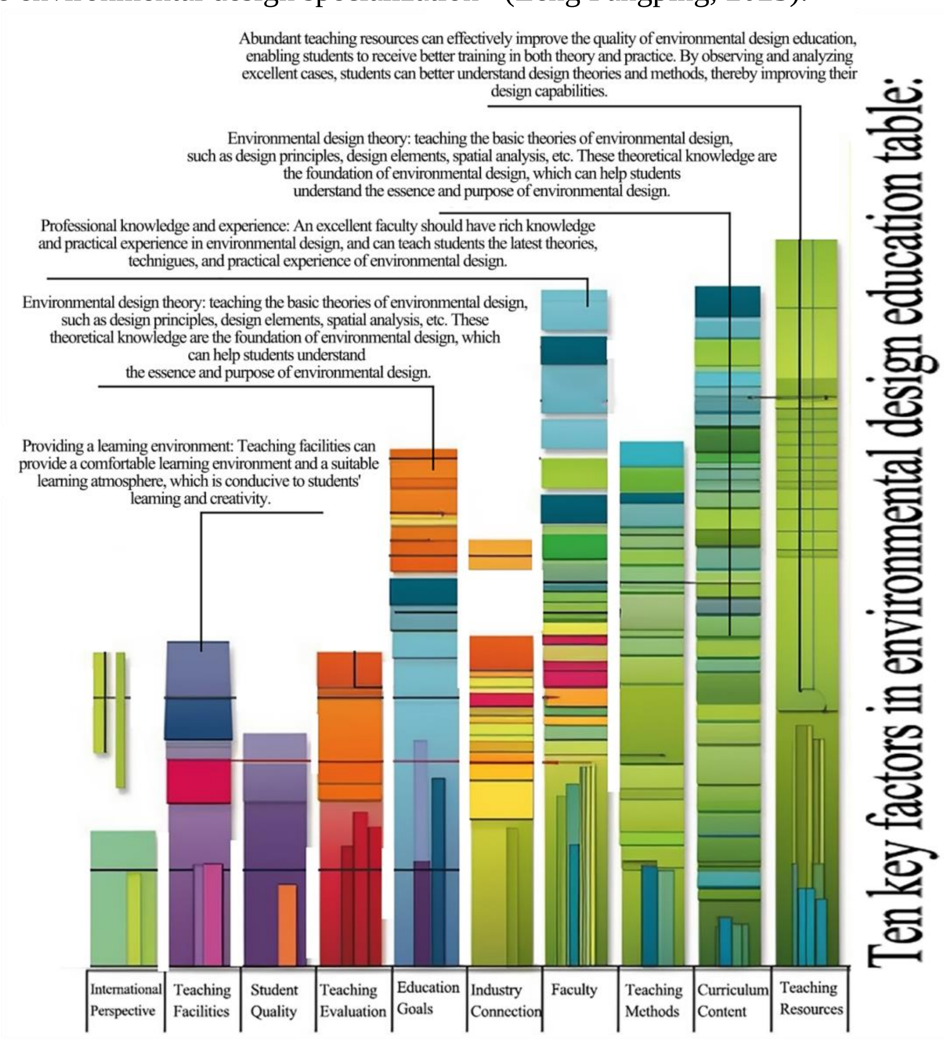

Figure 2: Factors affecting environmental design education

4. Exploration of Cultivating Practical Innovation Abilities in Environmental Design Specialties Based on the CDIO Concept

The primary objective of environmental design professional education is to cultivate applied talents imbued with an innovative spirit and practical abilities. However, issues persist in the cultivation of practical innovation abilities among environmental design students in local universities in our country. These issues include an overemphasis on theoretical constructs at the expense of practical applications, a prioritization of knowledge acquisition over pioneering and innovation, and an undue focus on individual contributions over teamwork[4] (Zhang Hui, Tian Chengsheng, Fu Xiaoyong, 2023).

The nurturing of practical innovation abilities in environmental design undergraduates, predicated on the CDIO (Conceive-Design-Implement-Operate) concept, aims to enhance the practical innovation abilities of these students. This approach adheres to the characteristics and laws of higher education talent training, incorporates the CDIO educational concept, and constructs a comprehensive and systematic educational teaching style and operating mode system mechanism. This unique blend of strategic elements forms a robust framework designed to optimize the development of innovative and practical skills in environmental design students.

4.1. Adjustment of the Environmental Design Curriculum Training Program and Establishment of Training Objectives

(1)The teaching model fully reflects the integration of theoretical knowledge, practice, and resear ch.

The intended goal is to shift from a passive absorption of textbook knowledge to active learning and the enhancement of comprehensive abilities, placing a strong emphasis on cultivating students' capabilities to actively acquire, apply, and innovate with knowledge. This transition significantly reduces the overall in-class credits for students.

Predicated on the core courses primarily within the realm of environmental design, the approach expands the class hours allocated for practical and internship courses. This encourages students to engage in project practice in teacher studios or industry enterprises during their third year of study, thereby providing a real-world context for the application of their learned skills. This shift in pedagogical focus aims to bridge the gap between theoretical understanding and practical application, fostering a more holistic educational experience.

(2)The training model strengthens the two stages of theoretical education in environmental desig n and engineering education.

In the initial academic year, while prioritizing foundational education, it is mandated that the distinctive characteristics of the environmental major are interwoven into the broad platform courses. Particularly in courses such as sketching, color, and composition, these are elucidated in tandem with the unique features of this major.

In the subsequent three years, educators conduct professional instruction and project practice in a scientific and orderly manner, in accordance with the principles of engineering education. This approach enhances the systematic cultivation of students' comprehensive abilities within the four domains of the Conceive-Design-Implement-Operate (CDIO) framework (Figure 3 CDIO integrated teaching model).

This pedagogical model, therefore, not only emphasizes the integration of discipline-specific characteristics into foundational coursework but also promotes the systematic development of comprehensive skills in alignment with the CDIO philosophy across the entire duration of the course.

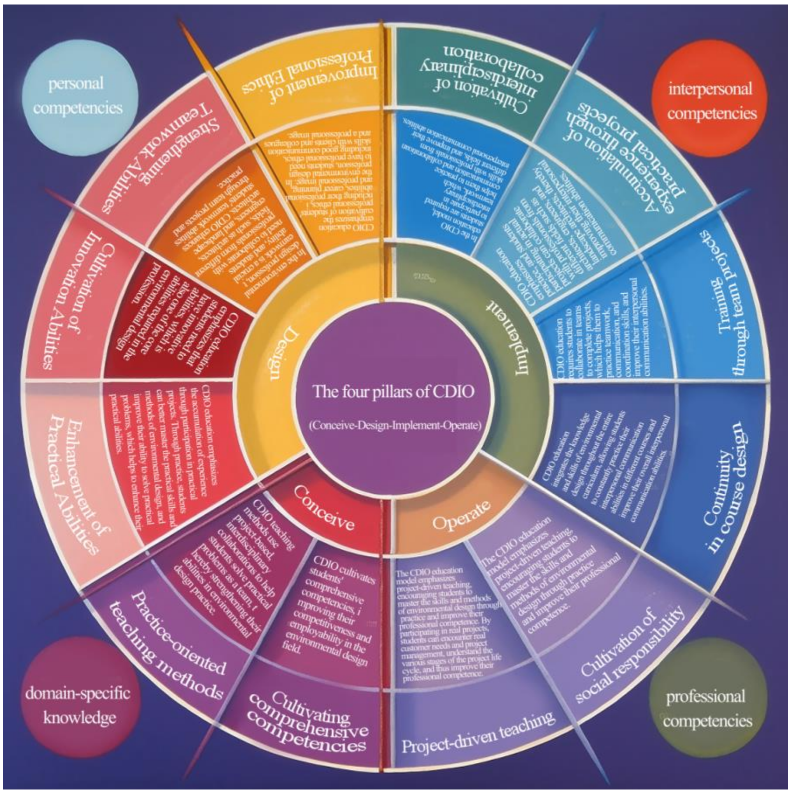

Figure 3: CDIO integrated teaching model

4.2. Modular Design of Curriculum System Based on the CDIO Concept

The curriculum system is designed according to the CDIO teaching concept (Figure 4 Modular Design of CDIO Curriculum System).

(1) C-Conceive: An innovative teaching approach based on a completely new "conception"

In step with the contemporary international art and design market, it is crucial to firmly grasp the overarching trend of "big design," breaking through traditional boundaries of various art and design specialties, and placing emphasis on professional permeation. This involves significantly increasing comprehensive practical courses across multiple subjects and specialties, enhancing the teaching environment, and transforming traditional classrooms into multimedia interactive classrooms that are suited to the contemporary era. The goal is to facilitate network-to-desk learning, with the ultimate aim of cultivating and fostering advanced practical art talents with robust innovative capabilities.

For instance, in the environmental design major, the comprehensive practice course of environmental projects and the environmental design student studio have realized several successful projects under the guidance of instructors. These include constructing aesthetically pleasing courtyards, designing rural landscapes, and renovating bed and breakfast establishments. These real-world applications serve to illustrate the successful integration of theory, practice, and innovation in the learning process.

(2)D-Design: Development through the Integration of "Design" and Competitions

Students in art specializations frequently participate in design competition activities. Prominent competitions for university students in the field of art design include the National University Student Industrial Design Competition, the China Human Settlements Environment Design Annual Award, the Asian Design Annual Award, and the Hope Cup, among others.

These competition activities share several common characteristics. They aim to cultivate university students' awareness of practical innovation, encourage innovative endeavors, and promote the application of science and technology in serving society. They guide and stimulate university students to be bold in their innovative pursuits, with a focus on nurturing students' consciousness of practical innovation. These competitions also aim to enhance university students' practical design abilities and place a strong emphasis on the novelty and uniqueness of the works produced[5] (Zou Zhihao, 2022). In essence, these competitive platforms serve as an effective medium to foster innovation and practical design capabilities in students within a real-world context.

(3)I-Implement: Bridging the "Implementation" Concept and Practice

In accordance with the evolution of the discipline and the market demand for talent, we continually update the course content in environmental design instruction, centering on the foundational and frontier nature of professional knowledge. Drawing from the Conceive-Design-Implement-Operate (CDIO) educational concept, we organize teaching content in a problem-centric manner, encompassing the identification, research, and resolution of problems. This approach effectively eliminates the occurrence of courses being established on an individualistic basis.

We formulate flexible curriculum systems and dynamic teaching plans, guided by industry requirements; establish a multi-tiered practical teaching model that integrates course instruction, course practice, project training, and enterprise internships; enhance practical teaching; encourage innovative thinking; and strive to cultivate students' foundational design ability, project development ability, and engineering practice ability.

This comprehensive and integrated approach to curriculum design and teaching plans aims to better align academic instruction with real-world industry requirements, thereby equipping students with the necessary blend of theory, practice, and innovation.

(4)O-Operate: Activating the Cultivation of Innovation through the "Operation" Mechanism

The cornerstone of the Conceive-Design-Implement-Operate (CDIO) educational concept lies in engineering practice. Talent cultivation in environmental design must establish connections with real-world engineering, enabling students to gain practical experience in enterprises and research institutions, and fostering the growth of exceptional engineers and budding research talents within an authentic environment. This strategy reinforces the development of hands-on skills and team capabilities through direct participation in actual engineering projects.

The primary objective of undertaking engineering project training within enterprises is to augment the efficiency and quality of students' engineering practice and professional innovation. This approach relies on practical teaching components, including studio experiments, enterprise training, course design, and graduation design, to cultivate students' engineering practice abilities.

In sum, the integration of the CDIO educational concept within environmental design education aims to provide students with a holistic and practical experience, bridging the gap between classroom learning and real-world application.

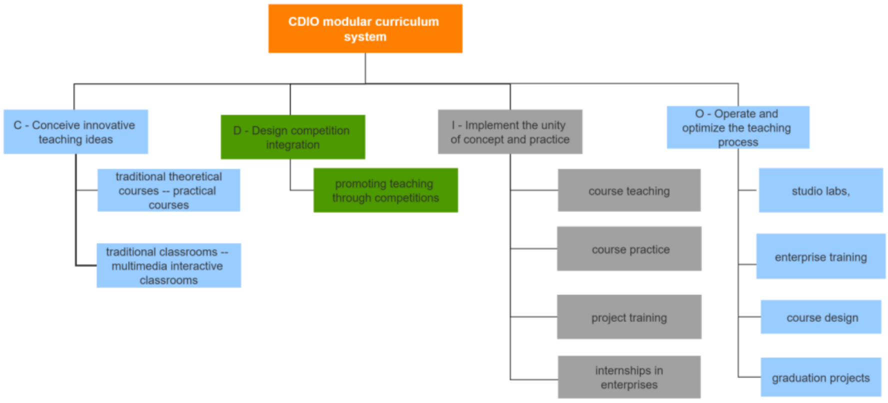

Figure 4: CDIO modular course system design

5. Reforming the Cultivation of Practical Innovation Ability in Environmental Design Majors Based on the CDIO Concept

The Conceive-Design-Implement-Operate (CDIO) engineering education model emphasizes individual capabilities, foundational engineering knowledge, systems engineering skills, and team collaboration abilities. These elements align precisely with the core market demands for talents in environmental design.

Hence, reforming the environmental design major in accordance with the CDIO engineering education concept, and constructing a conception-design-implementation-operation four-in-one teaching model (Figure 5 CDIO course design model), can have a profoundly significant impact on students' future entrepreneurial and innovative endeavors[6](Li Zhiwei, Xu Lingjun, Liu Haiqing, 2022).

Given the current employment climate, it is particularly necessary to nurture high-level composite talents in environmental design with a future-oriented perspective. This approach is both urgent and innovative, playing a vitally important role in advancing teaching work and improving the quality of instruction. To this end, the integration of the CDIO model within environmental design education provides a systematic approach to developing these high-level composite talents[7] (Wei Xuefei, Li Jianhua, 2021).

5.1. Adjusting the Environmental Design Curriculum Training Program and Establishing Training Goals

(1)Fully embody the integration of theoretical knowledge, practice, and research in the teaching mode.

The goal is to transition from passive absorption of textbook knowledge to active learning and enhancement of comprehensive abilities, emphasizing the cultivation of students' skills in actively acquiring, utilizing, and innovating knowledge. This necessitates a significant reduction in the overall in-class credits for students.

Building on the foundation of core courses primarily in the environmental design major, the duration of students' practice and internship courses should be expanded. Students are encouraged to participate in project practice in teacher studios or enterprises during their third year of university study[8](Yi Changwu, Lu Yang, 2020).

This shift towards active learning and practice-oriented teaching not only equips students with the theoretical knowledge necessary for their field but also provides them with the practical skills and innovative thinking required to excel in a professional setting.

(2)Strengthen the two stages of theoretical education in environmental design and engineering professional education in the training mode.

During the first academic year, while underscoring foundational education, it is critical that teaching incorporates the unique characteristics of environmental specialties into large-scale platform courses. Particularly in courses such as sketching, color, and composition, these should be elucidated in tandem with the distinctive features of the major.

In the subsequent three years, educators should conduct professional instruction and project practice in a scientific and orderly fashion, adhering to the principles of engineering education. This approach bolsters the systematic cultivation of students' comprehensive abilities within the four domains of the Conceive-Design-Implement-Operate (CDIO) framework[9] (Tang Yijia, 2019).

This pedagogical model, thus, not only emphasizes the integration of discipline-specific characteristics into foundational coursework but also promotes the systematic development of comprehensive skills in alignment with the CDIO philosophy across the entire duration of the course.

5.2. Strengthening Course Design Reform and Construction

(1)Construct the curriculum system of the environmental design major around the three progressive stages of basic education, professional education, and practical education [10](Wang Xinyuan, 2012). While professional theory and course design form the backbone of the curriculum, equal emphasis is placed on skill development, cultural perception, and concurrent practice.

The curriculum underscores a stepwise progression from technical details to course-specific professional foundations, and then to disciplinary knowledge. It focuses on the creation of related theoretical courses in environmental design, rooted in practical application. The relationship between elective and required courses is clearly delineated, allowing for informed choices and trade-offs to be made.

The curriculum also refines the management measures of practical course details, thereby strengthening the core professional courses. Simultaneously, it seeks to expand students' abilities for innovation and entrepreneurship, grounded in hands-on practice.

This comprehensive curriculum design, thus, strives to equip students with a robust blend of theoretical knowledge, practical skills, and innovative thinking, preparing them for professional success in the field of environmental design.

(2)Systematically construct groups of professional courses. Following the "learning by doing" principle, construct an overall pedagogical framework for environmental design, integrating discipline-specific course groups within a practical application platform.

This approach emphasizes the integration of theory and practice, providing a holistic learning environment in which theoretical knowledge is reinforced and expanded upon through practical applications. By structuring the curriculum in this way, students are afforded the opportunity to understand and apply their learning in a real-world context, enhancing both their understanding and their practical skills within the field of environmental design.

5.3. Conduct course design guided by project practice

The project-based teaching method represents one of the most effective instructional strategies for environmental design majors. Given that practical projects necessitate team collaboration, one of the objectives of the Conceive-Design-Implement-Operate (CDIO) model is to foster interpersonal team skills. Thus, implementing project-based teaching aligns with the reasonable demands of the CDIO model for the construction of the course teaching system.

This pedagogical approach not only offers students the opportunity to apply theoretical knowledge to practical tasks but also enhances their ability to work effectively in team settings - a crucial skill in the field of environmental design.

(1) The course teaching process is fully open to the outside world

Establish collaborative mechanisms with research institutes and large to medium-sized related enterprises, inviting senior professionals to participate in undergraduate teaching. These professionals can engage extensively with students, enabling them to grasp society's expectations for professional skills and deepen their understanding of the environmental design major (Figure 5 CDIO course design model).

This approach to academia-industry collaboration not only enriches the educational experience but also provides students with a real-world perspective on their field of study. It allows students to align their academic learning with industry requirements, thereby enhancing the relevance and applicability of their education.

(2) Based on project practice, reform teaching content

Certain teaching tasks within the environmental design major, particularly those pertaining to interior design and landscape design, must be derived from actual projects. Furthermore, the content should be demonstrative and at the forefront of current trends, offering students practical opportunities to comprehend the present state of professional development and the process of project implementation.

This approach ensures that students are not only exposed to theoretical knowledge but are also given the opportunity to engage with tangible, real-world projects. This facilitates a deeper understanding of the field and provides a practical context in which to apply and reinforce their learning, preparing them for their future roles in the industry.

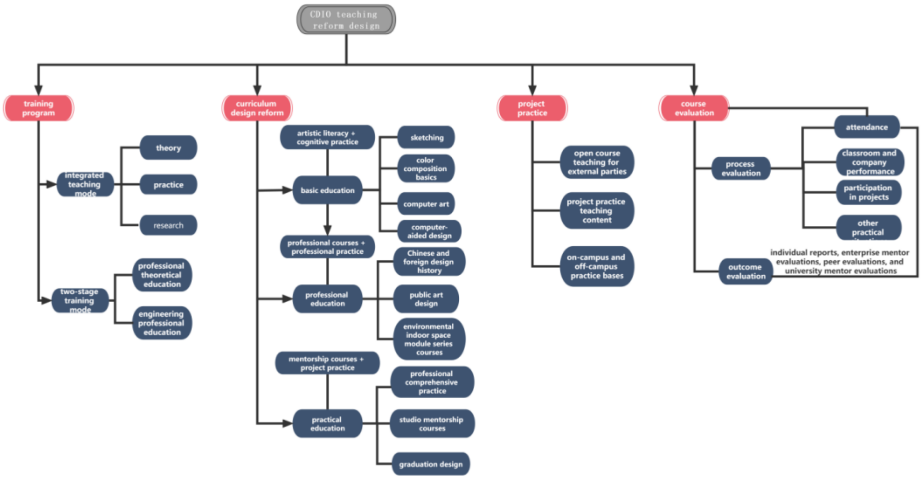

Figure 5: CDIO course design model

(3)Strengthen school-based and extracurricular practice teaching

Enhance the development of school-based and extracurricular internship programs, foster academia-industry collaborations, and establish relevant processes and assessment standards for professional internships and capstone projects. This approach allows students to gradually develop comprehensive abilities to address problems systematically within professional practice projects. It aids in helping them establish technical paths for scientific research and nurtures their sensitivity towards their discipline.

Such a strategy not only provides students with practical exposure but also encourages them to apply their knowledge in real-world scenarios. This approach, combined with comprehensive assessment standards, ensures that students are prepared for the professional demands of their field and are equipped to contribute to scientific research within their discipline.

5.4. Course evaluation system

(1) Process Evaluation

The transformation of assessment methods is projected to shift from a "result-oriented assessment" to a more "process-oriented assessment" in the future. Traditional result-oriented assessment, although adhering to the principle of "test scores + practical scores", often only attributes approximately 20% of the total score to practical work. This scoring system, based purely on practical outcomes, overlooks the unique talents and abilities exhibited by students during the practice process and lacks the scientific nature required for landscape design talent cultivation, thus contradicting the "Conceive-Design-Implement-Operate" model advocated by CDIO.

The process-oriented assessment content encompasses student attendance, classroom performance, implementation of teaching projects, and other practical activity execution situations. Process-oriented assessment does not entirely discard the result-oriented assessment method. Instead, the proportion of result-oriented and process-oriented assessment scores are set according to specific teaching objectives of the institutions, with the proportion of result-oriented assessment generally not exceeding 50%.

This shift towards a more balanced and holistic approach in assessment not only acknowledges the outcomes of students' work but also values the learning process, thereby providing a more comprehensive evaluation of students' abilities and development.

(2) Outcome Evaluation

The effective execution of project-based professional practice hinges on a precise and objective evaluation system. A comprehensive assessment method corresponding to practical training could be employed, integrating both the practice process and its outcomes. This comprehensive evaluation consists of individual reports, enterprise mentor evaluations, peer evaluations, and on-campus mentor evaluations.

When students participate in faculty-led research projects, whether cross-disciplinary (horizontal) or within the same discipline (vertical), their practical training is jointly evaluated by the course instructor and the project lead. The practical training process ought to implement a dual mentor system and employ bidirectional management.

This approach provides a multi-faceted evaluation of students' performance, considering diverse perspectives and multiple aspects of their work. Moreover, the dual mentor system ensures students receive a broad range of feedback and support, enhancing their practical training experience.

(3)Graduation Project Evaluation

The capstone project is a vital component in the comprehensive evaluation of students' professional competencies. Evaluation standards should align with the CDIO model, emphasizing students' abilities to conceive, design, implement, and operate. The evaluation content should encompass aspects such as design innovation, application of professional knowledge, design quality, design expression, team collaboration, communication skills, and more.

A comprehensive evaluation method, combining project reports, oral defenses, and project exhibitions, is adopted to effectively assess students' holistic abilities. This approach not only gauges students' acquired knowledge and technical skills but also evaluates their innovation, teamwork, and communication skills, providing a well-rounded assessment of their readiness for professional practice.

6. Conclusion

Contemporary talent development in universities should no longer be confined to textbook knowledge. There is an urgent need to shift towards a reform in engineering practice teaching. Drawing on the CDIO engineering education concept, the "Conceive-Design-Implement-Operate" process is incorporated throughout the environmental design curriculum system, permeating every aspect of the student's educational journey.

By leveraging an interdisciplinary and integrative professional foundation, a reform of team-based environmental design specialty project practice is undertaken. This approach adopts the joint guidance of industry mentors and on-campus educators, fostering students' practical innovation abilities and team collaboration skills, enhancing academic vision, and promoting the comprehensive improvement of students' overall qualities in environmental design.

The objective is to transform the traditional talent cultivation model of the environmental design major, construct an environmental design professional teaching system based on the CDIO engineering practice, and advocate the application of novel teaching philosophies and research-based teaching methods. This represents a fresh attempt to alter the talent cultivation model of the environmental design major, providing a potential blueprint for the reform of talent cultivation methodologies in higher engineering education.

Acknowledgements

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