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Construction of a Knowledge Graph for "Water Engineering Construction" and the Implementation of Precision Teaching Strategies

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Abstract: *Water Engineering Construction* is a core compulsory course for the major in Water Supply and Drainage Science and Engineering. It has long been plagued by problems including fragmented knowledge systems, disconnection between theory and practice, monotonous teaching modes and rigid integration of educational objectives. The course team constructed a course knowledge graph based on the Superstar Learning Platform. Following the principles of systematicness, practicality, cognitive adaptability, and dynamic updating, the team sorted out knowledge entities and their relationships in the course and formed a visual and interactive knowledge network with clear hierarchies. Accordingly, a four-in-one precision-teaching strategy of "accurate learning-situation diagnosis — stratified and classified teaching — personalized resource push — whole-process dynamic evaluation" was implemented, building a closed-loop of "diagnosis-teaching-evaluation-optimization". Teaching practices show that this mode effectively integrates fragmented course knowledge and accurately adapts to differentiated learning demands of students. Students have achieved obvious improvements in academic performance, classroom participation, professional identity and engineering-practical capabilities. It provides referable practical solutions for intelligent and precision-oriented teaching reform of water-supply-and-drainage-related professional courses.

Keywords: Water engineering construction; Knowledge graph; Teaching strategy

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1. Introduction

With the continuous advancement of Emerging engineering education and the full implementation of the national education-digitalization strategy, curriculum teaching in higher engineering education is gradually transforming toward a student-centered paradigm for competence cultivation. Intelligence and precision have become important development directions for curriculum-teaching reform. With its capability for structured sorting of knowledge systems and semantic associative expression of content, a knowledge graph

can integrate discrete teaching knowledge points into a visual associative network. It not only helps teachers accurately grasp learning situations, but also provides brand-new technical support for students to build complete knowledge frameworks, promoting the shift of teaching decision-making from traditional empirical judgment to scientific judgment based on learning data [1]. *Water Engineering Construction* is a 2-credit core course offered to junior-year students majoring in Water Supply and Drainage Science and Engineering. Its contents cover multiple engineering scenarios such as earth-rock engineering, pipeline construction and water-engineering-structure construction [2], imposing high requirements on students' comprehensive application capabilities. Nevertheless, in the implementation of traditional teaching modes, this course has long suffered from weak knowledge correlation and superficial integration of practice. In view of the above, this teaching reform takes the knowledge graph as the core carrier, reconstructs the course knowledge system and teaching-implementation procedures, and explores new precision-oriented teaching paths that fit professional talent-cultivation objectives.

2. Existing problems in the teaching of *Water Engineering Construction*

At present, prominent problems restricting teaching-quality improvement persist in the teaching of *Water Engineering Construction*, which are mainly reflected in four aspects. First, poor adaptability of the course-content system. The course contains multiple relatively independent sections, including water-engineering-structure construction, water-supply-and-drainage pipeline construction, and construction organization and management. Knowledge points within each section lack clear logical connections and present a fragmented state. In addition, current textbooks are updated slowly and can hardly cover new industrial technologies and specifications, resulting in a shortage of high-level learning resources. Second, insufficient effective linkage between theoretical teaching and practical cultivation. The course involves a large number of complex on-site engineering scenarios, yet on-campus students generally lack front-line construction-practice experience. Classroom case analysis mostly adopts one-way teacher lecturing. Students find it difficult to establish corresponding relationships between abstract theoretical knowledge and real-world engineering scenarios, which leads to disconnection between exam-oriented memorization and practical application. Third, relatively monotonous teaching modes with students' principal position not highlighted. Most teaching links still rely on one-way teacher lecturing. Classroom interaction is mostly limited to superficial activities such as roll-call and questioning, which can hardly stimulate active-learning willingness among students of different proficiency levels. Students remain in a passive-receiving state, and two-way positive interaction between "teaching" and "learning" can hardly be realized. Fourth, rigid integration of educational objectives into the curriculum. Previous teaching mainly focused on professional-knowledge imparting. Value-guiding content such as engineering ethics and industrial responsibilities has not been systematically explored. Value cultivation has not been organically embedded into daily teaching links, leading to low compatibility with talent-cultivation educational objectives for the major [3-4].

3. Construction of the knowledge graph for *Water Engineering Construction*

3.1. Core principles for graph construction

The construction of this course knowledge graph follows four principles that fit real-world teaching practices. First, the principle of systematicness: the graph fully covers core course-teaching contents, sorts

out the vertical progressive relationships of knowledge points from basic to advanced levels, and realizes horizontal application connections among knowledge points of different modules, so as to form a complete and comprehensive course-knowledge network. Second, the principle of practicality: the graph closely caters to actual classroom-teaching demands and competence requirements for construction posts in the water-supply-and-drainage industry. Obsolete theoretical contents are eliminated. Key and difficult points of the course, as well as core practical-operation essentials, are placed in core positions of the graph. Hence, graph contents can directly serve classroom teaching and also support students' post-development in the future. Third, the principle of cognitive adaptability: the graph fully conforms to the cognitive rules of junior-year students majoring in Water Supply and Drainage Science and Engineering. Knowledge-point hierarchies are arranged in logical order of "basic concepts — process principles — on-site practical operations", balancing consolidation of basic knowledge and expansion of cutting-edge content and avoiding learning obstacles caused by excessive knowledge leaps. Fourth, the principle of dynamic updating: adjustable content interfaces are reserved in the graph. Node contents can be continuously optimized and supplemented in accordance with newly-issued construction specifications and newly-promoted construction technologies in the industry, ensuring that graph contents keep pace with the latest industrial developments [5-6].

3.2. Implementation procedures for graph construction

The whole construction process of the graph follows standardized procedures: starting from basic sorting and moving on to visual realization. First of all, comprehensive knowledge sorting and entity extraction are carried out. Core content sources include current textbooks, teaching syllabi, industrial construction-acceptance specifications, cutting-edge scientific-and-technological achievements and course-assessment standards. Scattered course contents are integrated into four core knowledge modules: water-engineering-structure-c onstruction module, water-supply-and-drainage-pipeline-engineering-construction module, water-enginee ring-construction-organization-and-quality-management module, and comprehensive-practice module for physical-project construction. Each module is further decomposed into specific knowledge-point entities, covering everything from basic concepts to on-site practical operations. Secondly, correlation relationships among knowledge entities are defined. Combined with practical implementation logics of engineering construction, four core relationships are clarified: 1) subordinate relationships of whole-part attribution; 2) progressive relationships of learning sequence; 3) associative relationships for joint application of cross-module knowledge points; 4) standard-constraint relationships where industrial specifications restrict construction operations. This thoroughly breaks the previous isolation and fragmentation of knowledge points. Finally, the technical construction of the knowledge graph is completed relying on the intelligent-teaching platform. All knowledge entities and their correlations are converted into visual nodes and connecting lines, forming an interactive course knowledge graph with distinct nodes and clear associations [7-8].

4. Precision-oriented teaching strategies based on the knowledge graph

4.1. Realize accurate whole-process learning-situation diagnosis relying on the knowledge graph

To implement precision teaching, learning-situation diagnosis shall be completed first. With the node-mapping capability of the course knowledge graph, a dynamic-monitoring system covering the whole teaching process can be built. During pre-class preview, teachers release guidance tasks and pre-learning baseline assessments

via the intelligent-teaching platform. The system automatically collects students' answer data, maps each student's answer performance onto corresponding nodes of the knowledge graph, and automatically generates learning-situation reports for the whole class and for individual students. It presents the overall mastery of different knowledge points and identifies common knowledge weaknesses of most students in advance. Teachers can adjust teaching emphases before formal classes and avoid mismatches between teaching content and students' actual foundations [9]. During in-class teaching, supported by intelligent-assistant tools embedded in the platform, data from classroom interactions and in-class quizzes are aggregated in real time. Learning-situation markers on the graph are dynamically updated. Misunderstandings of students regarding currently taught content can be detected within class. Teachers can immediately adjust lecture rhythms and case selections, and deliver supplementary explanations and in-depth expansion for content where students generally have doubts. In the post-class consolidation phase, leveraging correlations in the knowledge graph, the system traces backward to pre-existing knowledge deficiencies corresponding to students' wrong answers. It not only counts wrong-answer records themselves, but also traces basic knowledge points that students have not fully mastered, helping students locate root causes of problems. This solves the long-standing difficulties in traditional teaching: ambiguous learning-situation understanding and unclear teaching orientations [10].

4.2. Conduct stratified and classified precision teaching based on learning-situation portraits

On the basis of accurate learning-situation diagnosis, students are divided into three tiers: basic-level, improvement-level and expansion-level, according to their knowledge foundations, learning abilities and development demands, so as to carry out stratified and classified classroom teaching. For the basic-level tier, emphasis is laid on consolidating core concepts and basic construction workflows. Visual presentations of the knowledge graph and step-by-step micro-lectures are adopted to help students make up for prerequisite knowledge gaps. Basic compensatory exercises are assigned to guide them to gradually build basic cognitive frameworks for the course and prevent disconnection caused by weak foundations. For the improvement-level tier, focus is placed on knowledge integration and analysis of process parameters. Forms such as typical-engineering-case seminars and flipped-class group presentations are adopted to guide students to connect scattered knowledge points into systematic frameworks and analyze routine problems in engineering-construction with systematic thinking. For the expansion-level tier, stress is put on comprehensive application for complex-engineering scenarios. Project-based and seminar-style learning is carried out relying on local physical-engineering cases and BIM virtual-construction tools. Students are instructed to independently complete designs for complex-construction-organization schemes to cultivate innovative thinking and comprehensive engineering-practical capabilities. Classroom questioning, group seminars, and practical-operation training are all designed following stratified principles and linked with the integrated-practice system of "drawing reading — process analysis — on-site cognition". Hence, students of all tiers can achieve steady progress at paces suitable for themselves.

4.3. Accurately push personalized teaching resources around knowledge nodes

With the node-mounting function of the knowledge graph, various teaching resources, including micro-lecture videos, specification provisions, engineering cases, and curriculum-ideological-and-political materials, can be categorized and associated with corresponding graph nodes to build a structured and dynamically-updated teaching-resource library. Based on students' learning-situation portraits and knowledge-mastery status, the

system intelligently pushes adaptive resources for students of different tiers. Basic-level students receive pre-requisite-knowledge remedial resources and step-by-step micro-lectures to rapidly make up for knowledge weaknesses. Improvement-level students are provided with typical-engineering-case analyses and real-exam training for vocational qualification examinations (First-Class Constructor) to strengthen their comprehensi ve-knowledge-application capabilities. Expansion-level students obtain cutting-edge disciplinary literature, BIM virtual-construction tasks, and extracurricular-innovation-practice projects to broaden their professional horizons further. Meanwhile, students can also independently retrieve required resources along associative paths of the knowledge graph to fill gaps in weak links. This mode overcomes limitations of the traditional unified-resource-supply pattern. Problems such as "cannot keep up" for under-prepared students and "insufficient learning load" for advanced students are alleviated. The efficiency of autonomous learning and the precision of resource utilization are greatly improved.

4.4. Build whole-process dynamic precision evaluation supported by teaching big data

In the teaching-evaluation link, the proportion of process-oriented assessment is raised to 50%. Assessment contents cover micro-lecture-video learning, pre-class preview tests and post-class consolidation exercises. Multiple links such as participation in construction-case seminars, flipped-class presentation performance and quality of comprehensive-case-analysis reports are also included to realize all-round tracking of students' learning processes. Evaluation dimensions expand from traditional memorization of theoretical knowledge to multiple facets: practical-operation competence, knowledge-integration-and-application capabilities, learning-participation attitudes and engineering-ethics literacy, which better fit competence-oriented requirements for engineering courses. Relying on the teaching platform, the system records in real time students' learning progress and mastery status at each knowledge node, dynamically updates individual learning-situation portraits, and regularly generates phased learning reports that clearly show students' learning-growth trajectories. Based on feedback from dynamic evaluation, teachers can timely adjust subsequent teaching rhythms, content arrangements and stratified-teaching strategies, and organize special Q&A sessions and tutoring for persistent knowledge weaknesses of students. Thus, a complete closed-loop of "learning-situation diagnosis — teaching implementation — dynamic evaluation — teaching optimization" is formed. As a result, teaching evaluation is no longer a one-off judgment upon course completion, but a dynamic-regulation tool running through the whole learning process, which can continuously drive steady improvement of students' learning outcomes.

5. Conclusion

The intelligent-teaching practice for the course *Water Engineering Construction* takes the knowledge graph as the core technical carrier. It completes the structural reconstruction of the course-knowledge system and implements a whole-process precision-teaching system covering "pre-class — in-class — post-class". It fundamentally solves prominent long-standing problems in traditional teaching, such as knowledge fragmentation, ambiguous learning-situation perception, and mismatches between teaching supply and student demands, and remarkable achievements have been made in course construction.

First, the course-construction system has become increasingly well-established. Knowledge-graph-based intelligent-course construction realizes precise alignment among teaching resources, teaching activities, teaching evaluation, teaching technologies and learning objectives. Students can fully understand learning

objectives and assessment criteria before the course starts, obtain timely solutions for problems encountered during learning, and consolidate knowledge immediately after class. Real-time monitoring and feedback throughout the whole process guarantee learning coherence and continuity. This course has successively obtained university-level first-class-course-construction projects, curriculum-ideological-and-political demons tration-course-construction projects and provincial-level education-and-teaching-reform research projects, and its construction quality has gained continuous recognition.

Second, students' learning outcomes have been greatly improved. With the further advancement of intelligent teaching, students' learning outcomes and quality are steadily enhanced. Their recognition, engagement and participation in learning increase significantly. Completion rates of after-class assignments and participation rates in construction-case seminars remain at high levels. In terms of academic performance, students' average course score, pass rate and excellence rate are obviously higher than those before the reform, and performance improvements are particularly prominent among students with weak foundations. Students' capabilities in construction-case analysis, scheme design and problem-solving are greatly enhanced, better matching competence requirements for water-supply-and-drainage-construction posts.

Teaching practices prove that this mode can systematically integrate course knowledge, accurately adapt to student differences and greatly boost teaching effectiveness. Students have achieved obvious improvements in academic performance, classroom participation, professional identity and engineering-practical capabilities. It provides feasible practical solutions for intelligent and precision-oriented teaching reform of water-supply -and-drainage-related professional courses. Follow-up research will further deepen the integrated application of knowledge graphs and AI teaching assistants, promote the sharing and migration of graph resources within the curriculum group for Water Supply and Drainage Science and Engineering, continuously perfect the precision-teaching system and support the construction of first-class courses.

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