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Research on Teaching Reform of Database Principles Course Based on the Integration of “Post-Course-Competition-Certification” and Digital Empowerment

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Abstract: “Database Principles” is a core fundamental course for computer-related majors, characterized by its theoretical abstraction and practical applicability. Traditional teaching models often suffer from problems such as the “disconnect between theory and practice, outdated teaching content lagging behind industry needs, and a singular evaluation system.” To address these challenges, this paper, based on the educational philosophy of integrating “Post-Course-Competition-Certification” (PCCC) and utilizing digital teaching tools, constructs a four-in-one teaching reform model. This model is built on the principles of “theoretical foundation, practical empowerment, learning promotion through competitions and certifications, and post-standard orientation.” Through optimizing the curriculum content system, innovating teaching implementation paths, and improving the multi-dimensional evaluation mechanism, teaching practice has been carried out over multiple student cohorts. The results indicate that this model can effectively enhance students’ theoretical literacy, practical competence, and job readiness, providing reference and insights for the teaching reform of core courses in computer-related majors in higher education institutions.

Keywords: Database principles; Integration of post; Course; Competition and certification; Digital teaching; Teaching reform practice; Capacity building

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1. Introduction

Against the backdrop of the rapidly developing digital economy, data has become a core factor of production. As the fundamental underpinning for data storage, management, and analysis, database technology finds increasingly wide application in fields such as artificial intelligence, big data, and cloud computing. The “Database Principles” course, offered in majors like Computer Science and Technology, Software Engineering, and Information Management and Information Systems at higher education institutions, aims to equip students with core database theories, design methodologies, and development skills, thereby laying a foundation for subsequent specialized course study and professional development [1–5]. However, the current teaching of the “Database Principles” course still grapples with several significant challenges. Firstly, theoretical instruction tends to prioritize the indoctrination of concepts and principles, often presenting abstract and obscure content, making it difficult for students to grasp their practical application scenarios. Secondly, practical teaching predominantly relies on verification-based experiments, lacking comprehensive, project-based training, which results in a disconnect from the actual demands of industry positions. Thirdly, teaching content is updated slowly, failing to promptly incorporate cutting-edge technologies such as distributed databases, cloud databases, and data security. Fourthly, the evaluation system remains heavily centered on final examinations, neglecting the assessment of process-oriented performance and practical abilities, making it difficult to reflect on students' overall competencies comprehensively.

In response to the aforementioned teaching challenges, academia and higher education institutions have undertaken a series of explorations in teaching reform. The current research landscape indicates that the integration of "Post-Course-Competition-Certification" (PCCC) has emerged as a core direction for curriculum reform in vocational education and application-oriented undergraduate programs. Related research primarily focuses on optimizing the alignment pathways between course content, occupational standards, and competition/certification requirements. For instance, scholars like Li Li, through teaching reform practices in database courses, have confirmed that PCCC integration can effectively narrow the gap between education and job market demands, enhancing students' professional adaptability [6]. Sun Ming et al. have further concentrated on the practical training component, proposing a design scheme for database practical training courses based on PCCC integration, thereby strengthening the targeted nature of practical teaching [7].

Regarding the empowerment of digital teaching, scholars such as Zhang Min have constructed a hybrid teaching model for the Database Principles course. By leveraging digital tools, this model achieves deep integration of online and offline teaching, effectively addressing the traditional disconnect between theory and practice [8]. Wang Qiang and colleagues, considering the learning characteristics of students in local institutions, explored the application paths of digital technology in database courses, providing personalized learning support for student groups with diverse foundational backgrounds [9]. However, existing research still exhibits shortcomings. Some studies emphasize a single dimension of reform, lacking a systematic integration of PCCC fusion and digital empowerment. Furthermore, there is a scarcity of differentiated teaching reform designs tailored for students from the second-tier admission batch in local undergraduate institutions, making it difficult to adapt to the learning characteristics and employment orientation of this specific student population [10,11].

In recent years, the Ministry of Education has proposed requirements for deepening the reform of integrated talent cultivation through "Post-Course-Competition-Certification" in vocational education, promoting the precise alignment of course content with occupational standards, vocational skill level certificates, and skill competition content [12–16]. Concurrently, the widespread adoption of digital teaching tools provides technological support for curriculum reform, enabling the visualization, interactivity, and personalization of the teaching process. Building upon this foundation and considering the specific learning context of students from the second-tier admission batch at Lingnan Normal University, this paper constructs a synergistic teaching reform model that integrates PCCC with digital empowerment. Through systematic reform, it aims to address the aforementioned traditional teaching dilemmas, bridge the gaps in existing research, and ultimately enhance both the teaching quality and educational effectiveness of the course.

2. Analysis of existing problems in the database principles course teaching

2.1. Disconnection between teaching content and industry demands

The content of traditional Database Principles courses primarily centers on relational databases, focusing on standard topics such as SQL language, relational algebra, and database design. It insufficiently covers cutting-edge technologies widely adopted in enterprises today, including distributed databases (e.g., HBase), cloud databases (e.g., Alibaba Cloud RDS), NoSQL databases, data backup and recovery, and data security compliance. Simultaneously, the course content lacks precise alignment with job requirements, failing to fully integrate the core competency demands of positions such as database development engineers and data operation and maintenance engineers. Consequently, students often struggle to rapidly adapt to the work pace in enterprises after graduation.

2.2. Rigid teaching mode and disconnection between theory and practice

Most higher education institutions still adhere to the traditional "theory lecturing + experimental verification" teaching model. Classroom instruction remains teacher-centered, with students passively receiving knowledge, lacking opportunities for proactive thinking and interactive communication. Practical teaching components are often subordinate to theoretical courses, with experimental content primarily consisting of verification tasks such as writing specified SQL statements or simple database design. There is a notable absence of comprehensive, innovative training based on real-world project scenarios. This model, which "emphasizes theory over practice" and "prioritizes verification over innovation, " results in students having an unstable grasp of theoretical knowledge, weak practical abilities, and difficulty applying acquired knowledge to solve actual problems.

2.3. Singular evaluation system and deviation in educational orientation

The current evaluation for the Database Principles course predominantly follows a model of "final exam score + regular assignments + lab reports." The final exam score carries excessive weight (typically 60%-70%), skewing the evaluation focus towards the memorization of theoretical knowledge while neglecting the assessment of students' comprehensive competencies, such as practical skills, innovative thinking, and teamwork abilities. This singular evaluation method fails to holistically reflect students' learning outcomes and their job readiness. Moreover, it inadequately guides students to prioritize the enhancement of practical skills.

2.4. Insufficient teaching resources and technological support

Teaching resources for the Database Principles course are relatively scarce in some institutions, lacking case libraries and practical training platforms aligned with real enterprise projects. Furthermore, the application of digital teaching tools remains superficial. Most instructors merely upload resources like PowerPoint presentations and instructional videos to online teaching platforms, failing to achieve deep integration of online and offline teaching. Consequently, they are unable to provide personalized instructional guidance tailored to students' varying learning needs.

3. Innovative design of teaching reform for database principles course: Integration of "post-course-competition-certification" and digital empowerment

This teaching reform initiative takes "basing on job requirements, strengthening competency cultivation, integrating competition and certification resources, and relying on digital technology" as its core objectives. It aims to construct a four-in-one teaching model to achieve systematic reform in course content, teaching methods, and the evaluation system. The overall logical framework flowchart is illustrated in **Figure 1**.

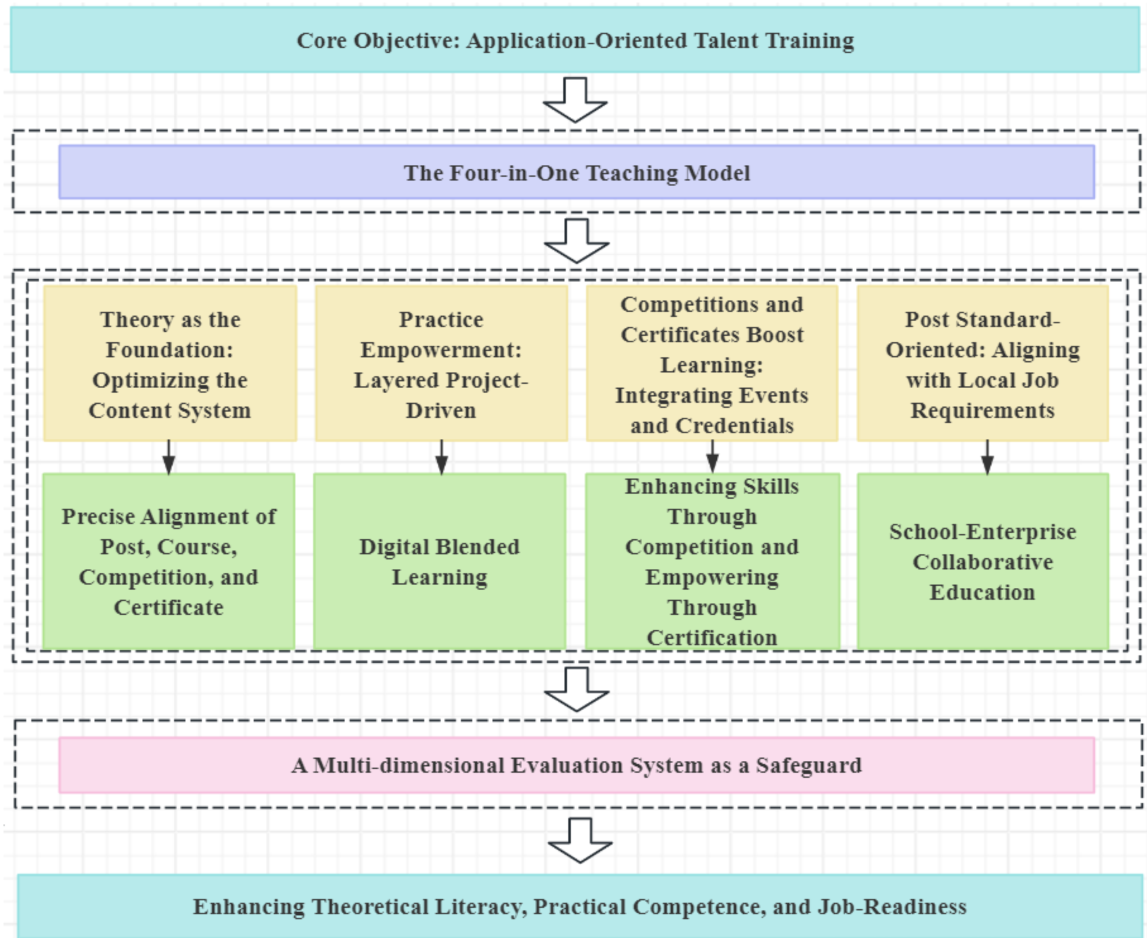

Figure 1. Overall logical flowchart of the teaching reform model for the database principles course.

3.1. Optimizing the curriculum content system to achieve precise alignment of 'post-course-competition-certification'

3.1.1. Aligning with post standards and restructuring course modules

Through visits to enterprises in fields such as internet technology, finance, and e-government, the core competency requirements for positions including database development engineer, data operation and maintenance engineer, and data analyst were investigated. These job skill points were deconstructed into specific course teaching objectives. Consequently, the curriculum content system was restructured into four modules: "Fundamental Theory Module," "Core Skills Module, " "Frontier Expansion Module," and "Post-oriented Practical Training Module." The Fundamental Theory Module retains core topics such as relational algebra, SQL language, and database design while simplifying obscure and difficult theoretical derivations. The Core Skills Module integrates essential job-related skills like database installation and configuration, stored procedure development, data backup and recovery, and database performance optimization. The Frontier Expansion Module introduces cutting-edge technologies such as distributed databases, cloud databases, NoSQL databases, and data security compliance. The Post-oriented Practical Training Module incorporates real enterprise project cases, such as "Database Design and Development for a Campus Library Management System" and "Construction of a User Data Management System for an E-commerce Platform," thereby achieving precise alignment between teaching content and job requirements.

3.1.2. Integrating competition and certification resources to supplement teaching content

The assessment content and grading standards from competitions related to the National College Student Database Design

Competition, the Blue Bridge Cup Software and IT Programming Contest, and similar events were integrated into the course teaching and practical training components. A dedicated "Competition Specialized Training" module was added to cultivate students' innovative thinking and competitive abilities. Simultaneously, by aligning with the assessment requirements of professional skill level certificates such as "Database System Engineer" and "Data Security Engineer, " the core examination points of these certificates—for instance, data security protection and database operation and maintenance standards—were incorporated into the course content. This guides students to "promote learning through competition" and "empower themselves through certification, " thereby enhancing their professional competitiveness.

3.2. Innovating teaching implementation paths and empowering teaching through digital technology

3.2.1. Constructing a "online + offline" blended teaching model

Leveraging digital teaching platforms like Chaoxing Learning, XuetangX MOOC, and EduCoder, an online teaching resource library was established. This library contains resources such as instructional videos, PPT courseware, knowledge point question banks, case analyses, and practical training guides, enabling students to conduct self-directed pre-class preview and post-class review and consolidation. Offline classroom teaching adopts a "scenario introduction + problem-driven + group collaboration" methodology. By creating teaching scenarios based on real enterprise project cases and posing targeted questions, students are guided to think actively and engage in discussion and exchange. For abstract theoretical knowledge, digital tools such as database visualization software (e.g., Navicat, MySQL Workbench) and animated demonstration courseware are utilized to concretize abstract concepts, aiding student comprehension and mastery.

3.2.2. Implementing "layered practical training + project-driven" practical teaching to suit the student profile of the second-tier admission batch

Considering the significant variation in foundational knowledge among students admitted via the second-tier batch at Lingnan Normal University, a three-tier practical training system—" Basic Verification Layer, " "Comprehensive Application Layer, " and "Innovative Design Layer"—was established to cater to the learning needs of students at different levels. The Basic Verification Layer focuses on fundamental skills like SQL statement writing and simple database design, supplemented with detailed operational guidance to help students with weaker foundations solidify their core competencies. The Comprehensive Application Layer requires students to complete the development of medium-sized projects in groups, tailored to local scenarios, such as "Database Design and Implementation for a Warehouse Management System" and "Building a Data Management Module for Online Shopping." This aligns with students' future employment orientation while fostering teamwork and project implementation abilities. The Innovative Design Layer encourages high-achieving students to independently design innovative projects based on competition themes or the needs of local enterprises and institutions, for example, "A Rural Education Data Statistics System Based on a Lightweight Database, " balancing practical depth and regional applicability.

Furthermore, authentic enterprise practical training platforms are introduced, connecting to the database development environments of local small and medium-sized enterprises. This reduces the difficulty for second-tier batch students in adapting to complex technical scenarios, allowing them to improve their practical skills in real-world settings steadily.

3.2.3. Building a "university-enterprise collaboration" teaching platform

Partnerships were established with local internet companies and software firms. Technical experts from these enterprises were invited to deliver special lectures, sharing application cases of database technology in actual projects and industry development trends. Students were arranged to participate in internships and practical training within these enterprises, engaging in the development and operation of real database projects, thereby achieving seamless integration between "classroom learning" and "on-the-job practice." Simultaneously, course case libraries and practical training materials were jointly developed with enterprises to ensure teaching content remains synchronized with industry frontiers.

3.3. Improving the multi-dimensional evaluation system and strengthening competency-oriented assessment

The traditional singular evaluation model was replaced by constructing a multi-dimensional evaluation system comprising "formative assessment + summative assessment + recognition of competition/certification achievements." The evaluation focus shifted from "knowledge memorization" to "competency enhancement", comprehensively assessing students' comprehensive qualities.

3.3.1. Formative assessment (40%)

This encompasses four dimensions: pre-class preparation (5%), classroom interaction (5%), quality of assignment completion (10%), and performance in practical training projects (20%). Pre-class preparation is assessed through online platform check-ins and knowledge point quizzes. Classroom interaction is graded based on student participation in discussions and verbal contributions. Performance in practical training projects is comprehensively evaluated based on project design proposals, code quality, teamwork ability, and project defense effectiveness, ensuring formative assessment permeates the entire teaching and learning process.

3.3.2. Summative assessment (50%)

A combination of "theoretical examination + practical assessment" is adopted. The theoretical examination emphasizes assessing students' understanding and application of core concepts and principles, primarily using question types like case analysis and application problems, reducing rote memorization questions. The practical assessment requires students to complete the design and development of a small-scale database project within a specified time frame, evaluating their comprehensive practical abilities.

3.3.3. Recognition of competition/certification achievements (10%)

Student achievements in participating in subject competitions and obtaining professional skill level certificates are incorporated into the course evaluation system. Students who win national or provincial-level awards in database-related competitions can receive corresponding credit towards their formative assessment scores or directly attain an excellent grade in the practical assessment. Students who obtain relevant professional skill level certificates receive additional points based on the certificate level, fully leveraging the role of competitions and certifications in promoting teaching and learning.

4. Analysis of the teaching reform practice process and effectiveness

4.1. Practice subjects and implementation process

This teaching reform practice selected students majoring in Computer Science and Technology from the 2022 and 2023 cohorts (admitted via the second-tier batch) at Lingnan Normal University as the subjects. As second-tier batch undergraduate students at a local institution, this group exhibits characteristics such as significant variation in foundational knowledge, relatively weaker theoretical deduction ability, but stronger practical motivation, and a future employment orientation primarily towards basic education or IT positions in local enterprises and institutions. Students from the 2022 cohort (120 students) were designated as the control group, taught using the traditional teaching model. Students from the 2023 cohort (126 students) formed the experimental group, taught using the reform model proposed in this paper. The course was offered in the first semester of their second year, with a total of 64 class hours (48 for theory, 16 for practice), aligning with the university's undergraduate teaching plan and the learning capacity of second-tier batch students.

The practice process was divided into three stages. The tasks and interconnections of each stage are illustrated in **Figure 2**, ensuring the orderly progression and closed-loop optimization of the reform implementation.

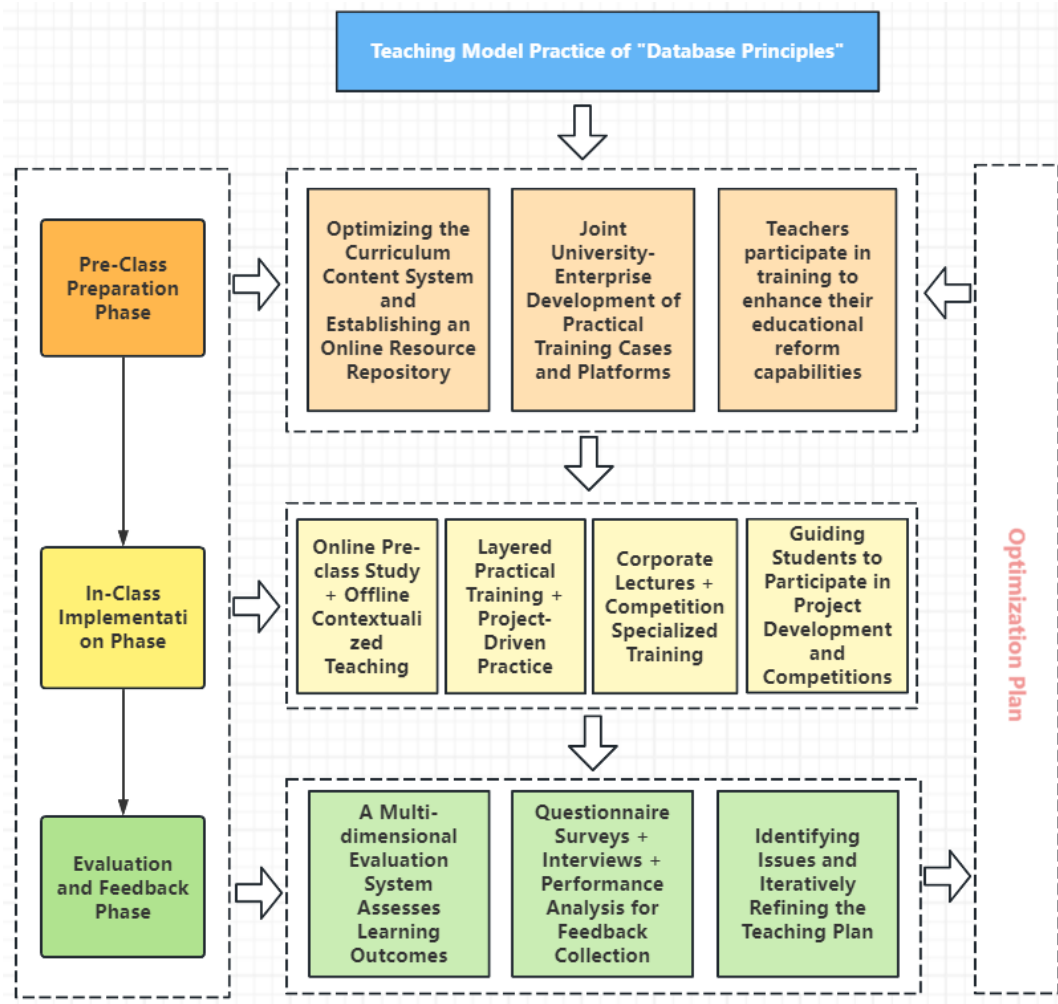

Figure 2. Flowchart of the three-phase implementation process for the teaching reform practice.

4.2. Analysis of teaching effectiveness

4.2.1. Significant improvement in student academic performance

Students in the experimental group achieved an average comprehensive course score of 82.3, which is 4.8 points higher than the control group's average of 77.5. The pass rate for the experimental group (94.4%) increased by 5.2 percentage points compared to the control group (89.2%). The improvement in practical assessment scores was the most pronounced, with the experimental group averaging 85.6 points, significantly higher than the control group's 72.1 points. This indicates that the reform model effectively enhanced students' practical abilities. A comparison of the key performance indicators between the two groups is presented in **Table 1**.

Table 1. Comparison of key performance indicators between the experimental group and the control group

Indicator Type	Experimental Group (Reform Model)	Control Group (Traditional Model)	Increase/Difference
Avg. Comprehensive Course Score	82.3	77.5	+ 4.8 points
Pass Rate (%)	94.4	89.2	+ 5.2 percentage points
Avg. Practical Assessment Score	81.6	72.1	+ 9.5 points

4.2.2. Substantial achievements in subject competitions and certificate acquisition

Thirty-two students from the experimental group participated in competitions such as the National College Student Database Design Competition, the Blue Bridge Cup, and computer programming contests, securing 12 awards at the provincial level or above. This represents a significant increase compared to the control group, which obtained only 3 provincial-level awards. Furthermore, 18 students from the experimental group obtained the entry-level professional skill certificate for “Database System Engineer,” whereas only 7 students from the control group did so. These results demonstrate a marked enhancement in students’ professional competitiveness.

4.2.3. Enhanced student satisfaction and job readiness

Questionnaire surveys revealed that student satisfaction regarding course content, teaching methods, and the evaluation system was significantly higher in the experimental group compared to the control group. Specific satisfaction comparison data is shown in **Table 2**.

Table 2. Comparison of student satisfaction between the experimental group and the control group (Unit: %)

Evaluation Dimension	Exp. Group Satisfaction (%)	Ctrl. Group Satisfaction (%)	Satisfaction Difference (percentage points)
Teaching Content	90.1	79.3	+10.8
Teaching Methods	98.6	78.5	+10.1
Evaluation System	83.7	72.4	+11.3

In line with the employment orientation of second-tier undergraduate students at Lingnan Normal University, follow-up tracking of the internship and employment status of the 2023 experimental group cohort showed that 83% were able to quickly adapt to positions such as IT roles in local primary and secondary schools or database operation, maintenance, and development roles in local enterprises and institutions. These students received recognition from their internship hosts and employers. This represents a 15-percentage-point increase compared to the control group (68%), indicating significantly improved job readiness and local employment competitiveness, which aligns with the university’s goal of cultivating application-oriented talents.

4.2.4. Continuous enhancement of teachers’ instructional capabilities

Teachers involved in the reform accumulated rich practical teaching experience through university-enterprise collaboration, competition guidance, and digital teaching practices. Their teaching proficiency and research capabilities improved notably. In recent years, they have published 9 teaching reform papers, led 8 provincial and university-level teaching reform projects, and received 4 provincial and university-level teaching achievement awards.

5. Reflection and outlook on the teaching reform

5.1. Issues identified in the reform

Although this teaching reform practice has achieved certain results, considering the specific learning context of the second-tier undergraduate students at Lingnan Normal University and the resource constraints typical of local institutions, some shortcomings remain. Firstly, the depth of integration of the “Post-Course-Competition-Certification” (PCCC) framework requires strengthening. The participation enthusiasm of local small and medium-sized enterprises in the teaching process is not high, and the collaborative education mechanism between universities and enterprises still needs improvement due to limitations imposed by regional resources. Secondly, the application of digital teaching tools is insufficiently precise. Personalized content delivery and tiered tutoring functions, tailored to the varied foundational knowledge levels of the second-tier students, are not fully utilized. Consequently, learning difficulties for some students with weaker foundations are not promptly addressed. Thirdly, some students with weaker foundational knowledge struggle to adapt to the pace of tiered practical training and project-driven teaching. Coupled with the limited extracurricular tutoring resources available at local institutions, this leads to increased learning pressure for these students, necessitating further optimization of tiered support and safeguarding measures.

5.2. Improvement measures and future outlook

In response to the aforementioned issues, and in consideration of Lingnan Normal University's educational positioning and the characteristics of second-tier undergraduate students, the following three areas will be prioritized for the continuous optimization of the teaching reform plan. First, deepen university-enterprise collaboration. Building on local resources, a collaborative education mechanism characterized by "joint curriculum development, shared teaching staff, pooled resources, and co-evaluation of outcomes" will be established. Emphasis will be placed on partnering with local primary and secondary schools and information technology enterprises, encouraging their active involvement in curriculum design, practical training guidance, and outcome assessment. This will ensure that the teaching content more closely aligns with local employment needs. Second, upgrade the digital teaching platform. By leveraging insights into the diverse foundational knowledge levels of second-tier students, learning behavior analytics and personalized resource recommendation functions will be optimized. Dedicated online Q&A zones and tiered instructional video libraries will be introduced to address the shortage of extracurricular tutoring support, thereby enhancing the intelligence and precision of instruction. Third, refine the tiered teaching support and safeguarding mechanisms. For students with weaker foundational knowledge, supplementary pre-class preparatory tutoring sessions and one-on-one guidance during practical training will be offered. Implementation steps for complex projects will be simplified to help these students progressively build their capabilities. These measures aim to ensure that all second-tier students can adapt to the reform's pace, in line with the goal of cultivating application-oriented talents at local institutions.

6. Conclusion

Looking ahead, with the continuous advancement of database technology and ongoing evolution in educational philosophies, the teaching reform of the "Database Principles" course will further align with the requirements of the "Emerging Engineering Education" initiative. It will deepen the integration of "Post-Course-Competition-Certification," strengthen the empowerment enabled by digital and intelligent teaching, and continuously refine the curriculum system and teaching models. These efforts will nurture more high-quality, application-oriented, and innovative database technology professionals capable of meeting the demands of the digital economy's development.

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Disclosure statement

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