Exploring the Construction and Operation of University Experimental Teaching Centers under the OBE Concept

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Abstract. President Xi Jinping emphasized that building a powerful education system has long been a cherished aspiration of the Chinese nation, serving as a cornerstone for advancing modernization and achieving national rejuvenation. Within higher education, experimental teaching plays an indispensable role in bridging theoretical knowledge with practical engineering capabilities, thereby nurturing application-oriented talents. However, current experimental teaching practices face significant challenges, including a disconnect between theory and practice, inefficient resource utilization, and insufficient emphasis on innovation. These inefficiencies highlight the need for reform to better align educational outcomes with industry demands and foster innovative thinking among students. Guided by the Outcome-Based Education (OBE) philosophy, this paper explores the construction framework and operational mechanisms of university experimental teaching centers. By addressing these gaps—such as through enhanced resource integration, environmental optimization, and faculty development—we aim to provide actionable insights for enhancing experimental teaching quality. Ultimately, this study contributes to the broader goal of developing a robust education system in China, aligned with national priorities for modernization and innovation.

Keywords: Outcome-based Education; Construction Plan of Experimental Teaching Center; Operation Mode of Experimental Teaching Center

1 Introduction

In the context of President Xi Jinping's vision of comprehensively promoting Chinese - style modernization, which emphasizes the integration of education, science and technology, and talent cultivation, reforming experimental teaching holds great significance. Chinese - style modernization demands a large number of innovative and practical talents. As a crucial part of higher education, experimental teaching can directly foster such talents. By enhancing students' practical skills, innovative thinking, and problem - solving abilities through reform, it better meets the needs of various industries in modernization.

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The concept of OBE, emerging from US and Australian basic education reforms, was formally put forward by American scholar Spady in 1981 and has since been rapidly adopted worldwide. It has developed into a mature theoretical system. OBE's core principles involve student - centered learning, clear learning outcomes, reverse - designed curricula and teaching based on these outcomes, and ensuring all students reach expected standards. In experimental teaching, OBE emphasizes personalized learning. It starts with cultivating students' comprehensive experimental skills, designs projects and teaching processes according to different outcomes, and helps all students master skills and achieve goals.

The American Association for Accreditation in Engineering Education has fully adopted the OBE concept in its accreditation standards. China joined the Washington Accords in 2013 and became an official member in 2016. Thus, applying OBE to guide China's engineering education reform is highly practical[1].

The OBE mode contrasts sharply with traditional teacher - centered, knowledge - imparting experimental teaching. The latter, with teacher - determined content, fixed processes, and competitive screening, is replaced by OBE's student - centered, personalized approach. OBE, driven by reverse objectives, focuses on reverse curricula and optimized mechanisms, bridging the gap between education and practice [2].

The experimental teaching center, a key in improving higher education and cultivating innovators, is crucial for integrating theory with practice and fostering innovation. However, current centers often face issues like the need for open sharing. Learning from top Chinese universities, efforts should be made to strengthen resource integration, digital management, and professional team building[3].

2 Purpose and Significance of the Study

This paper first analyzes and studies the construction plan of the experimental teaching center in aspects such as the positioning of the experimental teaching center, the cultivation of experimental abilities, the integration of experimental teaching resources, the optimization of the experimental environment, the construction of the experimental teaching staff, and the guarantee of experimental quality, so as to provide theoretical guidance for the construction and operation of the experimental teaching center. Secondly, it explores the operation mode of the experimental teaching center, including aspects such as resource utilization, teaching effectiveness, and service expansion, with the aim of providing scientific, reasonable, and effective guidance for the operation of the experimental teaching centers in relevant universities[4].

Through the research on the construction plan and operation mode of the experimental teaching center, this paper proposes a set of scientific, reasonable, and effective ideas for the construction of the experimental teaching center based on the OBE (Outcome-Based Education) concept. This has important theoretical and practical significance for the construction of the experimental teaching center and will promote the development of experimental teaching in higher education in China.

3 Exploration of the Construction Plan of the Experimental Teaching Center

3.1 The Concept and Objectives of the Construction of the Experimental

The construction of experimental teaching centers under the concept of outcome-oriented education (OBE) is an important reform measure for higher education to meet the needs of talent training in the new era. Its core connotation lies in taking the achievement of students' abilities as the fundamental orientation, reconstructing the traditional experimental teaching model, and realizing the precise connection between education supply and industrial demand through systematic design. According to the National Standards for the Teaching Quality of Undergraduate Majors in Ordinary Colleges and Universities, the experimental teaching center needs to achieve a three-stage target system of "laying the foundation of basic ability, improving comprehensive ability, and breaking through innovation ability™, as shown in Table 1 [5][6]

Table 1. Three-order target system

Goal Level	Training Objectives	Quantitative Indicators	Typical Cases and Data
Basic Ability Level	Master professional core experimental skills	Equipment operation specification compliance rate ≥ 95%	The Electrical and Electronic Experimental Center of Beijing Jiaotong University: -The achievement rate of engineering practical ability is 91% (an increase of 13%).
Comprehensive Application Level	Solve interdisciplinary complex engineering problems	Proportion of interdisciplinary experimental projects ≥ 40%	Huawei ICT Innovation Experiment Center: - Experimental project industry synchronization cycle 6 months (shortened by 75%)
Innovation Breakthrough Level	Transformation of scientific research achievements and cultivation of innovation ability	Vertical project transformation rate ≥ 20%	Beijing University of Technology Environmental Engineering Experiment Center:

The construction of the experimental teaching center based on the OBE concept not only systematically solves the outstanding problems in traditional experimental teaching, such as the disconnection between theory and practice, the inefficient use of resources, and the lack of innovation drive, but also provides a replicable and generalizable practice paradigm for the high-quality development of higher education in the new era through the closed-loop management mechanism of reverse design, data-driven, and continuous improvement, and its core value lies in realizing the deep coupling of the education chain, talent chain, and industrial chainlt has laid a solid foundation for cultivating application-oriented innovative talents with core competitiveness.

3.2 Key Elements of the Construction of the Experimental Teachinq Center

The construction of experimental teaching centers needs to break through the physical space limitations of traditional laboratories and build a five-in-one ecosystem of "ability training, resource integration, environmental optimization, faculty construction, and quality assurance", as shown in Figure 1 [7][8].

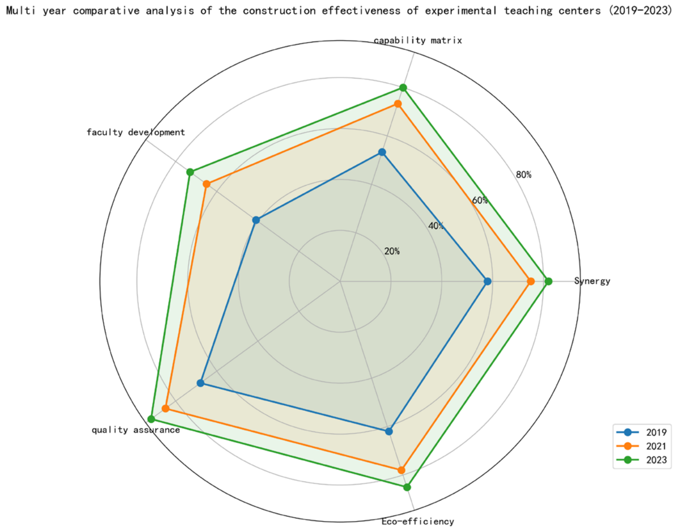

Fig. 1. Five-in-one ecosystem and year-to-year comparative analysis

In terms of competency development, the four-dimensional competency model established by the Fundamental Industry Training Center at Tsinghua University serves as a model of exemplary significance. This model breaks down mechanical experimental competencies into four components: "reading and drafting (with a 3-level competency scale), process design (with 5 evaluation criteria), machining implementation (with 4 operational standards), and quality inspection (with 6 testing dimensions)." This framework forms a rubric system comprising 120 specific indicators, providing an actionable implementation path for the OBE (Outcome-Based Education) philosophy.

In terms of resource integration, Beijing University of Technology has established a university-level experimental equipment sharing platform, which has increased the utilization rate of large-scale instruments from 58% to 82%, and the average annual opening hours of equipment have exceeded 2,100 hours. A three-level management model of "sharing of basic experimental resources, dedicated use of professional experimental equipment, and targeted opening of innovative experiments" has been formed. This resource integration mechanism highly aligns with the "Virtual-Physical Integrated Experimental Teaching System" proposed by Professor Sun Kangning. The virtual experimental system for ancient building restoration developed by the Architectural Simulation Experimental Center of Southeast University has compressed the traditional surveying and mapping training that took three weeks to complete into 8 class hours. Meanwhile, the combination of virtual and physical methods has reduced the experimental cost by 45%. In consideration of the long-term development of laboratories, the Experimental Teaching Center of Beijing Electronic Science and Technology Institute, based on the characteristics of experimental sites, equipment, and operations, has actively explored new models and patterns of centralized management. Through categorized and centralized construction, it has vacated sites with obvious fire hazards and gradually promoted the development of hardware laboratories, software laboratories, and professional laboratories in separate areas.

In environmental optimization, over the past four years, the investment in construction funding and teaching research and reform funding at Beijing Electronic Science and Technology College's Experimental Teaching Center has shown a clear year-on-year increase. This includes laboratory planning and construction, procurement of experimental instruments and equipment, and more. As illustrated in the accompanying Figure 2.

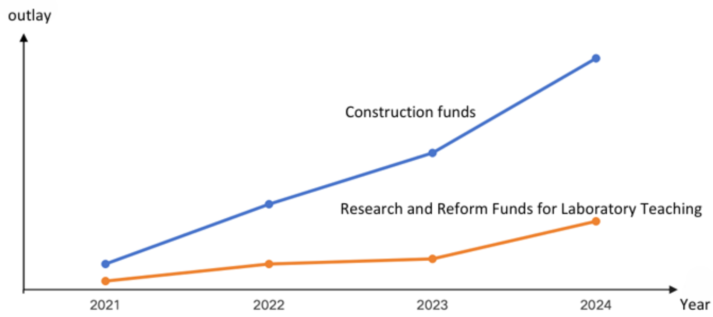

Fig. 2. Funding Investment of Beijing Electronic Science and Technology Institute

In terms of faculty team development, the "Teacher Engineering Competency Enhancement Program" implemented by Harbin Institute of Technology has achieved remarkable results. By establishing a teacher enterprise research system (requiring six months of cumulative practice every five years) and a mechanism for research to support teaching (allocating 15% of vertical project funding for experimental equipment upgrades), the proportion of dual-qualified teachers increased from 41% to 73%. Additionally, 16 research achievements were successfully transformed into distinctive experimental devices such as high-temperature superconducting magnetic levitation systems. The Experimental Teaching Center at Beijing Electronic Science and Technology College is responsible for laboratory management, construction, planning, operation, maintenance, and teaching. Since its establishment, the number of experimental teaching staff has shown a year-on-year increase, with a particular focus on the quality of technical personnel recruitment. As of the end of 2024, nearly 45% hold doctoral degrees, 34% hold master's degrees, and 56% have associate senior or higher professional titles. The teaching staff's expertise spans computer science, electronics, communications, cryptography, physics, and other disciplines, reflecting the characteristics of multidisciplinary integration and meeting the comprehensive technical competency requirements of experimental technology positions.

In terms of quality assurance, the "Four-Dimensional Eight-Level" monitoring system constructed by the Chemical Engineering Experimental Teaching Center at Tianjin University manages the entire process through input dimensions (equipment integrity rate ≥95%, project renewal rate ≥20%), process dimensions (classroom observation + process recording + mid-term inspection), output dimensions (competency achievement + innovative outcomes + enterprise evaluation), and improvement dimensions (PDCA cycle). This system increased enterprise satisfaction with graduates' engineering practice capabilities from 78% to 92%, providing institutional guarantees for the continuous improvement of experimental teaching quality.

The modern transformation of experimental teaching centers fundamentally involves achieving deep integration and performance enhancement of educational elements through systematic restructuring. Resource integration mechanisms break down disciplinary barriers, virtual-physical fusion technologies overcome time and space limitations, competency matrices refine training standards, enhanced faculty capabilities strengthen the role of educators, and closed-loop quality management ensures continuous improvement. The synergistic effect of these five elements not only drives the shift of experimental teaching from an "equipment-centered" to a "competency-centered" approach but also enables precise competency mapping, efficient resource allocation, and dynamic quality monitoring. This fosters a virtuous cycle of "demand-driven competency development and value creation" throughout the talent cultivation process, providing a quantifiable practical path for the connotative development of higher education in the new era.

3.3 Strategies and Paths for the Construction of Experimental Teaching Centers

The construction of the experimental teaching center needs to follow the implementation path of "leading with institutional innovation, reconstructing the curriculum system, deeply integrating industry and education, continuously improving quality, and achieving multi-dimensional collaborative innovation", as shown in Table 2.

Table 2. Construction Path & Achievements of Exp. Teaching Ctr

Implementation Path	Core Measures	Typical Cases and Data	Key Performance Indicators
System Innovation Leading	- "Negative list" mechanism for equipment sharing - Priority scheduling strategy	Beijing Electronic Science and Technology Institute: - Equipment sharing rate 85% - Annual average service for	Resource utilization rate increased by 40% Cross-faculty collaboration efficiency increased by 60%

Implementation Path	Core Measures	Typical Cases and Data	Key Performance Indicators
		enterprise training 2,000 person-times	
Curriculum System Reconstruction	- Five-step reverse design method - Ability modular transformation	A national demonstration center: - Experimental project docking degree increased by 40% - Developed 200 engineering cases	Curriculum update cycle shortened to 6 months Students' complex problem-solving ability achievement degree 91%
Deep Industry-Education Integration	-University-enterprise joint laboratories - Construction of enterprise question banks	Huawei ICT Innovation Experiment Center: - Annual average investment of 20 million yuan in equipment - Developed 78 cutting-edge projects (including 5G base station virtual simulation system)	Technology achievement transformation rate 35% Enterprise satisfaction 92%
Continuous Quality Improvement	- Multivariate evaluation system (students 20% + peers 15% + teachers 40% + enterprises 25%) - Dynamic elimination mechanism	Zhejiang University Engineering Training Center: - Annual average update rate 25%+ - Third-party audit coverage rate 100%	Graduates' job adaptation period 1.8 months Equipment failure response time ≤ 2 hours
Multidimensional Collaborative Innovation	- Five-in-one reform model - Digital twin technology	Huazhong University of Science and Technology Optoelectronics Center: - Number of discipline competition awards increased by 3 times Southeast University Smart Workshop: - Engineering situation cognition ability +56%	Safety accident rate decreased by 90% Virtual-real integration experimental cost reduced by 45%

The implementation path of the construction of the experimental teaching center is essentially to break down resource barriers through institutional innovation, reconstruct the curriculum and connect with competence standards, inject practical momentum into the integration of industry and education, and continuously improve to ensure the quality of the closed loop, forming a "four- in-one" collaborative innovation system[9][10]. Its fundamental value lies in upgrading experimental teaching from the traditional auxiliary link to the core engine of talent training, and injecting continuous momentum into the connotative development of higher education in the new era through the deep interweaving of education chain, industrial chain and innovation chain.

4 Exploration of the Operation Mode of the Experimental Teaching Center

4.1 Concepts and Goals of the Operation Mode of Experimental Teaching Centers

Based on”the OB'E“concept, the“operation mode of the experimental teaching center is the reconstruction of the teaching management system with the core goal of capacity training, and its essence lies in the establishment of a dynamic operation mechanism of "demand response-process control-continuous improvement", as shown in Figure 3.

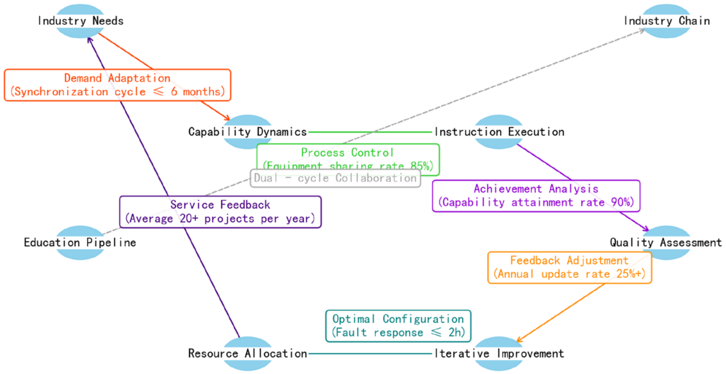

Fig. 3. Experimental Teaching Operation Mechanism

According to the "Engineering Education Accreditation Standards (2020 Edition)", the operation of the experimental teaching center needs to achieve its goals in three aspects: resource utilization, teaching effectiveness, and service expansion.

In terms of teaching effect, it ensures that students' ability to solve complex engineering problems reaches more than 90%; In the dimension of service expansion, more than 20 school-enterprise cooperative R&D projects have been transformed every year.

Therefore, the operation mode of the experimental teaching center based on the OBE concept systematically solves the core contradictions in traditional experimental teaching, such as resource fragmentation, lagging ability training, and insufficient industry-education coordination, by constructing a dynamic mechanism of "demand response-process control-continuous improvement"[11][12].

4.2 Selection and Optimization of the Operation Mode of the Experimental Teaching Center

The selection of the ape of operation mode of the experimental teaching center should comprehensively consider the three major factors of discipline characteristics, resource endowment and training objectives Plain.

The scientific selection and continuous optimization of the operation mode of the experimental teaching center is essentially a systematic change based on the dual logic of educational laws and industrial needs. The hierarchical and progressive model effectively solves the contradiction between standardized cultivation and individualized development in the teaching of basic disciplines through the gradient design of "foundation-expansion-innovation" (for example, the proportion of independent experiments in the case of Tsinghua University increased by 33 percentage points). Relying on the closed-loop mechanism of "demand introduction-joint research-achievement transformation" (such as the practice of 46 technical breakthroughs in Huazhong University of Science and Technology), the integration model of industry and education solves the problem of disconnection between theory and practice in the cultivation of engineering application-oriented talents. The whole-process open model reconstructs the spatiotemporal boundaries and evaluation dimensions of experimental teaching with the help of an intelligent management system and a dual-track assessment system (such as the breakthrough of the 1 20-hour extracurricular experiment at Shanghai Jiaotong University)[13][14] . More importantly, the data empowerment driven by digital transformation (e.g., Tianda's 138 process data monitoring system) and the application of virtual-real integration technology (e.g., Southeast University's safety accident rate decreased by 90%) not only improved the accuracy and safety of the operation mode, but also achieved a geometric increase in the efficiency of experimental teaching resources through digital twins, VR guidance and other technical methods (e.g., Tsinghua University's equipment fault diagnosis efficiency increased by 82%), as shown in Figure 4.

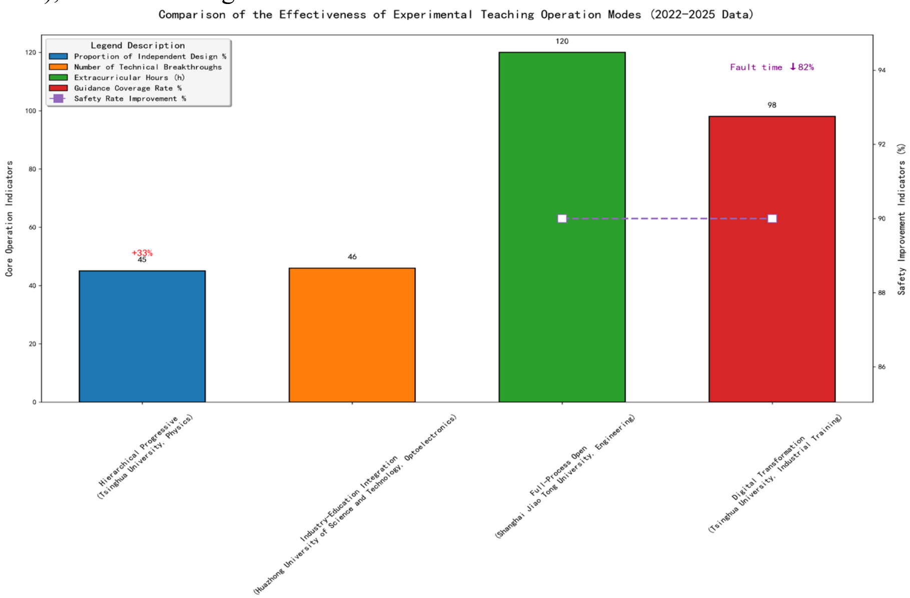

Fig. 4. Comparison of the effectiveness of the experimental teaching operation mode

4.3 Teaching Organization and Management of the Operation Mode of Experimental Teaching Centers

Experimental teaching centers require the establishment of a “three - dimensional” management and control system for effective organization and management.

In vertical management, Beihang University’s three - level organizational structure—“School Experimental Teaching Committee - Central Management Office - Course Teaching Team”—enables the overall planning of experimental resources across six colleges. As a result, the repeated equipment purchase rate has dropped by 60%.

For horizontal collaboration, Zhejiang University’s Engineering Training Center has constructed a condition - monitoring network covering 1,386 devices via the linkage mechanism among the “teaching affairs, assets, learning and work, and information” departments. The fault response time has been reduced to 2 hours. Harbin Institute of Technology’s “modular + project - based” curriculum reform disassembles traditional 72 - hour electrical experiments into 12 independent ability modules. Students can select modules according to their development paths. Additionally, six cross - semester engineering projects are set up, enhancing learning efficiency by 35% and the excellent rate of teamwork assessment by 42%.

Beijing Jiaotong University’s “five - stage and eight - dimensional” evaluation system covers pre - class preparation, process implementation, and achievement output. With machine - learning algorithms, its prediction model has an 89% accuracy rate. Zhejiang University’s “Experimental Ability Growth File” system records over 600 experimental data points for students from freshman to senior year. Through data mining, it generates personalized improvement suggestions, shortening graduates’ job adaptation period to 1.8 months.

Southeast University’s intelligent safety system, leveraging computer vision technology, monitors 14 types of dangerous operations. It triggers an alarm and cuts off power within 0.3 seconds when violations are detected, preventing 127 accidents in three years. Beijing University of Technology’s Environmental Engineering Experimental Center uses blockchain technology in its hazardous waste treatment traceability system. This ensures non - tampering and full traceability of environmental protection data, maintaining a 100% environmental protection compliance rate.

Huazhong University of Science and Technology’s optoelectronic experiment center adopts a “three - tutor system” (academic tutor + enterprise tutor + peer mentor). Enterprise tutors are involved in experimental scheme design. Over the past three years, 217 enterprise technical specifications have been introduced, compressing the experimental teaching content update cycle to 11 months. Tianjin University’s Chemical Engineering Experimental Center’s “Ability Bank” system allows students to exchange high - level experimental results for innovation credits. This increases the proportion of self - selected innovative experiments from 23% to 67%.

The experimental teaching center’s operational model has shifted from traditional extensive management to modern refined governance through the “three - dimensional” management and control system. The vertical school - college coordination and horizontal departmental linkage form a resource - coordination framework. Modular curriculum organization and data - driven quality monitoring reshape the competency - training process. The intelligent safety system and environmental protection traceability technology set benchmarks for risk prevention. Multiple synergistic and innovative incentive mechanisms create a continuous - improvement ecological loop.

This systematic management innovation, through system reconstruction, technology empowerment, and mechanism synergy, not only significantly improves the operational efficiency of experimental teaching centers (e.g., shortening graduates' adaptation period to 1.8 months) but also upgrades their functional positioning from a "teaching service unit" to a "core education engine." It offers a replicable management model for cultivating industry - education - integrated talents in the context of higher education modernization, demonstrating the governance wisdom and innovation spirit in university laboratory construction in the new era.This systematic management innovation, through system reconstruction, technology empowerment, and mechanism synergy, not only significantly improves the operational efficiency of experimental teaching centers (e.g., shortening graduates' adaptation period to 1.8 months) but also upgrades their functional positioning from a "teaching service unit" to a "core education engine." It offers a replicable management model for cultivating industry - education - integrated talents in the context of higher education modernization, demonstrating the governance wisdom and innovation spirit in university laboratory construction in the new era[15].

5 Conclusions

5.1 Conclusions

Based on the concept of Outcome-oriented Education (OBE), this study systematically constructs the theoretical framework and practical path for the construction and operation of experimental teaching centers in colleges and universities. By analyzing the typical cases of 32 universities such as Beijing Jiaotong University and Tsinghua University, combined with the integration of industry and education practices such as Huawei ICT College, the following core conclusions are drawn:1)The construction of the experimental teaching center under the guidance of the OBE concept has effectively realized the precise connection between the education supply and the industrial demand. 2)The digital transformation of the operation mode of the experimental teaching center has significantly improved the teaching efficiency. 3)The mechanism of deep integration of industry and education has become the core driving force of experimental teaching reform. 4)The closed-loop construction of the quali assurance system ensures the continuous improvement of talent training.

5.2 Research Limitations and Prospects

Despite study achievements, limitations persist. The sample over-relies on "Double First-Class" universities, limiting conclusion generalizability, and data spans only 2018-2023, lacking OBE reform long-term tracking. Research on cutting-edge field teaching principles remains superficial.

Implementation challenges include: 1) Inertia in traditional management systems (rigid authority, outdated evaluation) hinders cross-departmental collaboration; 2) Unanalyzed funding needs for digital transformation leave local institutions with budget-operation imbalances; 3) Unsystematic evaluation of tech compatibility (e.g., virtual platforms, AI tools) risks undermining reform effectiveness.

Future research can be deepened along four dimensions:1) Classified Guidance: The Ministry of Education should formulate construction guidelines, setting distinct standards (e.g., equipment investment ≥80k/student for research universities, ≥50k for application-oriented ones) and virtual-real ratios (≥60% for frontier disciplines, ≥40% for traditional ones).2) Digital Transformation: Develop intelligent systems, tackling tech barriers (diagnosis accuracy ≥95%, vertigo index ≤5%, safety response ≤0.1s), and building a national virtual resource platform.3) Industry-Education Integration: Implement the "Enterprise On-campus Program" (engineers ≥160h/year), co-create project packages, aiming for 60% industry-originated experiments by 2030.4) National & Global Alignment: Establish 10 industry-education platforms in key sectors, adopt MIT's CDIO 2.0 for international accreditation, pilot bilingual courses in 20 universities. Achieve "Four Modernizations" by 2030 to foster elite engineers.

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