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PAPER

Factors that Influence the Joint Construction and Operation of Experimental Teaching Demonstration Centers in the Context of Industry-Education Integration

Yanan Chen, Qin Xiao (✉)

Wuhan University of Technology and Business, Wuhan, China

xiaoqin@wtbu.edu.cn

ABSTRACT

Under the background of the deepening integration of production and education, the construction of a shared experimental teaching demonstration center as a key hub connecting the education chain and the industrial chain is profoundly influenced by a variety of complex factors. These factors are intertwined, collectively determining the center's collaborative education effectiveness and sustainable development capability.

KEYWORDS

industry-education integration, co-construction and sharing, experimental teaching demonstration center

1 INTRODUCTION

1.1 Macroeconomic background

To respond to the global competition in technological innovation, China's higher education has actively promoted the construction of "New Engineering" and the development strategy of innovation-driven, which has put forward new requirements for the existing practical teaching system of higher education. New Engineering emphasizes that practical teaching must be synchronized with the evolution of industrial technology, connected with real engineering scenarios, and aligned with the training objectives of composite talents. Against this backdrop, the integration of industry and education, as a bridge between enterprises and schools and a key role in talent training and curriculum reform, becomes particularly crucial.

The implementation plan for the action of empowering and enhancing vocational education through industry-education integration (2023–2025) proposes to "accelerate the formation of an integrated development pattern of industry-education interaction and complementary advantages between enterprises and schools, continuously

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optimize the supply structure of human resources, and provide strong human resource support for the comprehensive construction of a socialist modern country," and the importance of industry-education integration has been elevated to the level of national strategy. The Notice on Carrying Out Research on the Construction of Experimental Teaching and Teaching Laboratories issued by the Higher Education Department of the Ministry of Education emphasizes the three core tasks of enhancing the cultivation ability of experimental teaching, optimizing the construction and management of laboratories, and promoting the reform of experimental teaching. Through in-depth research and practice, it promotes the innovation of the experimental teaching system, improves the digital level of laboratories, and draws on advanced international experience to meet the needs of talent cultivation in the new era, constructs a new experimental teaching system, and provides strong support for higher education and scientific research. The introduction of a series of policies and plans reflects the national level's attention to industry-education integration and the urgency of in-depth cooperation between applied universities in industry-education integration.

1.2 Real-world issues and importance

Compared with the construction and operation of experimental teaching demonstration centers for joint building and sharing, traditional experimental teaching centers have more prominent problems in construction and operation, such as unclear positioning, lack of distinct characteristics, unreasonable courses, low resource sharing rate, and repeated construction, etc. [1]. Through the analysis of the impact of the innovation and entrepreneurship education system of colleges and universities on the cultivation of applied innovative talents, the outstanding problems existing in experimental teaching are further revealed, such as unreasonable processes, imperfect systems, and a focus on theory over practice, etc. [4]. Currently, the construction and operation of experimental teaching centers play a key role in talent cultivation in higher education, aiming to bridge the gap between theory and practice. However, a comprehensive analysis of existing literature shows that it still faces a series of systematic challenges in terms of construction concepts, resource allocation, technology integration, management models, and evaluation systems, which restrict the full play of its effectiveness.

1. Issues of construction concept and target orientation: The construction of experimental teaching centers often deviates from the goals of talent cultivation, with issues such as vague positioning, emphasis on theory over practice, and misalignment with industrial demands. Some centers lack a clear goal system based on outcome-based education (OBE) in the initial stage of construction, leading to unreasonable training standards [19]. Particularly in the process of integrating innovation and entrepreneurship education into experimental teaching, there are systemic mismatch issues such as the disconnection between the curriculum system and professional education, and insufficient practical platforms and guidance support. In addition, the traditional teaching model is difficult to meet the needs of interdisciplinary and innovative talents in the context of new engineering, showing that the construction concept lags behind the development of the times.
2. Dilemma of resource allocation and platform construction: In terms of hardware and software resource allocation, experimental teaching centers generally face the dual pressures of limited space, equipment, and a shortage of high-level

teaching staff [3]. Traditional physical experiments are constrained by time, space, and cost, making it difficult to carry out open and collaborative teaching [14]. Although digital technologies such as virtual simulation and digital twins provide possibilities for breaking through physical limitations [16], their construction and application still face obstacles. For example, the real-time data connection between different systems is insufficient, affecting the efficiency of intelligent management [27]; at the same time, if the design of virtual platforms is disconnected from the real industrial process, it may still lead to the formality of practical teaching [28].

3. Challenges of technological convergence and teaching model innovation: Digital technology deeply integrates into experimental teaching, which is a trend, but it faces challenges in effectiveness in implementation. Although virtual simulation platforms can enhance the accessibility and interest of experiments [10], it is difficult to ensure the learning outcomes if there is a lack of deep integration with curriculum design and teaching strategies. Research indicates that the success of online or blended experimental teaching is highly dependent on the ease of use, utility of technology, as well as multiple factors such as teacher support and family support [1]. In addition, new models such as mobile learning and collaborative learning require corresponding changes in teaching design and organizational management to support them, otherwise it is difficult to effectively mobilize students' enthusiasm and collaborative abilities [2].
4. Management and operation and quality assurance system defects: The operation and management mechanism of the experimental teaching Center is not yet perfect. In terms of industry-education integration, the "school-enterprise-community" collaborative education mechanism is not smooth, leading to a disconnect between experimental content and real industry needs, and weak practical teaching links [14]. In addition, the quality monitoring and evaluation system is often not scientific and sound, lacking routine, multi-dimensional monitoring and feedback on the process and effectiveness of practical teaching [20].
5. Insufficient personnel development and collaborative support: The efficient operation of the experimental teaching center is inseparable from the support of professional technical personnel (experimenters). However, the role and contribution of this group in academic institutions are often "neglected", there is a "disconnection" with the management, and their professional development, training, and recognition are insufficient, which affects the overall effectiveness of the laboratory technical support system [8]. At the same time, the experimental conditions and team guidance for postgraduate students and other high-level talents are also key factors affecting their scientific research and innovation capabilities [7].

In summary, the construction and operation of the experimental teaching center is a multi-dimensional, systematic project. The current main problems are concentrated in the disconnection between the target positioning and industrial demand, unbalanced resource allocation and insufficient depth of digital integration, imperfect management mechanisms and quality assurance systems, as well as weak support for the development of professional and technical personnel. "Joint construction and sharing" is an innovative model to solve difficulties, achieve the high-quality and sustainable development of the experimental teaching center, and deepen the integration of industry and education, its value lies in integrating high-quality resources, promoting knowledge transformation, cultivating compound innovative talents, and serving regional industrial development. Although scholars at home and abroad have conducted many research and analyses on the construction and operation of the experimental teaching center, there are few studies on the operational and functional influencing factors of the joint construction and sharing of the experimental teaching center, and the depth and breadth are insufficient. Therefore, this paper will systematically integrate existing research findings, construct a multi-level framework for the analysis of influencing factors, and provide a reference for subsequent theoretical research and practical optimization.

2 CORE CONCEPT ANALYSIS AND THEORETICAL BACKGROUND

2.1 Definition of core concepts

Production-education integration, school-enterprise cooperation, and the combination of engineering and technology are core concepts in modern vocational education and the cultivation of applied talents. The three are interrelated, but there are significant differences in connotation, level, and implementation focus. Overall, school-enterprise cooperation is the basic operational model, the combination of engineering and technology is a specific teaching method, and production-education integration is a higher-level strategic concept and ecosystem construction [5].

Industrial-education integration emphasizes the in-depth coupling and integrated development of the two major systems of industry and education in terms of structure, resources, culture, and goals. It is a strategic orientation at the national level, aiming to achieve the organic connection between the education chain, talent chain, and the industrial chain, as well as the innovation chain [6]. School-enterprise cooperation focuses on various cooperative activities and projects between the two specific subjects of schools and enterprises, centered around talent cultivation, technology research and development, and internships and employment, which is the main practical path for implementing industrial-education integration [11]. The combination of engineering and learning (or alternating between engineering and learning, work-based learning) mainly refers to the process and teaching method of talent cultivation that closely combines theoretical learning with practical work, which is a specific manifestation of school-enterprise cooperation at the micro-teaching level [12].

Jointly built and shared experimental teaching demonstration centers are the product of the deep integration of educational informatization and teaching reform. Their core connotation lies in breaking the closed and fragmented state of traditional teaching resources, through the coordinated participation of multiple subjects and the integrated application of advanced technologies, to build a comprehensive teaching platform integrating resource convergence, open services, collaborative innovation, and exemplary leadership [13]. This model emphasizes the intensification and efficiency of resource construction and utilization, aiming to maximize the use and sustainable updating of high-quality experimental teaching resources, and serve the cultivation of high-quality innovative talents [15].

1. Connotation definition: The connotation of jointly building and sharing a demonstration center for experimental teaching can be understood from three levels. At the conceptual level, it embodies a paradigm shift from "independent construction and independent governance" to "collaborative construction and open sharing", with the goal of forming a synergy in resource construction and avoiding redundant investment and resource waste [16]. At the operational level, it relies

on a set of clear collaborative mechanisms and technical support systems, such as organizational models such as government guidance, school-enterprise cooperation, and inter-school alliances, as well as cloud computing, grid technology, etc., as the technical foundation for resource integration and distribution[18]. At the goal level, its ultimate aim is to enhance the overall quality and utilization efficiency of teaching resources, and promote educational equity and teaching innovation [21].

2. Core feature analysis: Jointly built and shared experimental teaching demonstration centers mainly exhibit the following four core characteristics:
   i. Openness. The center breaks through the limitations of time and space and the subject, allowing users from different institutions, regions, and even industries to access resources as needed. This openness is not only reflected in the access to physical space and network platforms, but also in the open participation of resource content and teaching processes [22]. For example, cloud-based digital learning environments can provide on-demand services to a wide range of user groups [23].
   ii. Diversity. Its diversity is reflected in the diversification of participating entities, resource types, and service models. Participating entities include government, universities, enterprises, research institutions, etc.; resource types include virtual simulation experiments, case libraries, instrument and equipment information, etc.; and service models can support various teaching forms such as independent learning, collaborative inquiry, and remote experiments [24].
   iii. Innovativeness. The center is a testing ground for the integration and innovation of teaching and technology. It creates an immersive and highly interactive learning environment by introducing new technologies such as digital twins and pen computing, supports the collaborative construction and dynamic generation of knowledge, thereby innovating the traditional experimental teaching model [25]. For example, the Computer Integrated Classroom (CiC) innovatively supports collaborative activities by integrating hardware, software, and spatial design.
   iv. Demonstrative. As a "demonstration center," its value lies in forming replicable and scalable construction and operation paradigms. It provides a reference template and experience for the construction of similar institutions through successful practice cases, effective management mechanisms (such as point incentives, classification criteria), and significant application achievements [23].

Functional orientation is the integration of teaching, scientific research, production, and training. The functional orientation of this center goes beyond the traditional single teaching venue and evolves into an integrated comprehensive service platform. The core teaching function, which is its basic function, aims to support regular teaching and personalized learning through high-quality and open experimental resources, enhancing students' practical abilities and innovative qualities [26]. The scientific research support function provides advanced instrument and equipment sharing, data resource support, and collaborative research environment for teachers and students' scientific research activities. For example, the joint construction and sharing of medical case libraries can directly assist clinical medical research and improve research efficiency and practical abilities [28]. The production connection function allows the center to introduce real industry projects, technical standards, and production processes through school-enterprise cooperation, making experimental teaching closely connect with industrial needs. At the same time, enterprises' technical difficulties can also be tackled with the intellectual resources of the center, realizing the integration of production and education [29]. The training service function enables the center to provide skill training and continuing education for students, enterprise employees, and social learners. The teacher education technology training space constructed based on the cloud platform has been verified for its effectiveness in supporting the development of professional communities and promoting resource matching [23].

2.2 Relevant supporting theories

The stakeholder theory provides a key analytical framework for understanding and optimizing the integration of industry and education. The theory emphasizes that the success of the integration of industry and education depends on identifying and coordinating the interests, expectations, and contributions of diverse subjects, which mainly include universities, students, enterprises (industries), and the government, etc. [31]. Viewed from this perspective, the integration of industry and education is not only an innovation in teaching methods but also a complex process of multi-subject collaboration and governance. Its core lies in bridging the gap between theory and practice, education and employment through effective stakeholder participation [32].

Resource dependency theory reveals the dependency that organizations have on the external environment to obtain critical resources, which is one of the fundamental driving forces of inter-organizational interaction and cooperation. The cooperative model of "building and sharing" aims to integrate and optimize resource allocation, and its inherent logic and practice path are highly consistent with the core views of the resource dependency theory. In the innovation ecosystem, enterprises, universities, governments, and other diverse entities form a quadruple helix structure through the "building and sharing" mechanism to synergistically enhance the development capacity of the system, which is the embodiment of the strategy to cope with complex resource environments and achieve coexistence and win-win outcomes [33]. Further research shows that building strong relationship ties to promote the sharing of tacit knowledge or establishing weak relationships to promote the sharing of explicit technology are effective embedded ways for technology standard-setting alliances to manage dependencies based on resource types and enhance competitiveness [34].

Collaborative innovation theory is used to explain how multiple subjects collaborate deeply across organizational boundaries (academia-research-industry), integrate complementary knowledge and resources, and jointly create novel and valuable outcomes [35]. This is the theoretical core of "integration." Collaborative innovation, by opening the innovation process to multiple actors, can cross organizational and cultural boundaries, draw on extensive resources, and build broad social and political support [36], thereby overcoming the limitations of traditional closed innovation in experimental teaching centers that are difficult to produce innovative outcomes.

Educational ecology theory draws on the holistic, dynamic, and associative thinking of ecology, viewing education as a complex ecosystem composed of multiple interacting elements (such as students, teachers, curriculum, technology, policy, culture, etc.) [37]. This theory emphasizes the continuous interaction and collaborative evolution among various elements within the educational system, as well as between the educational system and the external social environment, aiming to reveal the ecological laws behind educational phenomena to promote the balance, health, and sustainable development of the educational system [38].

3 INFLUENCE FACTORS SORTING AND CLASSIFICATION

3.1 Conceptual consensus and top-level design factors

The depth of co-construction and sharing primarily depends on the conceptual consensus of the participating parties and the systematic top-level design. Currently, there is a common problem of inconsistent goals and insufficient consensus in cooperative concepts between universities and enterprises, leading to cooperation at the surface level and making it difficult to achieve "collaborative governance by multiple subjects" and "deep integration" [40] [46]. Policy guidance and overall planning by local governments and industry organizations are crucial. By constructing a "government-university-enterprise-research" four-party collaborative governance model, clarifying the main status of enterprises, it can provide a clear "conceptual guidance layer" and institutional guarantee [41] [53]. The lack of a strong top-level design and a common vision is the fundamental obstacle to restricting the center from "physical combination" to "chemical integration" [46] [52].

3.2 Management operation and evaluation feedback factors

Efficient management operation modes and scientific evaluation systems are the key to ensuring dynamic optimization and continuous improvement of the center. Traditional management modes have problems such as poor coordination and unclear responsibilities, and it is necessary to establish a modern governance system of "multi-party collaboration and joint management" [41]. In terms of the evaluation mechanism, it is necessary to break through the limitations of school-based evaluation and build a two-dimensional evaluation system that introduces multiple subjects such as corporate mentors and industry experts, forming a closed-loop feedback of "demand-teaching-evaluation" to accurately improve the quality of personnel training [43] [44] [51]. Digital empowerment provides this possibility, and through the construction of an intelligent management platform, it is possible to achieve two-way evaluation between schools and enterprises, data intercommunication, and scientific decision-making [44] [48].

3.3 Factors of resource input and collaborative mechanism

Efficient integration of resources and sustainable investment are the material foundation and operational guarantee for central construction. This is specifically reflected in multiple dimensions such as teaching staff, courses, and platforms. In terms of teaching staff, the shortage of "dual-qualified" teachers, insufficient motivation and mechanisms for enterprise mentors, are common bottlenecks [39] [56] [59]. In terms of curriculum and teaching resources, it is necessary for schools and enterprises to jointly develop a curriculum system that meets industrial standards, and to jointly build and share teaching resources using digital technology (such as virtual simulation platforms) to address the issue of the disconnect between teaching content and industry practice [45] [48] [50]. In terms of platform construction, the key to resource convergence is to build physical or virtual training bases and research and development centers, but they often face challenges such as insufficient intrinsic motivation for enterprise investment and uneven resources allocation [42] [47] [50] [58]. Establishing clear property rights, cost sharing, and benefit sharing mechanisms is the core to stimulate continuous participation by enterprises and ensure the long-term supply of resources [40] [49] [57].

3.4 External environment and policy support factors

Regional industrial development needs, technological trend changes, and National and local policy support constitute external driving and constraint environment for the central construction. The deepening of the digital economy, the rise of emerging technologies such as artificial intelligence, continuously reshaping the industrial ecology, requiring the experimental teaching center to maintain synchronous iteration of content and technology [50] [55] [56]. At the same time, from the national to the local, the industrial-education integration incentive policies (such as the construction of modern industrial colleges and city-level Industrial-education joint bodies) provide important project carriers and resource inclination for joint construction and sharing [41] [53] [54]. Whether it can effectively connect with the regional industrial chain and innovation chain, integrate into the local economic and social development strategy, directly determines the vitality and social service value of the center [47] [54] [24].

4 RESEARCH CHALLENGES, CONTROVERSIES, AND SHORTCOMINGS

The limitations of research methods. Existing research mainly focuses on descriptive case studies, lacking empirical tests and quantitative analysis with large samples, and the weight relationship and action path between factors are unclear. There is a lack of longitudinal tracking studies, and insufficient attention is paid to how influencing factors change dynamically over time and stages; controversies and insufficient integration of theoretical perspectives. Researchers from different disciplinary backgrounds (education, management, economics) have different focuses, and there is a lack of a unified analytical framework for systematic integration; there are controversies about the measurement criteria for "deep integration," whether it focuses on hardware investment, project quantity, or pays attention to learning outcomes, innovative output, or actual contributions to the industry; the in-depth exploration of key factors is missing. Although research on "soft factors" (such as inter-organizational trust, cooperative culture, leadership) has been mentioned, there is insufficient in-depth discussion of their generation mechanisms and cultivation strategies; discussions about the core issue of "interest balance" are mostly staying in principled discussions, lacking research on operational and differentiated models of interest distribution; the research on the role, experience, and ability development of "students as the main body" in joint construction and sharing is relatively weak.

5 CONCLUSION AND FUTURE RESEARCH DIRECTIONS

An influencing factor is a complex system with multi-level (macro-meso-micro) and multi-agent interactions. Sustainable governance mechanisms, complementary core resources and capabilities, mutually beneficial and win-win interest distribution, and deep integration of cultural identity are several key influencing domains recognized in existing literature.

It is necessary to construct an integrated analytical framework that combines the theories of stakeholder, resource-based, and collaborative innovation. It is urgent to carry out comparative studies across regions and industries, and verify the relationship assumptions between factors through methods such as structural equation model (SEM). There is a lack of a scientific, multidimensional valuation index system for the effectiveness of joint construction and sharing centers.

Future research directions, deepening mechanism research: explore the differences and matching conditions of influencing factors under different governance models (such as enterprise-led, university-led, and third-party operation); focus on dynamic processes: adopt case tracking or action research to explore the evolution path and key turning points of the center from "co-construction" to "sharing" and then to "win-win"; strengthen micro-level empirical research: deeply study how the participation motivation, behavior, and experience of micro-level individuals such as teachers ("dual-qualified"), enterprise mentors, and students are affected by macro-level factors and how they react back to the system; explore digital empowerment: systematically study how digital technologies such as artificial intelligence and the meta verse reshape the forms, resources, and influencing factor patterns of co-construction and sharing.

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8 AUTHORS

Dr. Yanan Chen is an Associate Professor at Wuhan Business University, Master's Supervisor, specializes in educational reform (E-mail: chenyanan@wtbu.edu.cn).

Qin Xiao is a Teacher at Wuhan Business University, Lecturer (E-mail: xiaoqin@wtbu.edu.cn).